Cherry Bayou Drainage Master Plan

Volume II – Final Report

TETRA TECH

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1.0 INTRODUCTION

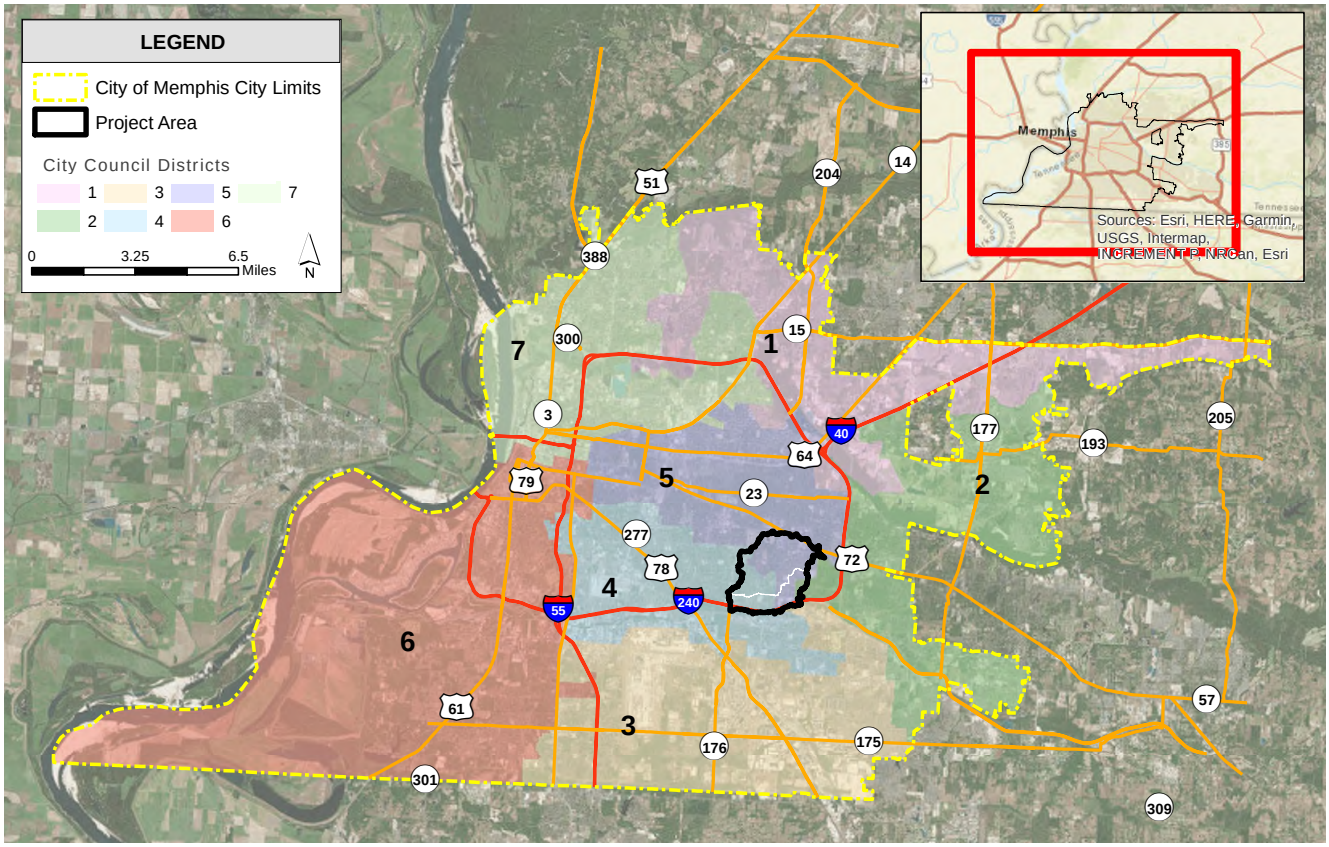
In 2014, the City of Memphis (City) initiated a multi-year citywide Stormwater Master Planning Program to evaluate the entire stormwater drainage system and identify improvement opportunities to help alleviate hydraulic restrictions and flooding. The Cherry Bayou Study Area falls into the third round of the Master Planning Program, based on flooding complaints received by the City of Memphis. To achieve this end, the City identified specific goals and determined a geographical implementation schedule. The goals are to:

- Collect data on the existing stormwater drainage systems and develop a comprehensive geographic information system (GIS) dataset for future City planning and maintenance efforts.
- Develop a SWMM model to identify flooding within the area.
- Identify areas that lack hydraulic conveyance capacity and the corresponding extents of flooding.
- Evaluate and recommend improvements to alleviate flooding in the stormwater drainage system.

The geographical implementation schedule was determined by subdividing the stormwater drainage system into seven Stormwater Districts that roughly correspond to the seven City Council Districts. Each of the Stormwater Districts were then sub-divided into smaller, more manageable sizes for implementing a complete master planning study.

The City intends to complete master planning studies of each sub-divided area until all areas have been evaluated. The sub-divided areas have been prioritized based on a “heat map” analysis of flooding complaints received by the City of Memphis Engineering and Public Works Departments. As stated above, the Cherry Bayou Study Area falls into the third round of the Master Planning Program. Figure 1.1 identifies the seven council districts, highlighting District 4 and 5 where the Cherry Bayou Study Area is primarily located.

Figure 1.1: City of Memphis Stormwater Districts

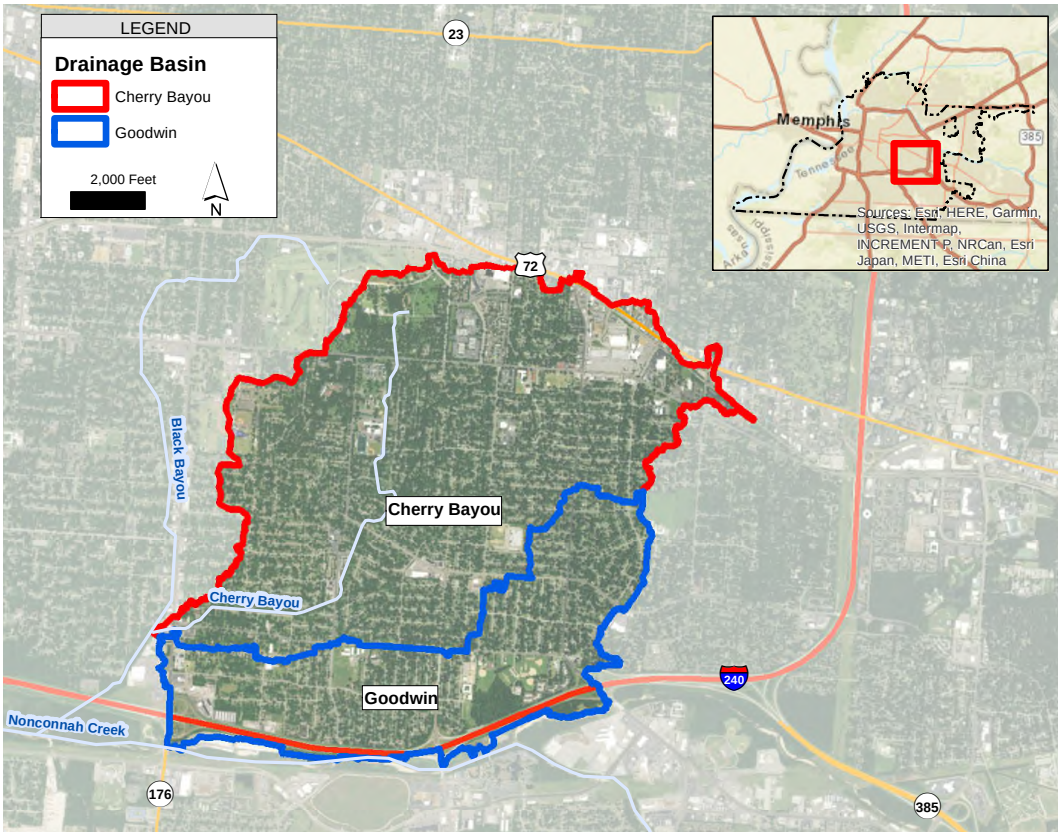


1.1 CHERRY BAYOU STUDY AREA

The Cherry Bayou Study Area (study area) is located northeast of the center portion of the City within Council Districts 4 and 5. The study area consists of approximately 3,168 acres situated between the Black Bayou to the west, the Nonconnah Creek to the south, Route 57 to the north, and South White Station Road to the east. The study area is predominantly single-family residential with some commercial land use in the northeast portion of the study area.

The Cherry Bayou Study Area consists of two watersheds: Cherry Bayou and Goodwin. The Cherry Bayou watershed drains to the Cherry Bayou, then to the Black Bayou, and finally discharges into the Nonconnah Creek. The Goodwin branch discharges directly into the Nonconnah Creek. Figure 1.2 presents the two watersheds that comprise the study area.

Figure 1.2: Cherry Bayou Study Area Watersheds

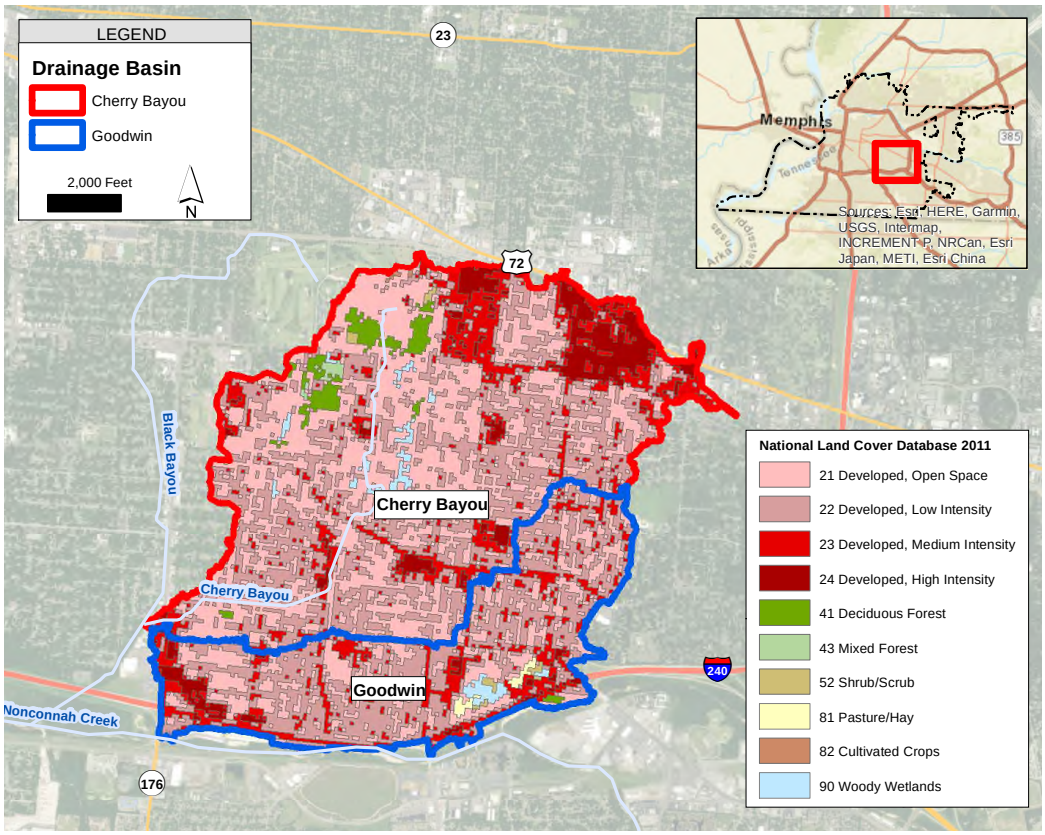


The study area has a population of approximately 20,900. Land cover for the study area is approximately 74 percent residential, 4 percent commercial, and 22 percent open space, roads, and other land use (NLCD, 2016). The Cherry Bayou watershed is the larger and more densely populated of the two within the study area. Table 1.1 provides a summary of the population and land cover characteristics for each of the two watersheds in the study area. Figure 1.3 provides a plan view schematic of the land uses across the study area.

Table 1.1: Land Cover Characteristics							
Watershed	**Population [1]**	**Area, ac**	**Residential, ac**	**Commercial, ac**	**Open Space, ac**	**Roads, ac**	**Other, ac**
Cherry Bayou	7,018	2,190	1,668	106	0	413	5
Goodwin	3,140	978	664	34	11	262	5
Total	**10,158**	**3,168**	**2,332**	**140**	**11**	**675**	**10**

1 – Population data based on 2019 US Census Bureau data.
2 – Land use data from the Shelby County GIS parcel data.

Figure 1.3: Land Cover



Using Natural Resources Conservation Service (NRCS) soil data, an analysis was performed to characterize the underlying soils. The NRCS soil data was obtained in GIS format and geo-processed for the two sub-watersheds. Table 1.2 presents a summary of each soil type and Hydrologic Soil Group by watershed. The dominant soil type is silty loam and is classified as NRCS Hydrologic Soil Group B (91%). The remainder is predominately Hydrologic Soil Groups C/D (8%) with Hydrologic Soil Groups B/D and D along with unclassified soil groups and water comprising the remaining 1% of the area.

Figure 1.4 presents the geographic extents of the NRCS soil data for the Cherry Bayou Study Area. The NRCS soil data is color-coded based on soil type and Hydrologic Soil Group. The central region of the project area is dominated by Soil Group B. The northeast and southern portion of the project area is dominated by Soil Group B/D and D soil types.

Table 1.2: NRCS Soil Classification and Hydrologic Soil Group Data			
Soil Classification	**Cherry Bayou, ac**	**Goodwin, ac**	**Total, ac**
Hydrologic Soil Group B	**2,141**	**689**	**2,830**
Graded Land, Silty Materials (Udorthent, Silty)	1,806	649	2,455
Memphis Silty Loam, 8-12% Slopes, Severely Eroded	0	0	0
Filled Silt Loam (Udorthent, Silty)	257	30	287
Memphis Silt Loam	78	0	78
Collins Silt Loam	0	10	10
Hydrologic Soil Group B/D	**33**	**275**	**308**
Falaya Silt Loam	33	275	308
Hydrologic Soil Group C/D	**1**	**0**	**1**
Grenada Silt Loam, 2-5% Slopes	1	0	1
Hydrologic Soil Group D	**4**	**10**	**14**
Calloway Silty Loam	4	10	14
Water	**8**	**1**	**9**
Unknown	**3**	**3**	**6**
Totals	**2,190**	**978**	**3,168**

Figure 1.4: NRCS Soil Classification and Hydrologic Soil Group Data

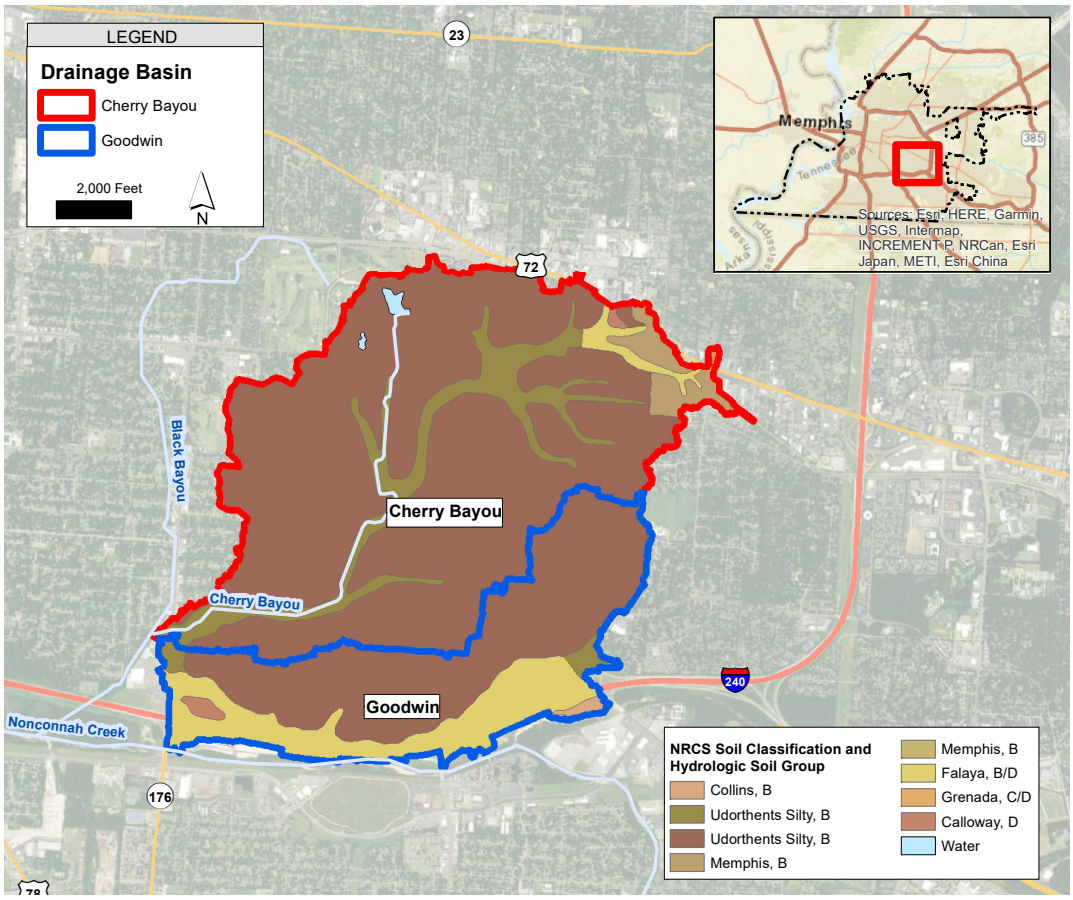
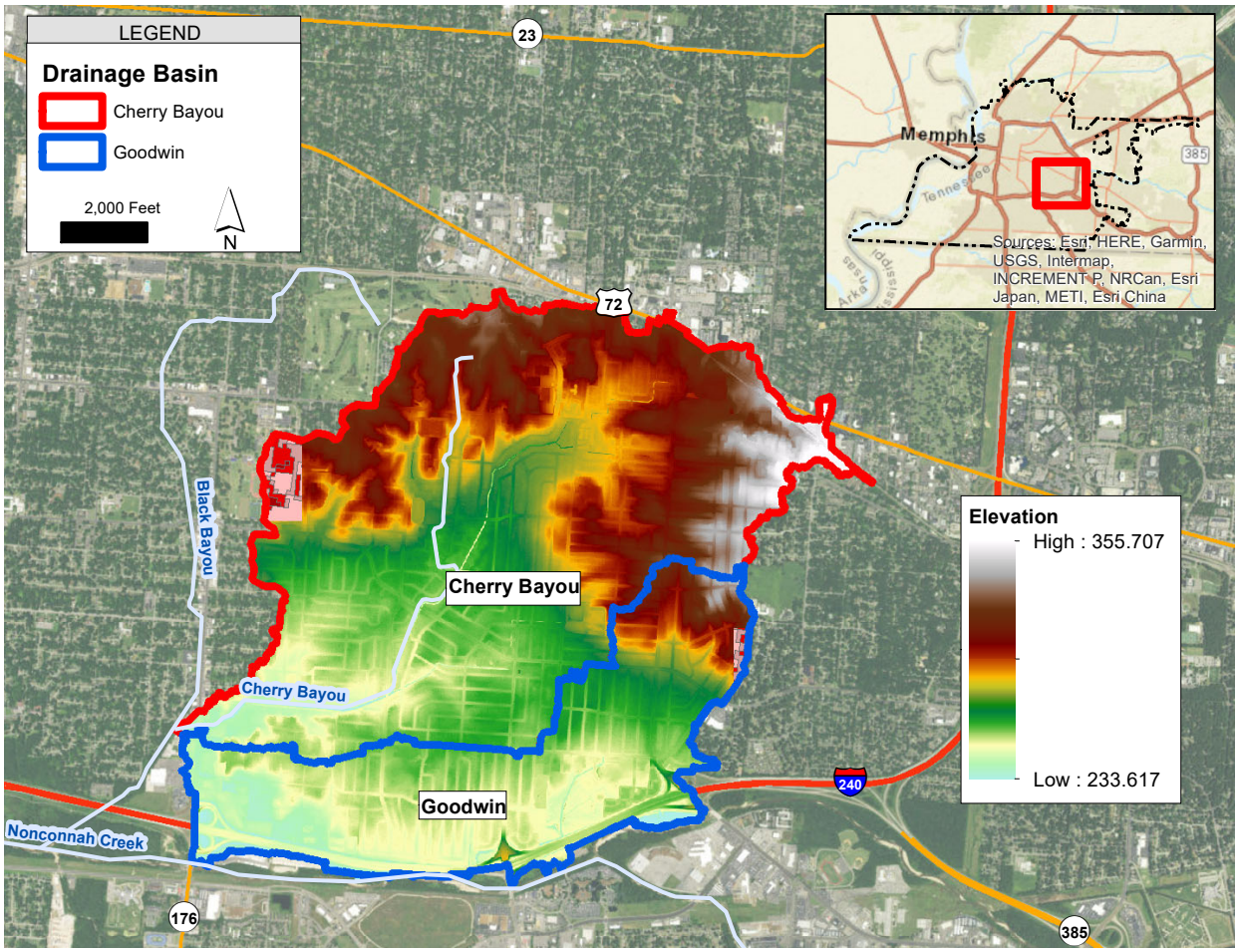


Figure 1.5 presents a topographic relief map for the study area. The study area experiences approximately 10 feet of fall from the highpoints along the northern boundaries. From this portion south, the Cherry Bayou watershed is relatively flat and contains most of the conveyance networks. The Goodwin watershed experiences approximately 15 feet of fall into the Nonconnah Creek along its southern border. The watershed does not experience significant slopes with only approximately 60 feet of fall across the entire project area.

The low-lying areas along the southern boundary of the study area are located within the Nonconnah Creek Flood Hazard Area. The Nonconnah Creek floodplain, although primarily dominated by backwater from the Mississippi River during periods of high river levels, is also affected by many other tributary watersheds, increasing the size of its floodplain.

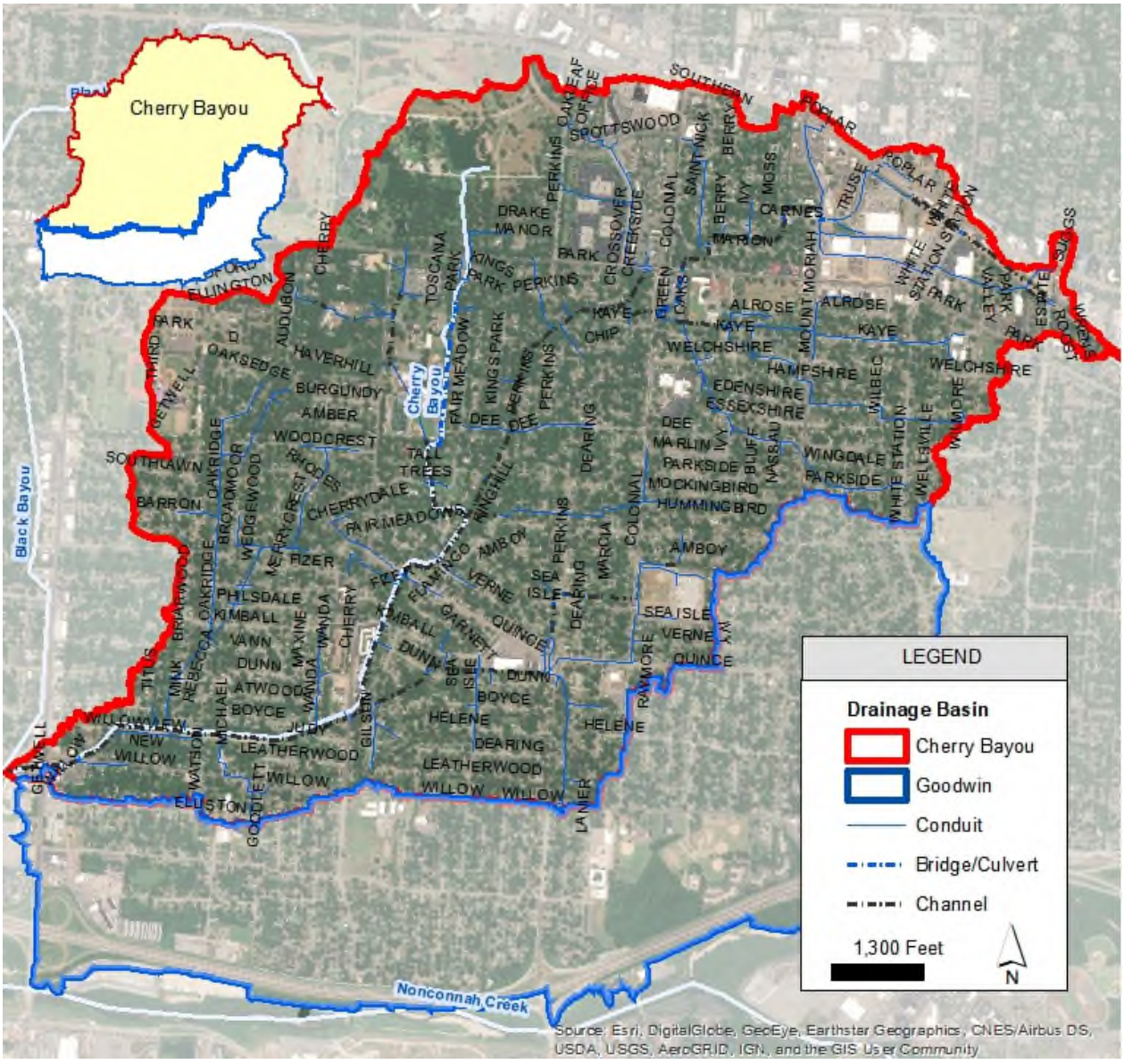
Figure 1.5: Topographic Relief



1.1.1 Cherry Bayou Watershed

The Cherry Bayou Watershed, as shown in Figure 1.6, is the larger of the two watersheds that comprise the study area (2,190 acres or approximately 68%). The watershed is drained by Cherry Bayou and flows to the Black Bayou and then on to Nonconnah Creek. Cherry Bayou starts at the Memphis Botanic Garden flowing south in a natural channel. Approximately 675 feet downstream from Park Avenue, Cherry Bayou is converted to a closed pipe system 4 feet in diameter before transitioning to a natural channel again. South of Harding Academy and north of Tall Trees Drive, Cherry Bayou becomes a concrete lined channel. From this point on, Cherry Bayou is a concrete lined channel, encountering occasional bridges, until joining the Black Bayou, which is also a concrete lined channel.

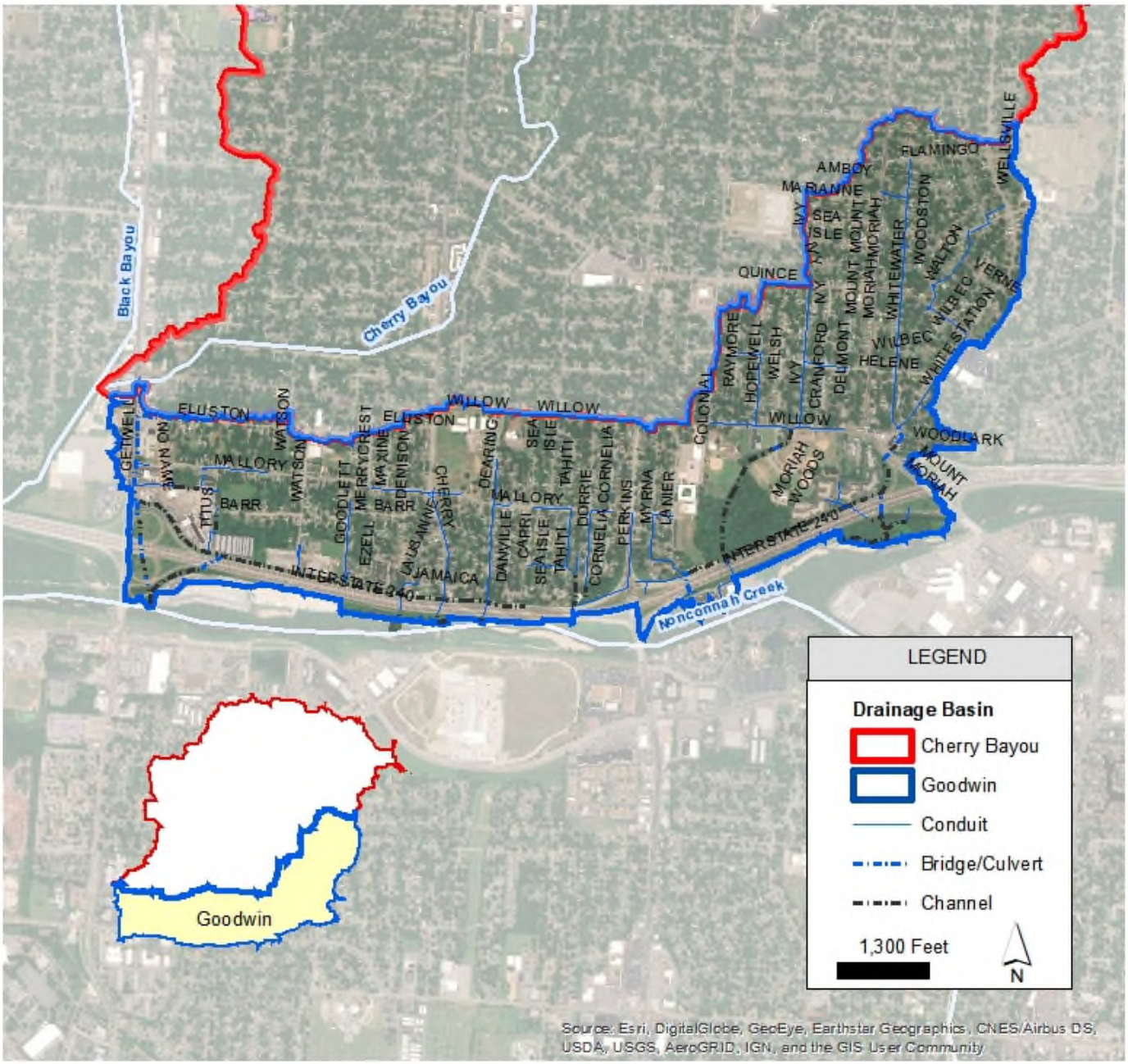
Figure 1.6: Cherry Bayou Watershed



1.1.2 Goodwin Watershed

The Goodwin watershed, as shown in Figure 1.7, is in the southern portion of the study area. The watershed consists of small drainage branches across its length, all independently draining into the Nonconnah Creek. The Goodwin basin does contain a portion of Interstate 240 and is responsible for its stormwater contribution. The majority of the basin is a closed pipe system with open channels and culverts spanning the southernmost portion of the watershed.

Figure 1.7: Goodwin Watershed



2.0 PUBLIC OUTREACH

At the project outset, the Tetra Tech team identified key stakeholders such as the Harding Academy and developed a distribution list of residents and businesses in the study area for invitation to the public participation process. The Tetra Tech team conducted a public meeting at White Station Church of Christ Community Life Center on March 29, 2018.

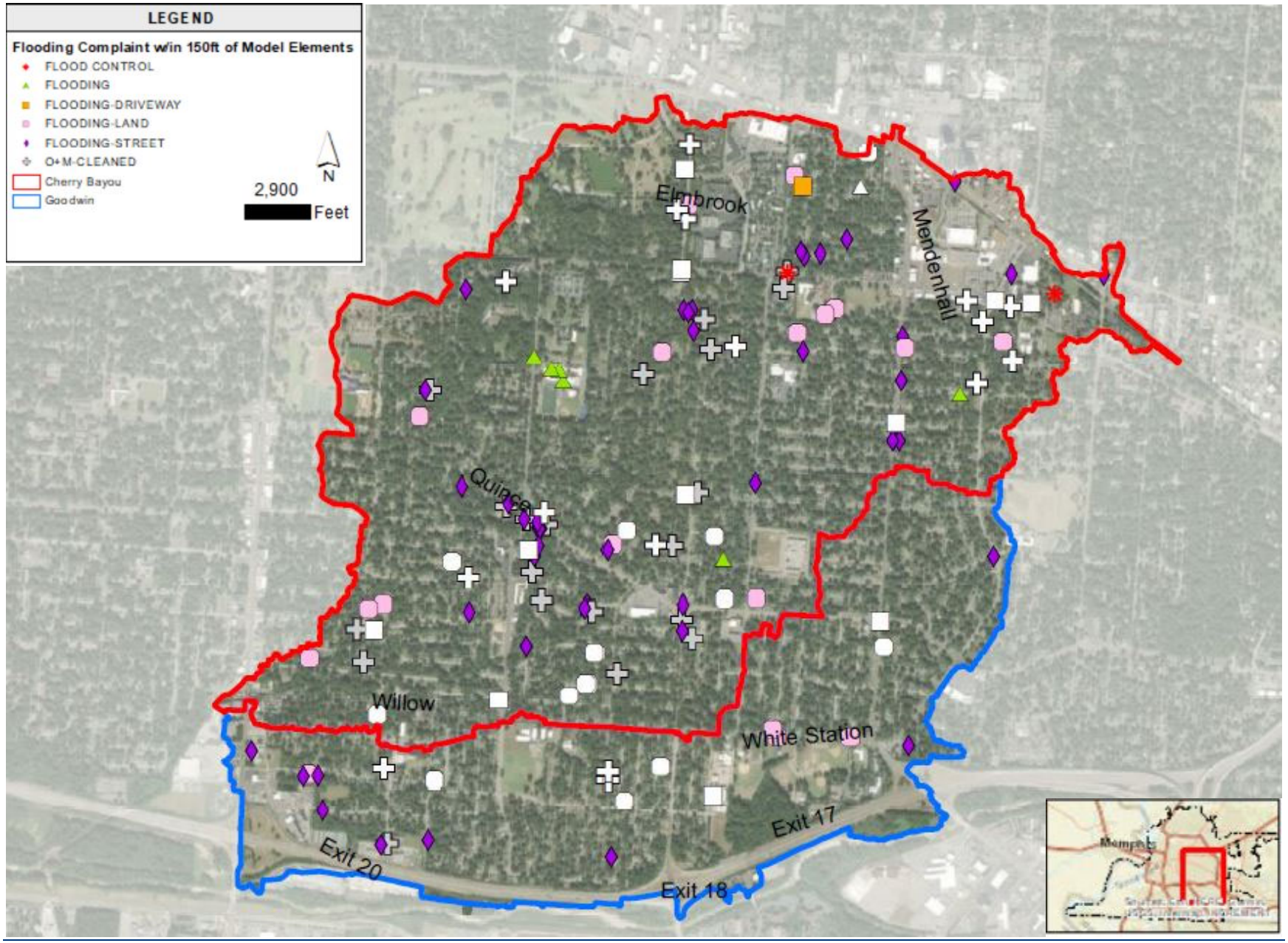
Information presented at the public meeting consisted of background information about the City of Memphis Stormwater Master Planning Program, the Cherry Bayou Study Area extents and scope of work, project goals, schedule update, and general examples of potential improvement projects. Especially important to the public meeting was giving citizens a forum to discuss observed drainage problems with the project team, and an opportunity to record input for use during the study. Tetra Tech provided a method of public comment via electronic forms, hard copy forms, and email address. Presentation slides and an attendance sheet from the public meeting are included in Appendix A. Feedback from local citizens improved the evaluation, identification, and prioritization of project opportunities during the study.

In addition to the flooding complaints received during the public outreach process, the City provided a GIS data file with prior flooding complaints that they received from November 2003 through May 2019. They are summarized in Table 2.1 below. Locations of the complaints are shown on Figure 2.1.

Table 2.1: Cherry Bayou Study Area Flooding Complaints

Watershed	Land	Street	Unidentified	Total
Cherry Bayou	29	55	2	86
Goodwin	4	10	0	14
Total	**33**	**65**	**2**	**100**

Figure 2.1: Flooding Complaints



3.0 MODEL DEVELOPMENT

The Stormwater Master Planning Program determined that InfoSWMM® would be the modeling platform used in the study. InfoSWMM is primarily a graphical user interface (GUI) for the US-EPA SWMM model and is well-suited for large scale stormwater planning activities. The US-EPA SWMM model includes an explicit solution of the Saint-Venant equations of motion. US-EPA SWMM is widely accepted and is capable of accurately modeling a wide range of hydraulic conditions including gravity closed pipe or open channel flow, surcharged systems, branched and looped networks, pump stations and force mains, diversion structures, pond/basin storage, and flow reversals.

The hydraulic model was developed to include storm sewer pipes and other closed conduits that are 24-inch diameter and larger. The City provided data for model calibration including stream level (depth of flow) and precipitation values. The model is intended to provide a basis for analyzing the existing storm sewer system, identifying hydraulic restrictions and capacity limitations, and evaluating improvement opportunities to reduce flooding at or near homes and businesses in the study area.

3.1 FIELD DATA COLLECTION

Prior to the implementing the Stormwater Master Planning Program, the City began GIS mapping of the existing public stormwater system. However, this was limited to digitization from record drawings, without any field verification.

To increase model accuracy and focus capital expenses to those areas most in need, the City included a significant field data collection effort in each of the master planning projects. The Tetra Tech team performed a field survey to locate each storm drainage structure connecting to a 24-inch diameter or larger pipe and record size and connectivity of storm sewers and cross-sectional data at open channels and culverts/bridges. In conjunction with the University of Memphis, the City separately collected stream level and precipitation data to provide information to support the model calibration.

3.1.1 Survey Data

The study area is approximately 3,168 acres and required a major surveying effort to accurately map the main tributary drainage network. For the purposes of this study, the main tributary drainage network is defined as the portion of the existing drainage system from the watershed outfalls up to and including the most upstream pipes 24-inches in diameter or greater. Generally, the survey scope included the following key items:

- 474 drainage structures (manholes, inlets, and non-culvert headwalls) connecting to storm sewer pipes that are 24-inches in diameter or larger, and other closed conduits of equivalent or larger size. To avoid system gaps, structures connecting to pipes smaller than 24-inch diameter were also surveyed when downstream of other surveyed features.
- 9 road crossings (bridges and pipe or box culverts), each including the bridge/culvert geometry, road centerline profile, and channel cross-sections immediately upstream and downstream of the crossing.
- 20 cross-sections along natural and concrete lined channels including locations of significant changes in horizontal/vertical alignment or cross-sectional geometry.
- Geo-referenced photos at open-to-closed flow transitions including road crossings, storm sewer outfalls and other features of interest. Common drainage structures such as manholes and inlets were typically not photographed, in accordance with City-provided criteria.
- 70 finished floor elevations at strategic locations along the study reaches.

In order to begin the GIS mapping and stormwater modeling effort as soon as possible, the study area was sub-divided into two areas which were surveyed separately by THY, Inc. and Geodesy Professional Services, LLC. The field surveying began in January 2018 and was completed in August 2018. After the existing conditions modeling was complete, the finished floor elevations were selected for surveying in March 2019 and the surveying was completed in May 2019.

3.1.2 Level & Precipitation Metering

The City of Memphis implemented a metering program within the study area to collect data suitable for model calibration purposes. The metering program included two level meters and three rain gauges installed from November 2017 through the end of May 2018. The City engaged the University of Memphis Ground Water Institute (GWI) to implement the Metering Program. The University was contracted to install and maintain level meters and rain gauges throughout the duration of the program, download data at regular intervals, provide quality assurance/quality control (QA/QC) activities, and transmit the data to the Project Team. Table 3.1 presents a summary of the level meter and rain gauge locations, and period of record at each location.

The two level meters, which metered water level exclusively, were installed at the following locations (see Figure 3.1):

- The Dee Street level meter was installed south of Dee Street along the Cherry Bayou where it is a concrete-lined channel, downstream of the Dee Street bridge. The concrete-lined channel at the meter location has a bottom width of 24 feet and vertical walls that extend 7.5 feet high. The channel bottom has a slight slope towards the center forming a shallow triangular section approximately 1.5 feet below the toe of the vertical walls. The Dee Street meter represents approximately 850 tributary acres of the total 2,190 acres in the Cherry Bayou drainage system.
- The New Willow Road level meter was installed along Cherry Bayou, where it is a concrete-lined channel, at the upstream end of a bridge crossing at Getwell Road. The concrete-lined channel at the meter location has a bottom width of 54 feet and vertical walls extending 10 feet high. The channel bottom has a slight slope towards the center forming a shallow triangular section, approximately 2.5 feet below the toe of the vertical walls. The New Willow Road meter represents approximately 1,340 tributary acres of the total 2,190 acres in the Cherry Bayou drainage system.

Figures 3.2 and 3.3 show photographs of the level meters installed at New Willow Road and Dee Street, respectively.

The three rain gauges were installed at the following locations (see Figure 3.1):

- The Fire Station 21 rain gauge was installed at the fire station located at 550 South Mendenhall Road. Rainfall was collected from November 2017 through the end of May 2018. Twenty-one rainfall events were recorded throughout the monitoring period. The largest event recorded at this rain gauge was 4.2 inches in 36.5 hours beginning on February 27, 2018 which equates to a two-year return frequency based on NOAA Atlas 14 data for the study area.
- The Fire Station 25 rain gauge was installed at the fire station located at 4735 Willow Road. Rainfall was collected from November 2017 through the end of May 2018. Twenty-one rainfall events were recorded throughout the monitoring period. The largest event recorded at this rain gauge was 4.8 inches in 36.5 hours beginning on February 27, 2018 which equates to a two-year return frequency based on NOAA Atlas 14 data for the study area.
- The Fire Station 30 rain gauge was installed at the fire station located at 1150 Getwell Road. Rainfall was collected from November 2017 through the end of May 2018. Twenty-one rainfall events were recorded throughout the monitoring period. The largest event recorded at this rain gauge was 4.7 inches in 36.5 hours beginning on February 27, 2019 which equates to a two-year return frequency based on NOAA Atlas 14 data for the study area.

Table 3.1: Level and Precipitation Metering				
Meter/Gauge ID	**Location**	**Latitude / Longitude**	**Tributary Area, ac**	**Metering Dates**
Dee Street Level Meter	Middle of Cherry Bayou. Downstream of the bridge over Dee Street.	35.100073° N 89.90962° W	850	11/09/2017 to 05/30/2018
New Willow Road Level Meter	Downstream end of Cherry Bayou. The intersection of New Willow and Getwell Road.	35.086646° N 89.931164° W	1,340	11/09/2017 to 05/30/2018
Fire Department 30 Rain Gauge	Fire Department #30 located at 1150 Getwell Road.	35.099836° N 89.93086° W	N/A	11/09/2017 to 05/30/2018
Fire Department 25 Rain Gauge	Fire Department #25 located at 4735 Willow Road.	35.085654° N 89.904146° W	N/A	11/09/2017 to 05/30/2018
Fire Department 21 Rain Gauge	Fire Department #21 located at 550 S Mendenhall Road.	35.115924° N 89.895765° W	N/A	11/09/2017 to 05/30/2018

Figure 3.1: Metering Locations

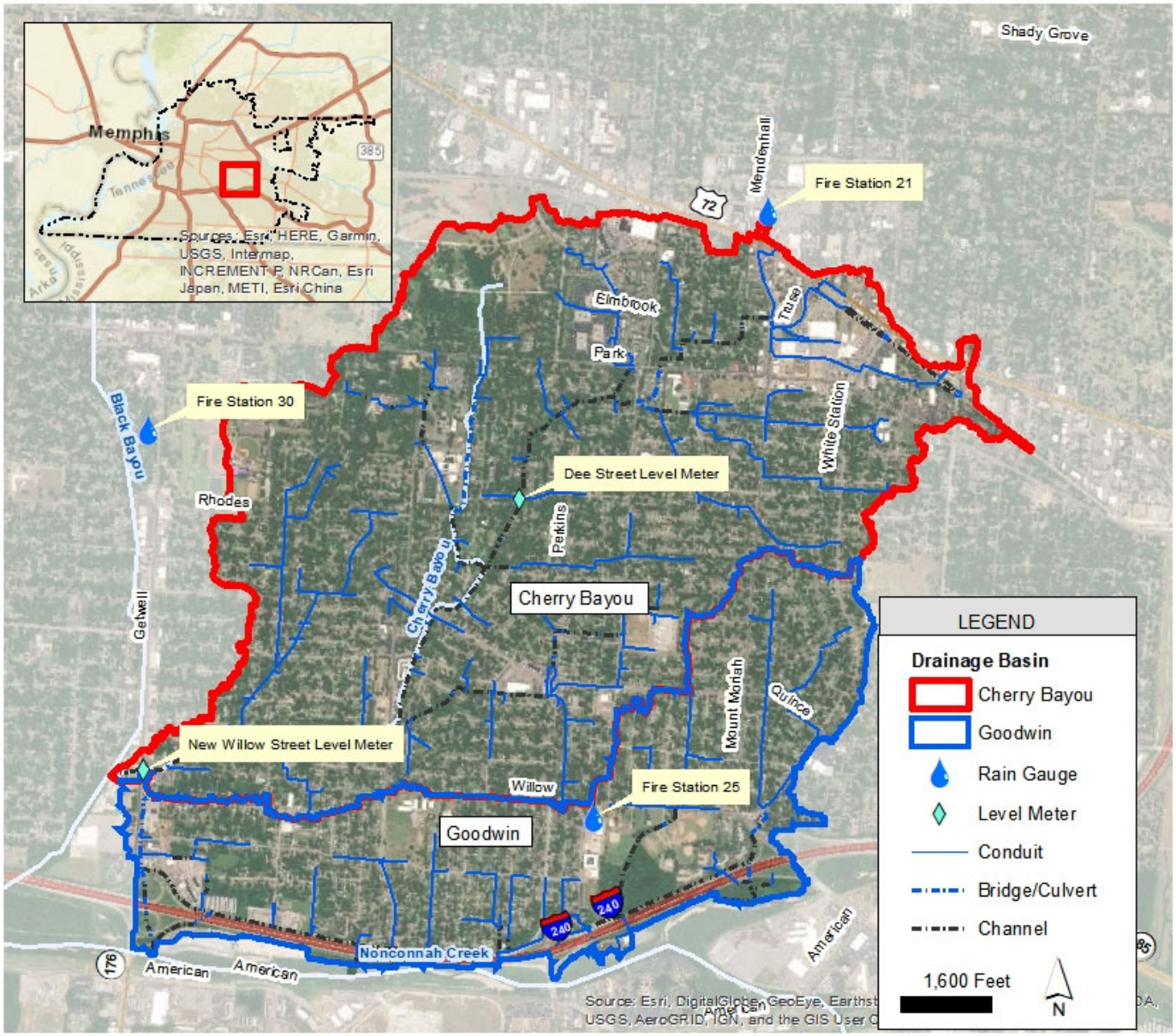


Figure 3.2: Location for Level Meter at New Willow Rd

Figure 3.3: Location for Level Meter at Dee Street

3.1.3 GIS Development

A significant deliverable for this project is the development of a GIS database of the storm drainage system. The field survey data was used as the basis to develop the GIS database. Field survey data was collected in both CAD and GIS formats. Data received in CAD format was brought into the GIS environment for quality checks. Once the data was confirmed, the line, point, and attribute data were imported into a GIS database schema created to support the project needs.

The points were then classified for the different feature types (i.e., manholes, catch basins, culverts, open channels, or closed pipes). This feature class was used to isolate omissions or problems with the data. After issues were resolved the data and attributes were loaded to the GIS point feature classes with the corresponding attribute information. The points were connected and the resulting pipes were populated with attributes using the features found in the point data. Record drawings were used to confirm connectivity as needed.

3.2 HYDRAULIC MODEL DEVELOPMENT

The GIS database was used as the starting point for the hydraulic model network. The GIS data was directly imported into the InfoSWMM modeling platform, including points for manholes or transitions in conveyance network and lines for pipes, open channels, culverts, and bridges. The survey efforts obtained the majority of the required data for each model element. Missing attributes were filled in from record drawings or subsequent field investigations.

The hydraulic model includes 46,062 lineal feet of open channel and 127,148 lineal feet of storm sewer drainage components. The model also includes 120,291 lineal feet of overland flow paths to convey flooded water to downstream locations where adequate capacity exists. The model includes 11 outfalls representing the downstream boundary or terminal node of each drainage system. A boundary condition for the Cherry Bayou was imposed by running the Black Bayou model with the associated rainfall period. Table 3.2 provides summary quantities of conveyance components included in the hydraulic model. Refer to Figure 3.1 in Section 3.1.2 for a plan view schematic of the modeled stormwater conveyance network.

	Table 3.2: Summary of Hydraulic Conveyance Network			
Watershed	**Storm Sewer, Feet**	**Open Channel, Feet**	**Overland Flow, Feet**	**# of Culverts or Bridges**
Cherry Bayou	89,033	29,013	80,642	49
Goodwin	38,115	17,049	39,649	32
Total	127,148	46,062	120,291	81

The Cherry Bayou watershed is the largest portion of the overall study area with over 68 percent of the stormwater conveyance network. The Cherry Bayou watershed hydraulic network is comprised of 118,046 lineal feet of open channel and storm sewer with 49 culverts or bridges. The Goodwin watershed contains the remaining 32 percent of the modeled drainage system and 32 bridges/culverts.

3.2.1 Representation of Open Channels

Typical of many urban stormwater drainage systems, the study area includes a combination of open channel and closed pipe systems. The open channel portions of the system were represented with cross-sectional data obtained though the field survey effort and existing County topographic datasets.

The field survey effort focused on collecting data within the channel banks. The Shelby County Light Detection and Ranging (LiDAR) data was used to characterize out-of-bank and floodplain areas. The field surveyed cross-sections were merged with the County LiDAR data to produce a single three-dimensional (3D) representation of the entire watershed including channel and floodplain areas. Model cross-sections were cut from the 3D surface at each open channel section. Development of a single 3D surface of the entire watershed increased the efficiency of model development, allowing for simple recreation or extension of cross-section limits at any phase

of the project. This 3D surface was also used to delineate floodplain limits for design storm simulations of existing and proposed conditions.

Photographs were used to characterize the channel and floodplain Manning "n" values for each reach. Typical Manning "n" values were obtained from the City of Memphis/Shelby County Stormwater Management Manual.

3.2.2 Representation of Bridges and Culverts

The system includes many culverts at road crossings of the open channel system. InfoSWMM includes routines that mimic culvert hydraulic calculations as presented in the United States Federal Highway Administration (FHWA) Hydraulic Design Series Number 5: Hydraulic Design of Highway Culverts (HDS5). Each culvert in the Cherry Bayou system was evaluated for size, material, and headwall configuration to select a FHWA Culvert Code to best approximate culvert hydraulics. Culvert specific entrance and exit minor loss coefficients were applied based on the inlet/outlet configuration.

The system includes 81 bridge spans at road or railroad crossings of the open channel system. InfoSWMM uses a relatively new curve type to construct a custom shape for closed conduits that cannot be reasonably defined using the standard shapes typically used for culverts. The curve represents depth to full depth ratio on the Y-axis, and width to full depth ratio on the X-axis. This specifies how the width of the cross section varies with height, where both width and height are scaled relative to the section's maximum depth. This allows the roadway bridge deck low chord to represent the top of a closed conduit over a natural or concrete channel. Bridge spans are then modeled as a closed conduit culvert as described above.

At each culvert and bridge span location in the model, parallel conduits were provided to represent the culvert and the overland flow in the event that the culvert capacity was exceeded. The overland flow path was visually determined from the topographic data. A new conduit was created for the overland flow and a cross-section was cut to represent the shape of the flow path.

3.3 HYDROLOGIC MODEL DEVELOPMENT

The City of Memphis determined that the US-EPA SWMM Runoff Method would be the hydrologic model for use in the Stormwater Program. The SWMM Runoff Method is well-suited for use in urban and rural stormwater runoff modeling and drainage system master planning.

The SWMM Runoff Method uses the Kinematic Wave Method to calculate hydrologic response to precipitation. The following hydrologic parameters determine the magnitude and shape of the runoff hydrograph produced by the SWMM Runoff Method for a given storm event:

- Subcatchment Area, Width, and Ground Slope
- Directly Connected Impervious Area (DCIA)
- Percent of Impervious Area with Zero Depression Storage
- Soil Infiltration
- Evaporation
- Depression storage
- Overland roughness

The surface runoff rate for a subcatchment is calculated by using Manning's equation solved for a rectangular plane with negligibly small side heights:

$$Q = \frac{1.486}{n} * W * (d - d_s)^{\frac{5}{3}} * S^{\frac{1}{2}}$$

Where,

Q = surface runoff rate (cfs),

n = Manning's roughness coefficient,

W = width of the plane (ft),

d = depth (ft),

d_s = depression storage (ft), and

S = average slope of the plane (ft/ft)

Subcatchments for the study area were manually delineated using the GIS shapefiles of the storm sewer system provided by the City and a digital elevation model (DEM) created from Shelby County LiDAR data. The DEM was processed to create a stream network file to assist in making manual delineation decisions. The delineations were performed based on the following general criteria:

- Provide an input to each of the upstream terminal ends of the system
- Subdivide the tributary areas at locations where open channel transitions to a closed pipe system
- Subdivide large catchments to prevent "overloading" of a single receiving node.

The final delineation resulted in 688 subcatchments with an average size of 4.6 acres. The subcatchments range in size from 0.009 to 53.6 acres. Subcatchments are generally larger in less urban areas that are not drained by the storm sewer system and smaller in the urban and dense residential areas which have an increased number of storm sewer inlets.

The overland flow paths were calculated for each subcatchment. The flow paths were then used to estimate catchment width and slope. Catchment widths were calculated utilizing the subcatchment manager within InfoSWMM. The method utilized sets the width equal to 1.7 multiplied by either height or width of the subcatchment, whichever is greater. Slopes were calculated as a difference between upstream and downstream elevation along the overland flow path divided by its length. The width and slope parameters are most sensitive to peak flow rate and timing. These parameters were used to provide necessary adjustments to the resulting runoff during the calibration process. The preliminary slope and width values were adjusted uniformly within a meter basin to achieve the desired calibration results.

3.3.1 Directly Connected Impervious Area

The Multi-Resolution Land Characteristics (MRLC) National Land Cover Database 2011 (NLCD) imperviousness coverage was used to calculate the initial imperviousness value for each subcatchment. The catchment delineations and NLCD coverages were overlaid to calculate the area weighted average percent imperviousness for each subcatchment. The percent of impervious area routed to pervious area (i.e., DCIA) is most sensitive to the total volume of runoff for a catchment. This percentage was used to adjust the total volume of the predicted runoff to best match measured values during the calibration process. This percentage was adjusted uniformly within a meter basin until the desired calibration results were obtained. Figure 3.4 presents the relative density of impervious areas in the Cherry Bayou Study Area. Table 3.3 summarizes the final calibrated and validated average percent impervious values used from the model input data file.

Figure 3.4: Cherry Bayou Study – Impervious Coverage

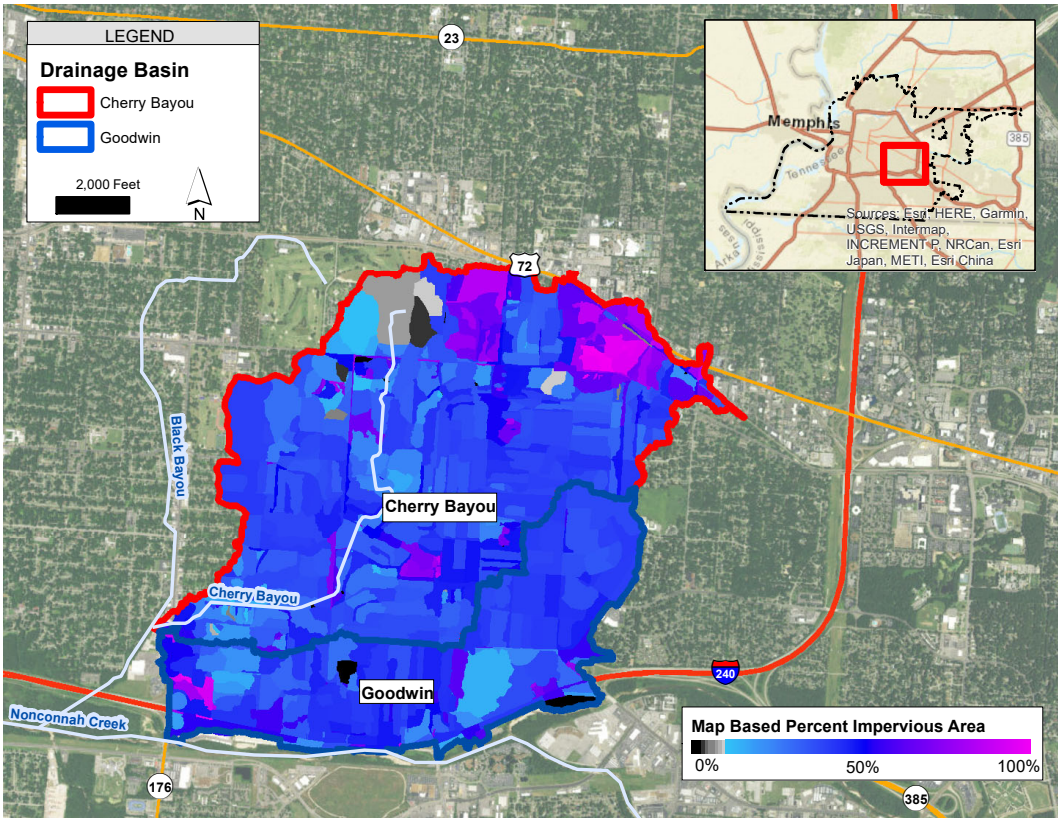


Table 3.3: Map Based Percent Impervious		
Watershed	**Area, ac**	**Percent Impervious[1]**
Cherry Bayou	624.5	28
Goodwin	239	34
Total	863.5	62

1: Impervious data from NLCD 2011 GIS overlay.

3.3.2 Soil Infiltration Parameters

Infiltration is the movement of water through the soil surface and into the soil and groundwater table. It is related to the moisture conditions in the surface soil zone. The infiltration capacity of a soil at any given time is the maximum rate at which water can enter the soil. Typically, on well-drained porous soils, recovery of infiltration capacity is quite rapid. However, for heavier clay soils the recovery rate is likely to be slower.

The City of Memphis standardized on the US-EPA SWMM Green-Ampt method. The Green-Ampt equation is a physically based model that can provide a good description of the infiltration process using readily available soil classification data.

The formulation of the Green-Ampt equation is a two-stage model. The first step predicts the volume of water that will infiltrate before the surface becomes saturated. From this point onward, infiltration capacity is then computed directly by the Green-Ampt equation.

$$I = \frac{K_a * S_w * (\theta_a - \theta_i)}{i - K_a}$$

Where,

I = infiltration volume (in^2)

K_a = saturated hydraulic conductivity (in/hr)

S_w = capillary suction head (in)

θ_a= saturated water contents (in)

θ_i = initial water contents (in)

i = rainfall (in/hr)

Three parameters need to be specified for each subcatchment. These parameters are capillary suction head, saturated hydraulic conductivity, and the initial moisture deficit of the soil. These parameters were selected from textbook values based on the percentages of soil types in each catchment. These values were used to adjust the total volume of the predicted runoff to best match measured values during the calibration process. Values were only adjusted within textbook tolerance and were adjusted uniformly within a meter basin until the desired calibration results were obtained. Table 3.4 presents the range of soil parameters used.

Table 3.4: Infiltration Parameters			
Parameter	**Minimum Value**	**Maximum Value**	**Median Value**
Saturated Hydraulic Conductivity (in/hr)	0.1	0.35	0.35
Suction Head (in)	6.57	11.42	6.57
Initial Moisture Deficit (ft/ft)	0.06	0.217	0.217

The United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) was used as the basis for classifying soil characteristics. Subcatchments were overlaid with SSURGO data to determine the underlying soil texture, hydrologic soil group (HSG), and hydraulic conductivity for each delineation. The resulting values represent area weighted averages for each parameter based on the percentage of a particular soil type within each subcatchment.

Suction head values were selected from typical textbook values (Rawls, W.J. et al., 1983, J. Hyd. Engr., 109:1316) based on the percentage of particular soil textures in each subcatchment. Initial Moisture Deficit (IMD) values were selected from the SWMM 4 manual (p. 112). Conductivity values were selected from typical textbook values as well (Saxton and Rawls, 2006, Soil Sci. Soc. Am. J. 70:1569–1578). The Manning's roughness coefficient was set to 0.055 for pervious areas and to 0.018 for impervious areas (City of Memphis/Shelby County Storm Water Management Manual). The depression storage value was set to 0.15 inches (SWMM 5.1 manual, Table A.5).

3.4 MODEL CALIBRATION AND VALIDATION

Model calibration is the process of adjusting both hydrologic (flow development) and hydraulic (flow routing) variables to best match actual measured flow, depth, and rainfall data. The result is a hydrologic and hydraulic model of an existing collection system that best represents flow responses to wet weather conditions and hydraulic grade lines within the drainage system. A properly calibrated hydrologic and hydraulic model provides a valuable tool for many types of analyses including simple capacity analyses and complex master planning evaluations.

Model calibration is the iterative process to identify the runoff and hydraulic routing parameters that most closely match the flow/rainfall data. An initial set of hydrologic parameters (catchment slope, width, and percent impervious) are input to the model and used to develop flow results. The results are compared to flow monitoring data and adjustments are made to the runoff variables (catchment slope, width, and percent impervious as well as soil conductivity, IMD, and suction head) to provide a closer fit to the measured data. This process is performed until model predictions best fit the monitoring data.

The validation process requires that some events are set aside during the model calibration process and used at the end to confirm the parameter optimization efforts. The verification process includes two components: (1) presentation of model predictions for the verification events set aside during calibration efforts and (2) for all events, a statistical analysis of modeling and flow monitoring data to confirm the model calibration results provide the best fit to measured flows and rainfall data. Refer to Section 3.4.2 for a discussion of model parameters adjusted during the calibration process and overall ability of the model to predicted measured conditions.

3.4.1 Event Data

The study area model was validated using data collected at two level meter locations: upstream Cherry Bayou branch at Dee Street and downstream Cherry Bayou branch at New Willow Road and Getwell Road. The in-stream data included level measurements from November 2017 to the end of May 2018. The City also collected precipitation data at Fire Stations #21, #25, #30.

The level data was directly used to validate peak level predictions to measured data for wet weather conditions. A total of 21 wet weather events were identified. Table 3.5 provides a summary of the events including precipitation, level, and flow statistics. The two largest precipitation events occurred on February 27, 2018 (4.17-4.81 inches of rainfall) and December 22, 2017 (3.60-4.08 inches of rainfall). These events resulted in significantly greater peak level flow and event volumes as compared to other events, with predominantly less than one inch of total rainfall.

Of the 21 rainfall events that occurred during the monitoring period, two events were kept aside for the model verification process (e.g., not included in the calibration analyses). The January 11, 2018 and February 9, 2018 events were used for the verification process. The other nineteen events were used in the model calibration. Figure 3.5 and Figure 3.6 present the peak level events for the New Willow Road and Dee Street monitoring locations, respectively. The time-series flow data was used to validate the peak flow and event volumes for rainfall events in the calibration period.

Table 3.5: Calibration and Verification Events

Event No.	Date	Event Type	Fire Station 21 Rain Gage	Fire Station 25 Rain Gage	Fire Station 30 Rain Gage	Dee Street Level Meter	New Willow Road Level Meter
1	12/4/2017	Calibration	1.01 in, 0.61 in/hr	1.03 in, 0.62 in/hr	0.91 in, 0.54 in/hr	3.21 ft	2.4 ft
2	12/17/2017	Calibration	0.72 in, 0.31 in/hr	0.7 in, 0.3 in/hr	0.71 in, 0.3 in/hr	0.88 ft	1.45 ft
3	12/19/2017	Calibration	1.59 in, 0.33 in/hr	1.43 in, 0.28 in/hr	1.75 in, 0.35 in/hr	1.05 ft	1.79 ft
4	12/22/2017	Calibration	3.76 in, 0.93 in/hr	3.6 in, 0.83 in/hr	4.08 in, 0.91 in/hr	2.40 ft	6.2 ft
5	1/11/2018	Verification	1.02 in, 0.29 in/hr	1.07 in, 0.33 in/hr	1.24 in, 0.41 in/hr	1.14 ft	1.73 ft
6	1/22/2018	Calibration	0.69 in, 0.5 in/hr	0.76 in, 0.58 in/hr	0.69 in, 0.54 in/hr	1.54 ft	2.48 ft
7	1/27/2018	Calibration	0.79 in, 0.33 in/hr	0.78 in, 0.36 in/hr	0.76 in, 0.31 in/hr	0.87 ft	1.70 ft
8	2/6/2018	Calibration	1.37 in, 0.35 in/hr	1.48 in, 0.34 in/hr	1.39 in, 0.35 in/hr	1.01 ft	2.25 ft
9	2/9/2018	Verification	2.33 in, 0.65 in/hr	2.26 in, 0.52 in/hr	2.35 in, 0.65 in/hr	2.45 ft	4.77 ft
10	2/13/2018	Calibration	1.14 in, 0.43 in/hr	0.87 in, 0.39 in/hr	1.14 in, 0.45 in/hr	1.21 ft	2.37 ft
11	2/21/2018	Calibration	3.64 in, 0.43 in/hr	3.44 in, 0.41 in/hr	3.69 in, 0.53 in/hr	1.31 ft	3.30 ft
12	2/24/2018	Calibration	0.8 in, 0.34 in/hr	0.88 in, 0.46 in/hr	0.82 in, 0.36 in/hr	1.20 ft	2.24 ft
13	2/27/2018	Calibration	4.17 in, 0.5 in/hr	4.81 in, 0.58 in/hr	4.72 in, 0.69 in/hr	1.84 ft	4.70 ft

Table 3.5: Calibration and Verification Events							
Event No.	**Date**	**Event Type**	**Fire Station 21 Rain Gage**	**Fire Station 25 Rain Gage**	**Fire Station 30 Rain Gage**	**Dee Street Level Meter**	**New Willow Road Level Meter**
14	3/4/2018	Calibration	0.56 in, 0.17 in/hr	0.62 in, 0.27 in/hr	0.65 in, 0.2 in/hr	0.55 ft	0.86 ft
15	3/28/2018	Calibration	1.9 in, 0.91 in/hr	2.06 in, 0.91 in/hr	1.8 in, 1.1 in/hr	2.22 ft	4.50 ft
16	4/13/2018	Calibration	2.83 in, 1.02 in/hr	3.08 in, 1.17 in/hr	3.08 in, 1.17 in/hr*	4.24 ft	8.35 ft
17	4/21/2018	Calibration	2.04 in, 0.35 in/hr	2.46 in, 0.41 in/hr	2.46 in, 0.52 in/hr*	1.02 ft	2.34 ft
18	4/25/2018	Calibration	2.33 in, 0.39 in/hr	2.25 in, 0.41 in/hr	2.25 in, 0.41 in/hr*	1.39 ft	3.68 ft
19	5/17/2018	Calibration	0.2 in, 0.13 in/hr	0.9 in, 0.72 in/hr	1.35 in, 1.25 in/hr	1.21 ft	3.03 ft
20	5/21/2018	Calibration	0.85 in, 0.69 in/hr	1.3 in, 1.12 in/hr	1.03 in, 0.85 in/hr	1.87 ft	3.64 ft
21	5/29/2018	Calibration	0.26 in, 0.17 in/hr*	0.24 in, 0.14 in/hr	0.26 in, 0.17 in/hr	1.81 ft	3.47 ft

*Data was supplemented from rain gage Fire Station 30 due to inaccurate rainfall forecast or a data deficiency.

The model was validated against four criteria to best match the shape and magnitude of the measured data:

- Peak event depth of flow
- Visual comparison of model predicted and measured time-series level data.

The validation process includes a graphical and statistical comparison of the model predictions against metering data. For each event, the values predicted by the model (y-axis) were plotted against the measured data (x-axis). A theoretical 1:1 line (i.e., a 45 degree line) is plotted to divide the chart into two zones. Ideally, the modeled vs. measured data points would fall exactly on the 1:1 line indicating a perfect match. Complete datasets rarely fall on the 1:1 line due to uncertainties in rainfall and flow measurement equipment and varying meteorological and antecedent moisture conditions. Data points that fall below the 1:1 line indicate the model is under-predicting the measured data. Conversely, if the data point lies above the 1:1 line, the model is over-predicting the measured data. In practice, the calibration process is meant to develop a model that best represents the average conditions for which the model will be applied. A visual comparison was also performed for each event to confirm the model predicted hydrograph includes similar shape, timing and responsiveness as measured in the field. An example of the graphical validation results and visual hydrograph comparison is presented in the following section. The event numbers are identified in Table 3.5.

3.4.2 Calibration and Validation Results

Current industry standards (i.e., Chartered Institution of Water and Environmental (CIWEM) modeling guidelines) suggest that model calibration is acceptable when a trendline drawn through the modeled versus metered data has a slope of -10% to +15% for event volume and -15% to +25% for peak flow. In general, the model developed for the Cherry Bayou Study Area meets these criteria and is considered well calibrated.

The Dee Street level meter (CB-2) includes approximately 845 acres (37%) of the Cherry Bayou branch drainage area including the majority of developed residential and commercial areas. This meter was calibrated by balancing events that overpredict and underpredict to achieve the most overall accurate calibration. In general, events that slightly overpredict are not analyzed in this section of the report since they will only make the model more conservative. However, the May 29th event is thought to greatly overpredict as a result of inaccurate rainfall or level data. Therefore, this event is considered an outlier. For the December 4th event, the model underpredicts by 41%. However, for the May 21st event, a comparable event for rainfall amount and peak intensity, the model accurately predicts. Therefore, the model is thought to underpredict as a result of inaccurate rainfall or level data. For the March 4th event, the model underpredicts by 40%. This event is the smallest event in the monitoring period and it is bordering on being large enough to be considered as a calibration event. The model is calibrated to predict more accurately during larger rainfall events. For the May 17th event, the model underpredicts by 29 percent. The following event on May 21st recorded a similar meter response, but the total rainfall and peak intensity recorded for this event is much greater, approximately 73 and 75 percent respectively. Therefore, the model is thought to underpredict as a result of inaccurate rainfall or level data.

The New Willow Road and Getwell Road level meter (CB-1) includes approximately 1,340 acres (59%) of the Cherry Bayou branch drainage area including the majority of highly developed residential areas. In general, the model either predicts or slightly overpredicts most events with two exceptions: the March 4th, 2018 event and the April 13th, 2018 event. The April 13th event is the largest event in the monitoring period. For this event, the model underpredicts peak flow level by approximately 19 percent. For the April 13th event, the model underpredicts peak level by approximately 17 percent.

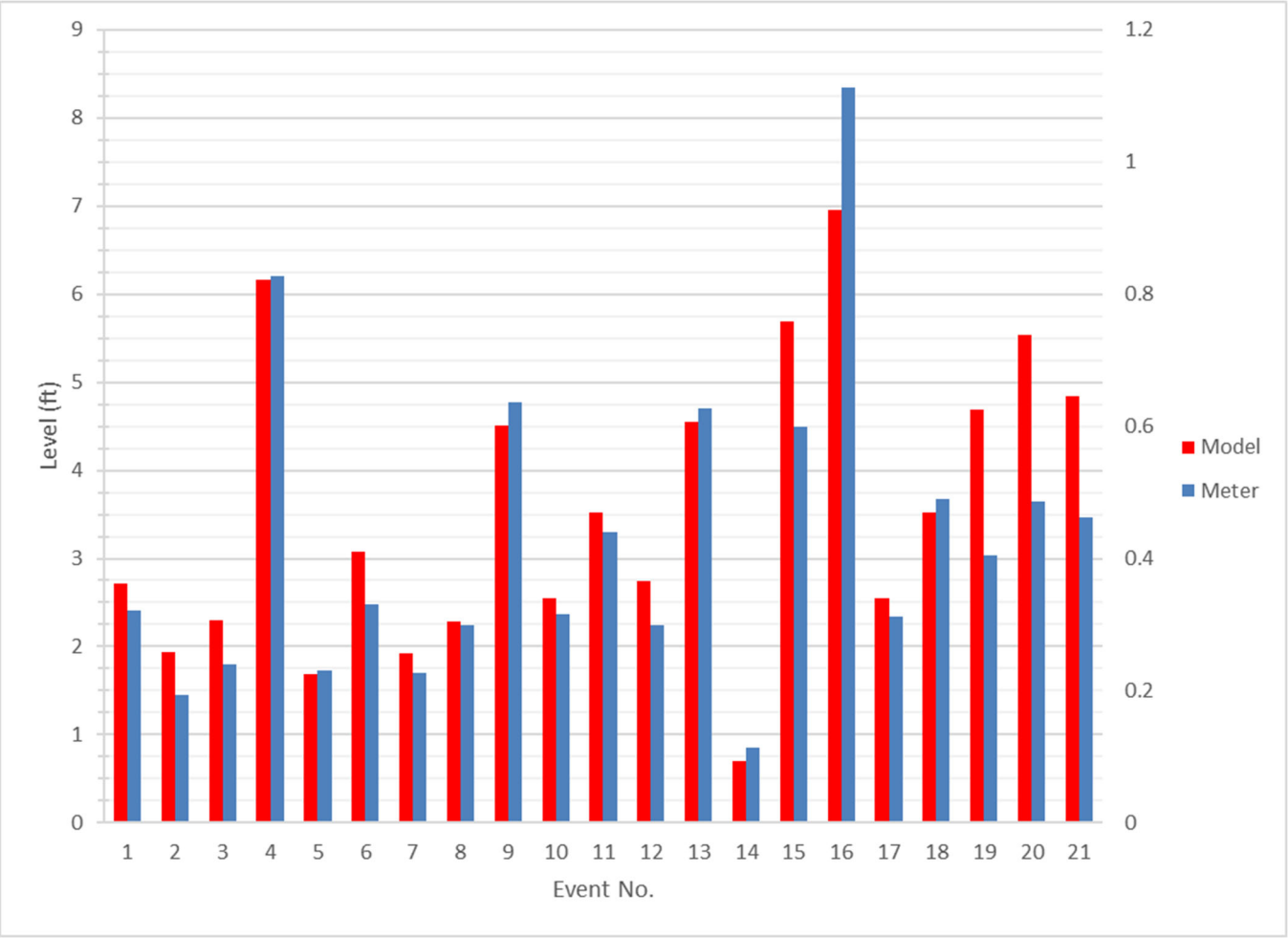
The subcatchment percent impervious, width, and slope are the model parameters adjusted during the calibration process. The percent of impervious area routed to pervious was 35% for the Dee Street meter basin and 40% for the New Willow and Getwell Street meter basin. The subcatchment slopes were decreased by 30% for the Dee Street meter basin and increased 10% for the New Willow and Getwell Street meter basin. The soil hydraulic conductivity was also adjusted, but less uniformly, in order to achieve accurate calibration. In some instances, it was increased, and others decreased. The Goodwin basin did not contain any level meters. As such, these subcatchment parameters were adjusted to match the Dee Street meter basin. Table 3.6 shows the discussed parameters pre- and post-calibration.

In general, the model overpredicts for smaller events and is in line with larger events that would be more similar to a design storm event condition. Since the model is intended to be simulated for larger design storm event conditions, the model is considered to be well calibrated.

Table 3.6: Pre- and Post-Calibration Parameters

Parameters	Original	CB-1 Meter Basin	CB-2 Meter Basin
Impervious Area Routed to Pervious	0%	40%	40%
Slope	Calculated via DEM	- 40%	- 50%
Width	Calculated via subcatchment manager in InfoSWMM	- 25%	- 25%
Initial Depression Storage for Pervious Area	0.15	0.2	0.4
Initial Depression Storage for Impervious Area	0.07	0.15	0.15
Soil Conductivity	0.26	0.1	0.35
Meter Offset	--	-0.15	-0.335

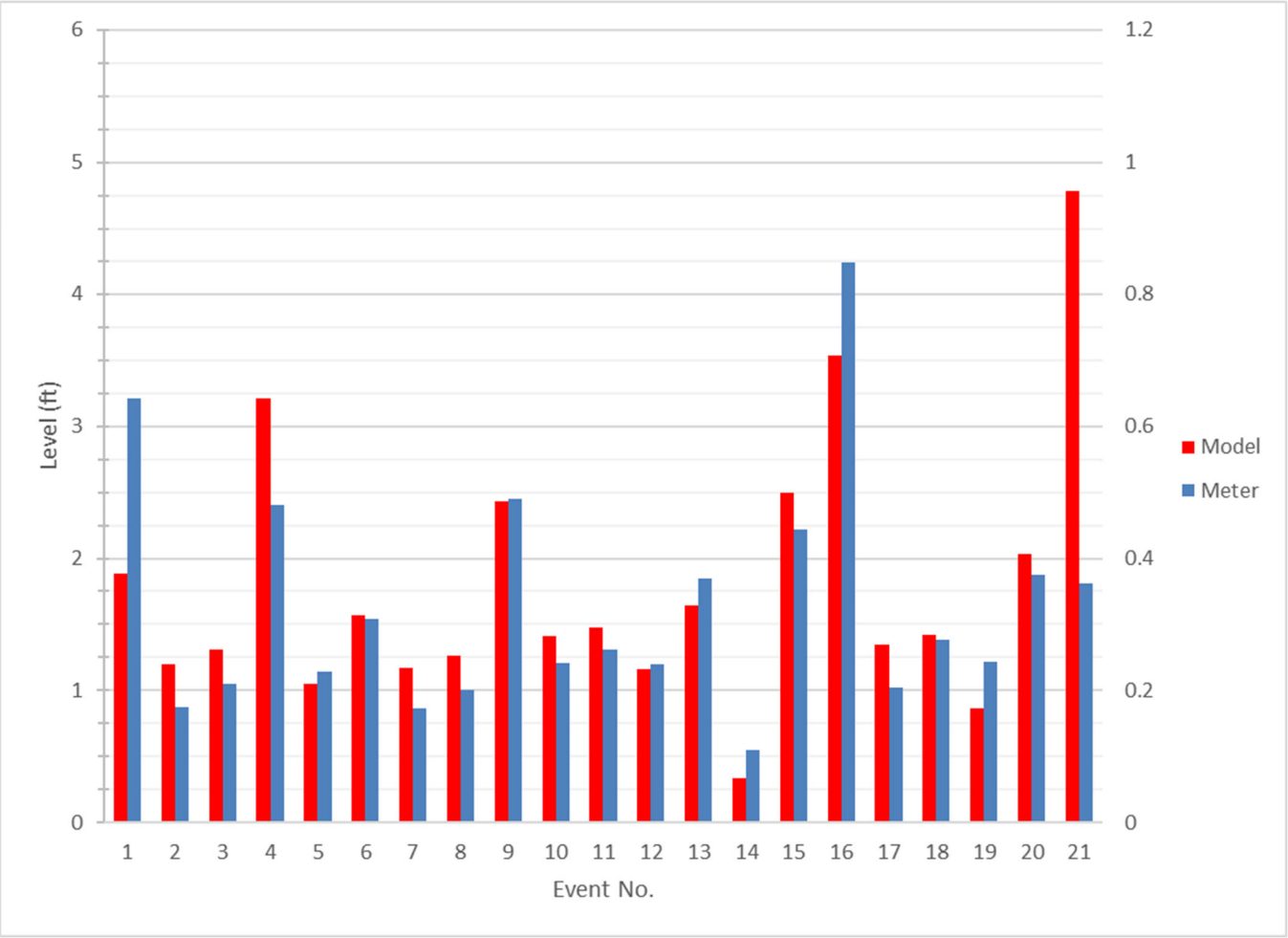
Figure 3.5: New Willow Road Calibration – Peak Level Results



Note: Events #5 and #9 were used for model validation. All others used for model calibration purposes.

Table 3.7: New Willow Road Calibration – Peak Level Results					
Event ID	**Event Date**	**Rainfall (in)**	**Duration (hrs)**	**Peak Observed Level (ft)**	**Peak Modeled Level (ft)**
1	12/4/2017	0.91	9.00	2.40	2.71
2	12/17/2017	0.71	4.00	1.45	1.94
3	12/19/2017	1.75	23.75	1.79	2.29
4	12/22/2017	4.08	25.75	6.2	6.16
5	*1/10/2018*	*1.24*	*21.83*	*1.73*	*1.68*
6	1/22/2018	0.69	3.33	2.48	3.08
7	1/27/2018	0.76	13.25	1.70	1.92
8	2/6/2018	1.39	11.25	2.25	2.29
9	*2/9/2018*	*2.35*	*36.00*	*4.77*	*4.51*
10	2/13/2018	1.14	24.42	2.37	2.54
11	2/21/2018	3.69	23.33	3.3	3.52
12	2/24/2018	0.82	27.00	2.24	2.74
13	2/27/2018	4.72	36.50	4.70	4.54
14	3/4/2018	0.65	9.67	0.86	0.70
15	3/28/2018	1.80	11.67	4.5	5.70
16	4/13/2018	3.08	9.25	8.35	6.96
17	4/21/2018	2.46	34.25	2.34	2.54
18	4/25/2018	2.25	14.67	3.68	3.52
19	5/17/2018	1.35	6.75	3.03	4.69
20	5/21/2018	1.03	4.42	3.64	5.54
21	5/29/2018	0.26	4.25	3.47	4.85

Figure 3.6: Dee Street Calibration – Peak Level Results



Note: Events #5 and #9 were used for model validation. All others used for model calibration purposes.

Table 3.8: Dee Street Calibration – Peak Level Results					
Event ID	**Event Date**	**Rainfall (in)**	**Duration (hrs)**	**Peak Observed Level (ft)**	**Peak Modeled Level (ft)**
1	12/4/2017	1.01	8.58	3.21	1.89
2	12/17/2017	0.72	5.75	0.88	1.2
3	12/19/2017	1.59	48.75	1.05	1.31
4	12/22/2017	3.76	22.92	2.40	3.21
5	*1/10/2018*	*1.02*	*31.92*	*1.14*	*1.05*
6	1/22/2018	0.69	3.17	1.54	1.57
7	1/27/2018	0.79	12.50	0.87	1.18
8	2/6/2018	1.37	11.33	1.01	1.27
9	*2/9/2018*	*2.33*	*36.50*	*2.45*	*2.43*
10	2/13/2018	1.14	24.50	1.21	1.41
11	2/21/2018	3.64	53.17	1.31	1.48
12	2/24/2018	0.80	27.08	1.20	1.16
13	2/27/2018	4.17	36.50	1.84	1.65
14	3/4/2018	0.56	20.00	0.55	0.33
15	3/28/2018	1.90	28.00	2.22	2.50
16	4/13/2018	2.83	9.25	4.24	3.54
17	4/21/2018	2.04	49.50	1.02	1.35
18	4/25/2018	2.33	14.58	1.39	1.42
19	5/17/2018	0.20	7.58	1.21	0.86
20	5/21/2018	0.85	13.42	1.87	2.03
21	5/29/2018	0.26*	4.25*	1.81	4.78

*Data was supplemented from rain gage Fire Station 30 due to inaccurate rainfall forecast.

4.0 EXISTING CONDITIONS

4.1 APPROACH

The model was calibrated and validated to the recorded flow monitoring data. Design storm events were used to evaluate the system's capacity. The events that were chosen included the 2-, 5-, 10-, 25-, 50-, and 100-year, 24-hour design storms. These storm events were developed using the published Intensity-Duration-Frequency (IDF) charts specifically assigned for the City and Shelby County to create design storm hyetographs. The IDF curves for the City are based on data published in the "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 2 (G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M. Yekta, and D. Riley). Hyetographs for the City and Shelby County for a 24-hour storm duration were developed using the National Resource Conservation Service (NRCS) Type II 24 Hour Storm Distribution. For example, a dimensionless unit hyetograph for a 24-hour storm event is shown in Figure 4.1. Table 4.1 indicates the total depth for each design event. The design storm event cumulative distribution curve is presented in Figure 4.1. Figure 4.2 and Figure 4.3 present the design storm event hyetographs applied for this project.

Table 4.1: Design Storm Rainfall Depth

Design Event	Rainfall Depth, in
2-year, 24-hour	4.01
5-year, 24-hour	4.89
10-year, 24-hour	5.58
25-year, 24-hour	6.52
50-year, 24-hour	7.27
100-year, 24-hour	8.02

Figure 4.1: NRCS Type II, 24-Hour Design Storm Cumulative Distribution Curve

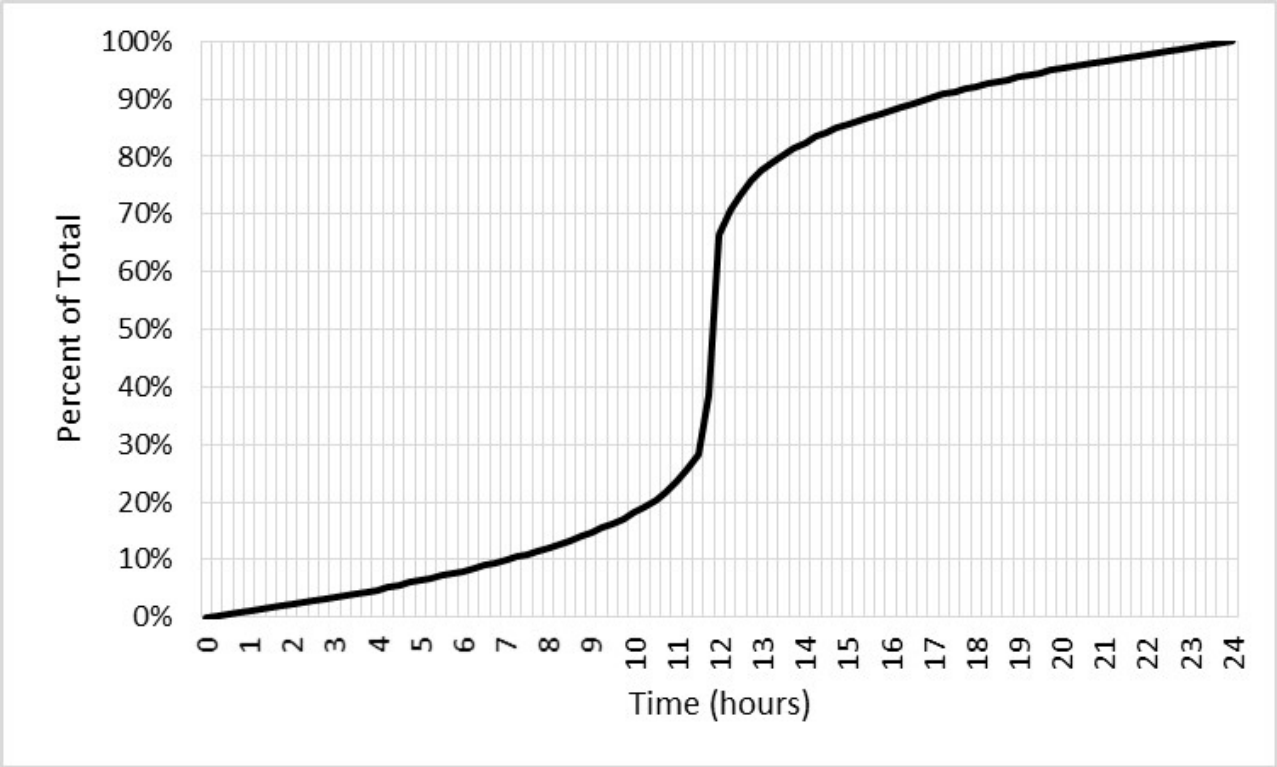


Figure 4.2: NRCS Type II Design Storm Event Hyetograph – Hours 10-14

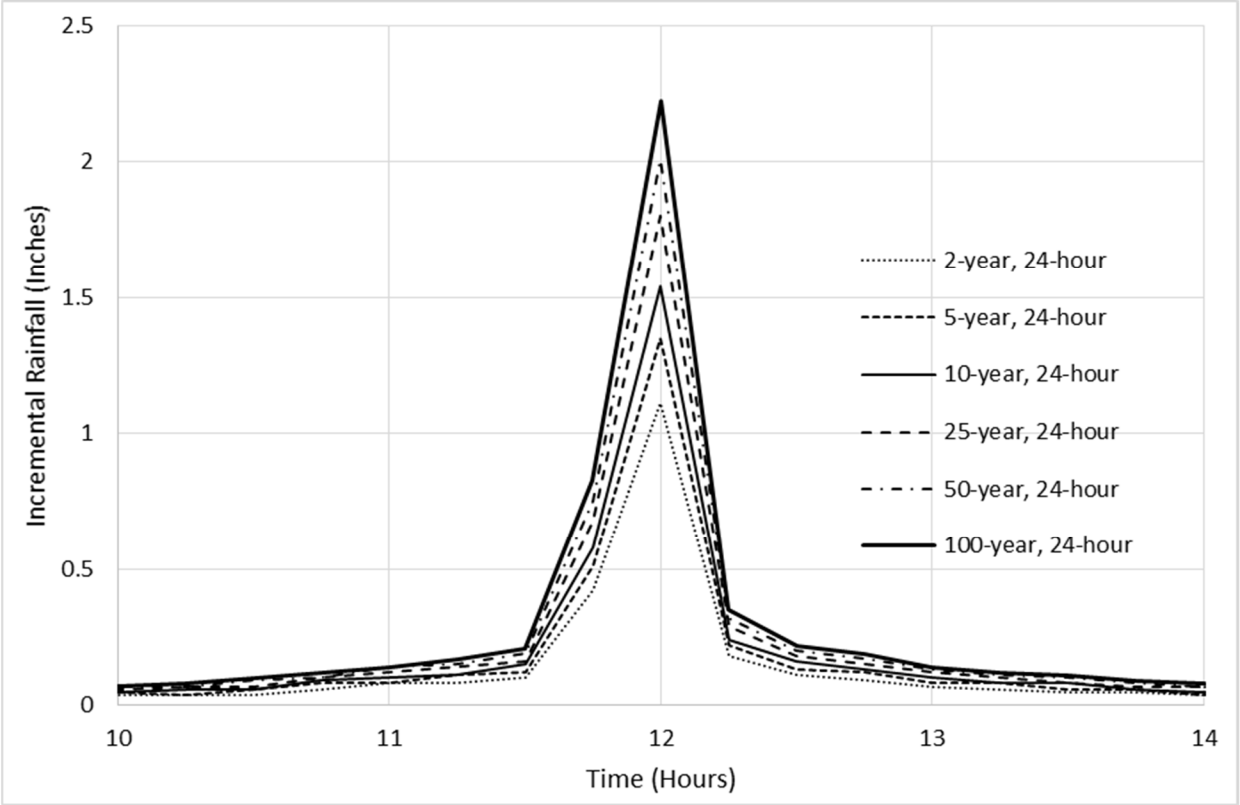
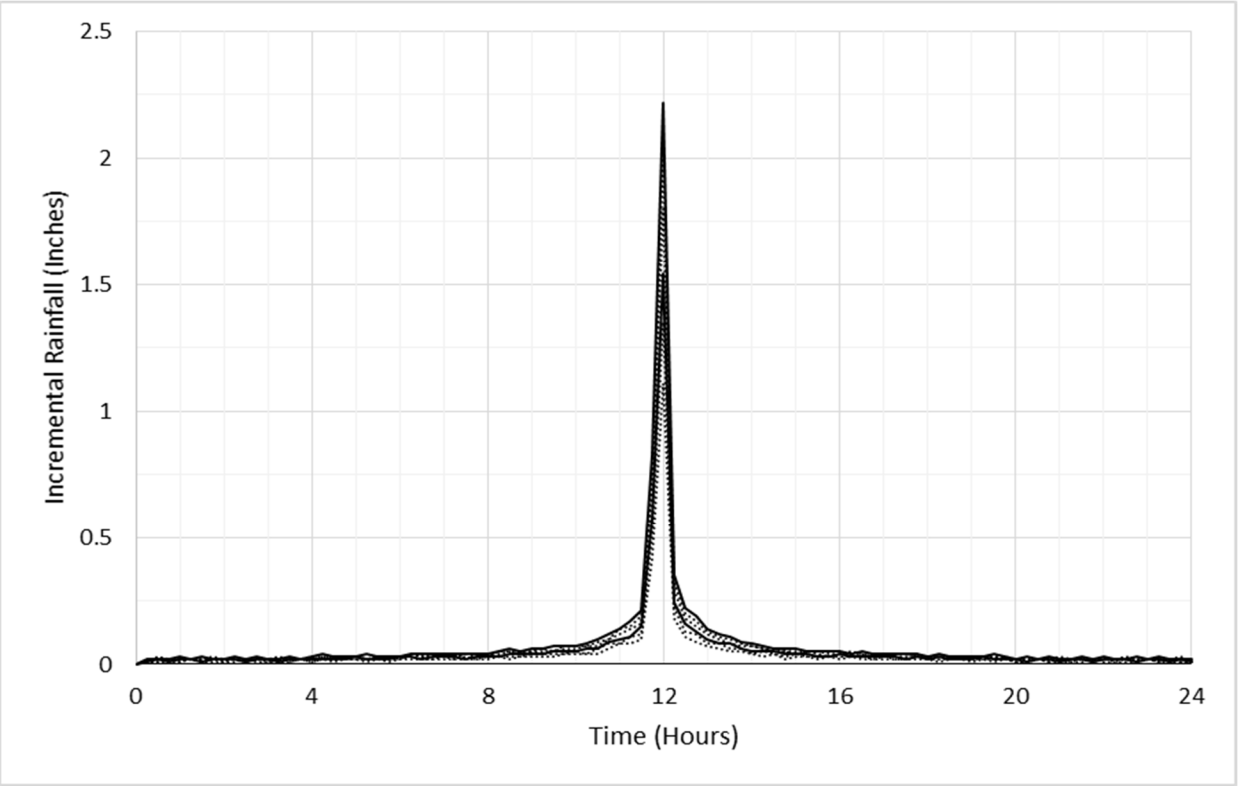


Figure 4.3: NRCS Type II Design Storm Event Hyetograph – Hours 0-24



The existing conditions model was run with the design storm events over a 2-day simulation period and then evaluated for capacity and flooding. The "capacity" of the system can be described in many ways. In simple terms, capacity is based strictly on the cross-sectional area, slope, and material surface roughness. This is referred to as full flow capacity, which is the maximum flow conveyed without becoming surcharged, or operating under pressure. When a pipe is surcharged, the water level at one end of the pipe is higher than the pipe itself. The higher water level, referred to as head, puts the pipe under pressure and forces more flow through the pipe. Greater surcharge depths will result in more flow through the pipe. Therefore, "capacity" is a relative term that corresponds with the amount of head on the pipe.

Often, a term such as "10-year capacity" is used to describe a storm sewer. A more specific description would be "10-year full capacity without surcharging," or "10-year capacity with the hydraulic grade line (HGL) below the rim." The HGL is synonymous with head; when drawing a profile of a storm sewer line, the HGL connects the water level at each manhole on the sewer line.

The City's storm sewer system is extensive and complex, with multiple interconnected systems consisting of storm sewer pipes, culverts, bridges, and open natural and concrete channels. It is not sufficient to solely assign an "X-year capacity" description to a reach of pipe or channel; the purpose of this study was to develop a more detailed understanding of the system's function and identify existing capacity limitations that cause localized and system wide flooding. With this understanding in mind, there are several figures and exhibits in this report that are key to describing the capacity of the system. They are described below:

Hydraulic Grade Line Profiles: A series of hydraulic profiles have been developed including the stormwater conduit size, invert, rim, ground elevation, and 10-year, 24-hour design storm event hydraulic grade line. These exhibits, presented in Appendix C, show each significant branch of the drainage network per watershed.

Floodplain Maps: The floodplain inundation maps were produced using InfoSWMM Risk Assessment Manager to create flood inundation Digital Elevation Maps (DEMs) based on the maximum hydraulic grade line. These exhibits show a plan view of the modeled network and the extent of the 10-year, 24-hour and 100-year, 24-hour design storm event flooding events. An existing conditions surface model DEM (five foot by five foot pixels) was created by merging the topographic survey data collected via this project with the Shelby County LiDAR elevation

data. The floodplain delineations are based on interpolating the HGL between model nodes and comparing the water surface elevations to the surface model. The floodplains are color-coded by depth of flooding: Red is greater than two feet in depth; Yellow is between one and two feet in depth; and Green is between zero and one foot in depth.

These exhibits are presented in Appendices D and E (existing conditions: 10-year and 100-year floodplains, respectively) and Appendices G and H (proposed conditions: 10-year and 100-year floodplains, respectively).

Overland Flow Locations: Typical with many stormwater conveyance networks, the system includes areas where the local storm sewer does not have sufficient inlet and/or conveyance capacity that results in surface flooding or overland flow to locations that have sufficient capacity.

Finished Floor Elevations: The existing conditions model (2-year, 24-hour design event results) were used to identify structures that potentially flood more frequently than others. Seventy (70) residential structures were identified to be field surveyed to obtain a finished floor elevation (FFE).

The surveyed FFEs were compared to the five-foot pixel DEM surface elevations at each structure's location. It was determined that 84% of the surveyed FFEs were equal to or greater than one foot above the DEM surface elevation. Therefore, when analyzing the extent of surface flooding, the study did not include solutions to eliminate structures within the floodplain if the depth of flooding was less than one foot.

4.2 SYSTEM CAPACITY ANALYSIS RESULTS

The following results are based on the 10-year, 24-hour design storm event model run for existing conditions. The hydraulic profiles for each branch of the model are presented in Appendix C. The following sections include Profile Identifications that reference the appropriate sheet in Appendix C. For example, the model branch CB-00 is associated with Sheet CB-00 of the profiles. Profiles were sub-divided into areas and are organized in this section and Appendix C by area. Profiles beginning with CB indicate a profile within the Cherry Bayou basin and GW indicates a profile within the Goodwin basin. The branch subtitles are described from downstream location to upstream location. For example, branch CB-02 is located at the downstream end of Cherry Bayou Main Branch and CB-40 is located at the upstream end.

Appendices D and E provide enlarged maps for the existing system as well as floodplain delineations for the 10-year, 24-hour and 100-year, 24-hour design storm events. Following each individual branch analysis, the corresponding Appendix D/E (10-year/100-year) detail map pages are provided for cross-reference purposes. The Appendix pages are listed from downstream to upstream, similarly to the branch subtitle descriptions.

The Cherry Bayou system is the larger of the two drainage areas studied, containing over 35 sub-drainage areas contributing to Cherry Bayou. The total drainage area is 2,190 acres. The main branch of Cherry Bayou outfalls to the Black Bayou River, west of Getwell Road and south of Elliston Street. The Cherry Bayou System consists of open natural channel, open and closed concrete channel, bridges, culverts, and storm sewers.

The Goodwin system consists of 8 sub-drainage areas which all drain south of Interstate 240, to the Nonconnah Creek. The total Goodwin drainage area is 978 acres. The drainage system consists of open channel (concrete and natural), bridges, culverts, and storm sewer pipes.

Each basin has multiple areas assigned with multiple profiles.

Figure 4.4: Example Appendix D Figure

Figure 4.5: Example Appendix E Figure

4.2.1 Area 1

GW-01: from Flamingo to I-240

GW-01 is primarily located in a residential area. It begins at Flamingo and Whitewater and is piped south along Whitewater in a 3' closed pipe, at Sea Isle the pipe size increases to 4', at Quince the pipe size increases to 4.5' and then to 5' at Helene. At Willow, the pipe upsizes to a 5' by 8' box culvert and continues onto Woodlark where it is converted to a concrete lined channel that continues southwest between properties, then a 6' by 12' bridge/culvert conveys flow under Mount Moriah Road. From there flow continues south in an open concrete lined channel until it reaches Interstate 240, where it is conveyed under the interstate via a 6' by 12' box culvert. The stormwater is released into Nonconnah Creek just south of Interstate 240.

The 10-year, 24-hour HGL for the pipes, culverts, and open channels is above full-pipe capacity for most of the profile. However, along Whitewater road where the 60 becomes a 5' by 8' culvert, slightly upstream of White Station road, the HGL is greater than the ground elevation which causes localized flooding. It is difficult to distinguish flooded structures resulting from GW-01 and GW-02. Therefore, there are 63 structures that are within the zero-to-one-foot-depth floodplain impacted by either the GW-01 or GW-02 reach of storm sewer. The City has received three flooding complaints from locations along GW-01.

(Appendix D/E detail map pages: 5, 11, 16, 21)

GW-02: from White Station to Whitewater

GW-02 is primarily located in a residential area. It begins at White Station Road as a 2' closed pipe and is piped southwest, parallel to Sea Isle to Wilbec. The closed pipe is then routed southeast along Wilbec until it reaches Sea Isle and is piped southwest along Sea Isle. At Walton, it is piped south along Walton road and increases to a 3' closed pipe. The closed sewer continues southwest along Walton until it reaches Woodston where it is piped south along the road, and then southeast on Quince, where it increases to a 4' closed pipe. At White Station and Quince, the sewer increases to 4.5' and is piped southwest in a 5' closed pipe along White Station until it reaches profile GW-01 at Whitewater and White Station.

The 10-year, 24-hour HGL for the pipes, culverts, and open channels is above full-pipe capacity and ground level for most of the profile, due to a downstream control at GW-01. It is difficult to distinguish flooded structures resulting from GW-01 and GW-02. Therefore, there are 63 structures that are within the zero-to-one-foot-depth floodplain impacted by either the GW-01 or GW-02 reach of storm sewer. The City has received one flooding complaint from locations along GW-02.

(Appendix D/E detail map pages: 11, 16)

4.2.2 Area 2

GW-03: From Sea Isle to I-240

GW-03 is a 2.5' closed pipe that originates at Ivy and Sea Isle and follows Ivy south to Willow, gradually increasing to a 4' closed pipe along the route. The sewer is piped west along Willow until it reaches Willow Road Park, where it becomes a natural channel. The channel continues southwest through the park and converts briefly to a 5.5' by 10' bridge/culvert. The channel continues south to Interstate 240 where it is converted to a 3' culvert for conveyance under the interstate and the sewer is then discharged into Nonconnah Creek.

The 10-year, 24-hour HGL for the pipes, culverts, and open channels is above full-pipe capacity and ground level for most of the profile, due to a down stream control caused by the culvert under the interstate. It is difficult to distinguish flooded structures resulting from GW-03 and GW-16. Therefore, there are ten structures that are within the zero-to-one-foot-depth floodplain impacted by either the GW-03 or GW-16 reach of storm sewer. The City has not received any flooding complaints from locations along GW-03.

(Appendix D/E detail map pages: 4, 10, 15)

GW-04: from Colonial to Ivy

GW-04 is a circular storm sewer that originates at Willow and Colonial as a 21” sewer and continues east along Willow. At Raymore, the sewer increases to a 27” circular storm sewer and at Hopewell the sewer increases to a 48” circular storm sewer. At Ivy and Willow, the storm sewer joins with profile GW-03.

The 10-year, 24-hour HGL for the closed pipe sewer stretch is greater than full-pipe capacity and ground level for the entire profile. This is attributed to a downstream control. There are three structures flooded within the zero-to-one-foot-depth floodplain. The City has received one flooding complaint along GW-04.

(Appendix D/E detail map page: 10)

GW-05: from Helene to Hopewell

GW-05 is a circular storm sewer that originates at Helene and Raymore as a 27” sewer and continues east along Helene to Hopewell. At Hopewell, the pipe increases to a 36” and is piped south along Hopewell. The profile continues until the pipe reaches Willow and joins profile GW-04.

The 10-year, 24-hour HGL is above pipe capacity after approximately 250 feet south of the intersection of Hopewell and Helene. No flooding is observed, and capacity issues are a result of a downstream control. The City has received one flooding complaint along the downstream end of GW-05.

(Appendix D/E detail map page: 10)

GW-16: from Delmont to Ivy

GW-16 is a circular storm sewer that originates at Delmont and Willow and is piped west along Willow. At Cranford and Willow, the sewer size increases to a 36” circular storm sewer. The sewer continues west along Willow until it reaches GW-03 at Willow and Ivy.

The 10-year, 24-hour HGL is above pipe capacity and ground level for the entire profile. This is attributed to the downstream control at GW-03. It is difficult to distinguish flooded structures resulting from GW-03 and GW-16. Therefore, there are ten structures that are within the zero-to-one-foot-depth floodplain impacted by either the GW-03 or GW-16 reach of storm sewer. The City has received one flooding complaint along the upstream end of GW-16.

(Appendix D/E detail map page: 10)

4.2.3 Area 3

GW-06: from Capri to I-240

GW-06 originates as a 24” circular storm sewer at the intersection of Capri and East Mallory and is piped east along East Mallory. At Sea Isle, the sewer size increases to a 30” sewer. At Tahiti and East Mallory, the sewer size increases to a 42” circular pipe and turns south along Tahiti. Adjacent to Leona, the sewer increases to a 48” circular pipe and heads southeast, and then continues south as an open concrete channel. The sewer changes from a channel to a 4’ by 4’ culvert for conveyance underneath I-240 before discharging into Nonconnah Creek.

The 10-year, 24-hour HGL is greater than pipe, channel, and culvert capacity as well as ground level for the entire profile. This is attributed to a capacity issue at the outlet. There are no structures in the floodplain. The City has records of two flooding complaints in the surrounding area of GW-06.

(Appendix D/E detail map page: 3)

GW-07: from Perkins to I-240

GW-07 originates as a 30” circular storm sewer at the intersection of Perkins and East Mallory and is piped south along Perkins. Adjacent to Jamaica, the sewer increases to a 36” circular pipe and is piped southwest, parallel to I-240 until it joins profile GW-06.

The 10-year, 24-hour HGL is greater than the sewer capacity and the ground level for almost all of the profile. This is attributed to a downstream control from GW-06. There are no structures in the floodplain. The City has no records of flooding complaints near profile GW-07.

(Appendix D/E detail map page: 3)

GW-08: from East Mallory to I-240

GW-08 originates as a 24” circular storm sewer at the intersection of East Mallory and Cornelia and is piped west along Mallory. After 81 feet, the sewer increases to a 30” circular pipe. At Mallory and Dorrie, the sewer size increases to 36” and the sewer is piped south along Dorrie. At Leona and Dorrie, the sewer size increases to a 42” pipe for 250 feet until it opens into a natural open channel. The sewer then converges with profile GW-07.

The 10-year, 24-hour HGL is greater than the sewer capacity and mostly greater than the ground level. There are two structures within the zero-to-one-foot-depth floodplain. The City has record of one flooding complaint in the surrounding area of profile GW-08.

(Appendix D/E detail map pages: 3)

GW-09: from Dearing to I-240

GW-09 originates as a 24” circular storm sewer at the intersection of Dearing and Danville and is piped south along Dearing. At the intersection of Dearing and East Mallory the sewer size increases to 42” for 841 feet where the sewer size is then increased to 48”. The profile ends just before I-240 where it enters a natural open channel.

The 10-year, 24-hour HGL is greater than the sewer’s capacity. However, there is minimal flooding because the HGL is barely greater than ground level at the upstream end of the sewer. There are no predicted flooding structures and no recorded complaints from the City.

(Appendix D/E detail map pages: 2)

4.2.4 Area 4

GW-10: from Merrycrest to Jamaica

GW-10 originates as a 24” circular storm sewer north of East Mallory between cross-streets Merrycrest and Maxine and is piped south for 21 feet where it reaches Mallory. The sewer size increases to 27” and is piped west along East Mallory to Cherry. At Cherry, the sewer size increases to 48” and is piped southeast along Cherry. At the intersection of Cherry and Lausanne, the sewer size increases to 54” and continues south along Cherry until it discharges into a natural open channel just before I-240.

The 10-year, 24-hour HGL is greater than the sewer for the entire profile as a result of a bottleneck at the downstream end of the 54” sewer. However, only minimal flooding upstream is observed and approximately seven structures are within the zero-to-one-foot-depth floodplain. There is one flooding complaint recorded from the City near the upstream end of profile GW-10.

(Appendix D/E detail map page: 2)

GW-11: South Goodlett

GW-11 originates as a 22” by 34” elliptical storm sewer on Goodlett, just north of the intersection of Barr and is piped south along Goodlett. At the intersection of Goodlett and Barr, the sewer size increases to a 29” by 46” elliptical sewer and continues south along Goodlett to profile GW-13.

The 10-year, 24-hour HGL is greater than crown of pipe for the entire profile and greater than ground level for the first stretch of sewer along the profile. Approximately 16 structures are within the zero-to-one-foot-depth floodplain, 12 structures are within the one-to-two-foot-depth floodplain, and six structures are within the greater-than-two-foot-floodplain. There is one flooding complaint recorded from the City along profile GW-11.

(Appendix D/E detail map page: 2)

4.2.5 Area 5

GW-12: from Getwell to I-240

GW-12 originates as an open channel at the Getwell Street Exit Ramp of I-240 and it piped northwest. Approximately 50 feet before Getwell the sewer transitions to a 24” pipe and is piped west. At Getwell, the sewer

increases to a 30” by 54” box culvert and is piped south along Getwell for 110 feet where the sewer size then increases to 42” by 54” box culvert and is piped south along Getwell for another 145 feet. The sewer transitions to a concrete lined channel along Getwell for 145 feet before it transitions back to a 42” by 52” box culvert along Getwell for another 300 feet. The sewer transitions back into a concrete lined channel for the final 220 feet of the profile.

The 10-year, 24-hour HGL is greater than crown of pipe/top of channel as well as ground level for most of the profile. However, no structures are impacted. Additionally, there are no record flooding complaints from the City near profile GW-12.

(Appendix D/E detail map page: 1)

GW-13: from South Goodlett to I-240

GW-13 originates as a natural channel south of South Goodlett and parallel to I-240 and continues northwest along I-240. Near Titus, the channel transitions to a 5’ by 10’ box culvert for southwest conveyance underneath I-240. Afterwards, the sewer transitions back to a natural channel and into Nonconnah Creek.

The 10-year, 24-hour HGL is within the sewer’s capacity and there are no flooded structures. The City does not have record of any flooding complaints along profile GW-13.

(Appendix D/E detail map page: 1, 2)

GW-14: from Mallory to Getwell

GW-14 originates as a 24” circular storm sewer located just north of East Mallory between cross-streets Titus and Watson where it is piped southwest for 20 feet to East Mallory. At East Mallory, the sewer size increases to a 30” and is piped west along East Mallory. 230 feet west of Titus, the sewer size increases to a 30” by 66” box culvert and is piped south 160 feet where it then increases to a 43” by 66” elliptical sewer and is piped south for 153 more feet. The sewer then becomes an open concrete channel and continues west for 360 feet before transitioning into a 55” by 88” elliptical pipe continuing west to Getwell. At Getwell, the sewer size increases to a 59” by 95” box culvert and heads south along Getwell to profile GW-12.

The 10-year, 24-hour HGL is greater than the sewer’s capacity for the entire profile and greater than ground level for half of the profile. Approximately 24 structures are within the zero-to-one-foot-depth floodplain, 11 structures are within the one-to-two-foot-depth floodplain, and five are within the greater-than-one-foot-floodplain. The City has received three flooding complaints along profile GW-14 and 2 more within the vicinity.

(Appendix D/E detail map pages: 1, 7)

GW-15: from Elliston to Getwell

GW-15 originates as a 30” by 18” box culvert on Elliston and is piped west to Getwell. At the intersection of Getwell and Elliston the sewer size increases to a 30” by 48” box culvert and is piped south to Mallory. At the intersection of Mallory and Getwell the sewer size increases to a 30” by 54” box culvert and continues south until it joins with profile GW-14 on Getwell.

The 10-year, 24-hour HGL is greater than the sewer’s capacity along the entire profile and greater than the ground level for the first half of the profile. There is one flooded structure within the zero-to-one-foot-depth floodplain and one structure within the one-to-two-foot-depth floodplain. The City does not have record of any flooding complaints along profile GW-15.

(Appendix D/E detail map pages: 1, 7)

4.2.6 Area 6 & 10

CB-00A: from Marion to Outlet

CB-00A consists of the second part of Cherry Bayou from Marion to the outfall into Black Bayou. Most of Cherry Bayou is open concrete channel except for a section of 7.5’ by 10’ box culvert from Park to Colonial. There are approximately 10 bridge sections along the profile.

The 10-year, 24-hour HGL is within the sewer's capacity except for the section of bridge under Kimball. There are approximately four structures in the zero-to-one-flood-depth floodplain along CB-00A. The city has received approximately ten flooding complaints along CB-00A.

(Appendix D/E detail map page: 6, 7, 8, 13, 19, 23)

4.2.7 Area 6

CB-02: from New Willow to Cherry Bayou

CB-02 originates as a 24" circular storm sewer on New Willow approximately 1,000 feet west of the intersection of Watson and New Willow and is piped west to Cherry Bayou. After approximately 450 feet the sewer size increases to 30".

The 10-year, 24-hour HGL is greater than the pipe capacity for the entire profile and equal to ground level for the first 250 feet. As a result of the capacity issue along the 24" sewer, approximately 13 structures are within the zero-to-one-foot-depth floodplain and one structure is within the one-to-two-foot-depth floodplain. There are no flooding complaints along CB-02 recorded by the City.

(Appendix D/E detail map page: 7)

CB-03: along Willowview

CB-03 originates as a 24" circular storm sewer about 65 feet west of the intersection of Willowview and Watson and is piped west along Willowview. After about 65 feet, the sewer size increases to a 30" circular sewer and continues west to Cherry Bayou along Willowview.

The 10-year, 24-hour HGL is greater than the pipe capacity for the entire profile and greater than ground level in a few localized areas. Based on a capacity issue along the downstream portion of the profile, approximately one structure is within the zero-to-one-foot-depth floodplain and 12 structures are within the one-to-two-foot-depth floodplain. There are no flooding complaints along profile CB-03 recorded from the City.

(Appendix D/E detail map page: 7)

CB-07: from South Goodlett to Willowview

CB-07 originates as a 24" storm sewer about 100 feet south of the intersection of New Willow and South Goodlett and is piped west for 240 feet. The storm sewer size then increases to a 36" sewer and is piped north for about 180 feet to New Willow. The sewer turns west along New Willow and continues for about 365 feet. The sewer size then increases to 42" and turns north for 175 feet, then turns west for about 85 feet. The sewer size then increases to 48" and turns north and is piped to Cherry Bayou.

The 10-year, 24-hour HGL is greater than the sewer's capacity and is at or above ground level until the 48" stretch of sewer. As a result of the capacity issue, there are approximately 14 structures within the zero-to-one-foot-depth floodplain and two structures within the one-to-two-foot-depth floodplain. There are no flooding complaints along profile CB-07 recorded from the City.

(Appendix D/E detail map page: 8)

CB-10: from Kimball to Wanda

CB-10 originates as a 24" circular storm sewer at Kimball between cross-streets Maxine and Wanda and is piped south. After about 615 feet, the sewer size increases to 30" and continues south another 600 feet before the size increases to 42". The sewer continues south until it reaches Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for most of the profile. In a few localized areas, the HGL is greater than ground level resulting in 1 structure predicted to be within the zero-to-one-foot-depth floodplain. The City has record of two flooding complaints within the reach of profile CB-10.

(Appendix D/E detail map page: 8, 13)

CB-15: from Fizer to Cherry Bayou

CB-15 is a 24” circular storm sewer that originates at Fizer between the cross-streets Cherry and Fredericks. The sewer is piped north for 275 feet, turns southwest, and continues to Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe but less than ground level. Therefore, there are no flooded structures. However, there are three flooding complaints recorded by the City in the vicinity of CB-15. These complaints are explained by the City’s database as a result of the asphalt grading in this location.

(Appendix D/E detail map page: 13, 18)

CB-16: from Cherrydale to Deb

CB-16 originates as a 24” circular storm sewer at the intersection of Cherrydale Cove and Cherrydale Road and is piped west along Cherrydale Road. After about 200 feet the sewer size increases to 30” for 100 feet before it turns southwest and follows Rhodes Avenue and increases to 36”. At Cherry, the sewer size increases to 42” and continues along Rhodes Avenue until it reaches Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile. The HGL is greater than ground level for the first half of the profile. There are approximately three structures within the zero-to-one-foot-depth floodplain. There are approximately 12 flooding complaints recorded by the City in the vicinity of CB-16.

(Appendix D/E detail map page: 18)

CB-17: along Quince

CB-17 is a 24” circular storm sewer that originates at Quince between cross-streets Flamingo and Sea Isle. The sewer is piped northwest along Quince until reaching Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than ground level for the first portion of the profile. However, there are no predicted flooded structures. Additionally, the City has no records of flooding complaints along CB-17.

(Appendix D/E detail map page: 14)

CB-19: along Verne

CB-19 originates as a 24” circular storm sewer at Verne between cross-streets Flamingo and Amboy. The sewer is piped northwest along Verne for approximately 205 feet until the sewer size increases to 30”. The sewer is piped northwest until it reaches Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for the first part of the profile. However, there are no observed flooded structures. The City has record of one flooding complaint along profile CB-19.

(Appendix D/E detail map page: 14, 19)

4.2.8 Area 7

CB-05: from Woodcrest to Cherry Bayou

CB-05 originates as a 27” circular storm sewer at Woodcrest between cross-streets Merrycrest and Cherry and is piped west along Woodcrest. At Merrycrest, the sewer turns south and is piped along Merrycrest. Slightly before Rhodes, the sewer size increases to 36” and continues south along Merrycrest. At Cherrydale Road and Merrycrest the sewer size increases to 42” and the sewer turns and continues west along Cherrydale Road for about 435 feet. The sewer size then increases to 48” and continues southwest, crossing Fizer and Fredricks. At Philsdale, the sewer size increases to 66” and continues southwest crossing Kimball, Mink, and Dunn – where it turns and heads south until reaching Cherry Bayou.

Th 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than ground level between Rhodes and Fizer. There are approximately 127 flooded structures in the zero-to-one-foot-depth floodplain, 35 structures in the one-to-two-foot-depth floodplain, and five structures in the greater-than-two-foot-

depth-floodplain. It is difficult to distinguish flooded structures resulting from CB-05 and CB-05.04. The City has record of five flooding complaints in the vicinity of profile CB-05.

(Appendix D/E detail map page: 7, 12, 13, 18)

CB-05.4: from Wedgewood to Cherry Bayou

CB-05.4 originates as a 21.6” by 33.6” elliptical storm sewer at Amber between cross-streets Haver Hill and Burgundy and is piped west for 230 feet. The sewer size changes to 24” and is piped south for about 375 feet and then increases to a 36” and continues southwest to Rhodes. At Rhodes, the sewer size decreases to a 30” and is piped west along Rhodes. At Oakridge and Rhodes, the sewer size increases to 42” and continues south along Oakridge. At Fizer, the sewer size increases to 48” and continues south along Oakridge. At Fredericks, the sewer size increases to 54” and continues south until joining profile CB-05.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and at or above ground level for most of the profile. There are approximately 127 flooded structures in the zero-to-one-foot-depth floodplain, 35 structures in the one-to-two-feet-depth floodplain, and 5 structures in the greater-than-two-foot-depth-floodplain. It is difficult to distinguish flooded structures resulting from CB-05 and CB-05.04. The City has records of 6 flooding complaints in the vicinity of profile CB-05. The City has record of three flooding complaints along the north end of profile CB-05.4.

(Appendix D/E detail map page: 12, 18, 22)

4.2.9 Area 8

CB-12: from Willow to Cherry Bayou

CB-12 originates as a 24” circular storm sewer at Willow between cross-streets Perkins and Myrna and is piped north. After about 71 feet, the sewer size increases to 36” and continues north. Adjacent to Leatherwood, the sewer size increases to 42” and at Dearing the sewer size increases to 48” and continues north. About 200 feet before Dunn, the sewer size increases to 60” and turns west. At Perkins, the sewer size increases to 72” and is piped west for 100 feet before transitioning into an open concreate channel. The sewer continues west, parallel to Dunn. When Dunn turns northwest, the sewer turns and heads southwest, parallel to Boyce until reaching Cherry Bayou. There are approximately three bridge sections throughout the open concrete channel.

The 10-year, 24-hour HGL is greater than the pipe and channel capacity and intermittently greater than ground level. There is one structure within the one-to-two-foot-depth floodplain. The City has received two flooding complaints along CB-12.

(Appendix D/E detail map page: 9, 13, 14)

CB-12.1: from Helene to Cherry Bayou

CB-12.1 originates as a 24” circular storm sewer at Helene and is piped northwest. At the intersection of Boyce and Flamingo the sewer size increases to 30” for about 50 feet before it increases to 42”. The sewer continues northwest until it reaches Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and ground level for most of the profile. There are three structures within the zero-to-one-foot-depth floodplain. There is one flooding complaint near where profile CB-12.1 joins profile CB-12.

(Appendix D/E detail map page: 8)

CB-12.3: from East Dearing to Cherry Bayou

CB-12.3 originates as a 30” circular storm sewer at the intersection of East Dearing and Sea Isle and is piped north. At Helene, the sewer size increases to 42” and continues north. At Boyce, the sewer size increases to 48” and continues north to Profile CB-12.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are approximately six structures within the zero-to-one-foot-depth floodplain. The City has received 2 flooding complaints in the area surrounding CB-12.3.

(Appendix D/E detail map page: 9, 14)

CB-12.6: from Flamingo to Cherry Bayou

CB-12.6 originates as a 30” circular storm sewer at Flamingo between cross-streets Colonial and Ivy and is piped south. About 100 feet after crossing Amboy, the sewer transitions to a concrete open channel and heads west parallel to Amboy for about 250 feet. The sewer then transitions into a 36” closed pipe and continues west to Colonial. At Colonial, the sewer size increases to 42” and heads south along colonial for about 500 feet. The sewer turns west and after 55 feet transitions to a concrete open channel and continues west. About 100 feet west of Perkins, the channel turns south. About 125 feet south of Verne, the channel transitions to a 68.4” by 42” horizontal ellipse pipe and is piped southwest for about 80 feet. The pipe then turns south, and the sewer size increases to a 48” circular pipe under Quince and again to a 60” circular pipe after Quince and continues south to profile CB-12.

The 10-year, 24-hour HGL is greater than the crown of pipe/top of channel for most of the profile and greater than ground level intermittently. There are approximately 37 flooded structures within the zero-to-one-foot-depth floodplain and 7 within the one-to-two-feet-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-12.6 and CB-12.8. The City has received 1 flooding complaint along CB-12.6 and two more in the vicinity.

(Appendix D/E detail map page: 14, 15, 20)

CB-12.8: from Verne to Dunn

CB-12.8 originates as a 27” circular storm sewer alone Verne between cross-streets Colonial and Hopewell and is piped west. At Colonial, the sewer size increases to 36” and the sewer turns and is piped south along Colonial. At Quince, the sewer size increases to 42” and the sewer turns and is piped west along Quince. At the intersection of Quince and Dearing, the sewer size increases to 48” and continues west. At Perkins, the sewer turns and is piped southwest until reaching profile CB-12.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile but only greater than ground level at the upstream end of the profile. There are approximately 37 flooded structures within the zero-to-one-foot-depth floodplain and seven within the one-to-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-12.6 and CB-12.8. The City has received 4 flooding complaints along CB-12.8.

(Appendix D/E detail map page: 14, 15)

CB-43: from Leatherwood to Cherry Bayou

CB-43 originates as a 24” circular storm sewer at Gilson and is piped north along Gilson. After about 615 feet the sewer size increases to 30” and continues north until it reaches Boyce and Flamingo where the sewer direction changes to northwest. The last 135 feet of sewer is 42” in size and continues northwest until it reaches profile CB-12.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are eight structures within the zero-to-one-foot-depth floodplain and four structures in the one-to-two-feet-depth floodplain. The City has received one flooding complaint within the vicinity of profile CB-43.

(Appendix D/E detail map page: 8)

4.2.10 Area 9

CB-20: from Park to Cherry Bayou

CB-20 originates as a 42” circular storm sewer at Park between Cherry Bayou and Cherry Road and is piped south. After about 105 feet the sewer size increases to 48” for another 480 feet where it transitions to open channel with one 36” culvert pipe. After about 1,000 feet the open channel transitions to a 72” circular sewer pipe and turns southeast. After 1,350 feet the sewer transitions to an open concrete channel with one bridge section under Tall Trees. The profile continues southwest until it reaches Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe/top of channel for the entire profile and greater than the ground level for most of the profile. There are approximately 14 structures within the zero-to-one-foot-depth floodplain and one structure within the one-to-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-20 and CB-20.4. The City has received five flooding complaints along profile CB-20, with three of those located at Harding Academy.

(Appendix D/E detail map page: 19, 22, 27, 28)

CB-20.4: from Park to Tall Trees

CB-20.4 originates as a 27" circular storm sewer in the Memphis Botanical Gardens and is piped west for about 590 feet. The sewer size then increases to 42" and is piped south, parallel to Fair Meadow. After about 500 feet the sewer size increases to 48" and continues south. After another 650 feet south, the pipe size decreases to a 3' by 5' culvert for 60 feet before increasing in size to a 3.5' by 5.5' box culvert that continues south for another 1,650 feet. The sewer size increases to a 3.5' by 6.5' box culvert and heads southwest until joining profile CB-20.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are approximately 14 structures within the zero-to-one-foot-depth floodplain and one structure within the one-to-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-20 and CB-20.4. The City has not received any flooding complaints along profile CB-20.4.

(Appendix D/E detail map page: 19, 23, 28)

CB-20.6: from Audubon to Harding Academy

CB-20.6 originates as a 24" circular storm sewer at Audubon and is piped south for 170 feet. The sewer is then piped east for about 250 feet before transitioning to an open channel for 180 feet. The sewer then transitions back into a 24" sewer for about 400 feet until once again becoming an open channel for about 140 feet. The sewer continues west after transitioning into a 31" by 50" box culvert. The last 130 feet of the profile is a 37" by 32" box culvert. The profile continues west until reaching Profile CB-20.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There is one structure within the one-to-two-foot-depth floodplain and two structures within the greater-than-two-foot-depth-floodplain. The City has received one flooding complaint along profile CB-20.6 and another one in the vicinity.

(Appendix D/E detail map page: 22)

4.2.11 Area 10

CB-21: from Ivy to Cherry Bayou

CB-21 originates as a 24" circular storm sewer at Ivy between Mockingbird and Hummingbird and piped west parallel to Hummingbird. After about 650 feet the sewer size increases to 27" and continues west, over Colonial and southwest another 450 feet before the sewer size increases to 42" at Marcia. The sewer is piped west another 170 feet before turning south for 120 feet, and then back to west. At South Perkins Road the sewer size increases to 48" and again at Perkins Trail to 54" where the sewer continues west for another 375 feet before transitioning into an open concrete channel.

The 10-year, 24-hour HGL is greater than the crown of pipe/top of channel for the entire profile and greater than the ground level for most of the profile. There are approximately 30 structures within the zero-to-one-foot-depth floodplain and one structure within the one-to-two-foot-depth floodplain. The City has received three flooding complaints along profile CB-21 and another one in the vicinity.

(Appendix D/E detail map page: 19, 20)

CB-22: along Dee

CB-22 originates as a 24" circular storm sewer at Dee between cross-streets Perkins and Dearing and is piped west along Dee. After 230 feet, the sewer size increases to 27" and after another 230 feet the sewer size increases to 42" and continues west. The last 220 feet of sewer is 48" and discharges into Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are approximately three structures within the zero-to-one-foot-depth floodplain. The City has not received any flooding complaints along profile CB-22.

(Appendix D/E detail map page: 19, 23)

CB-23: along Dee

CB-23 is a 36" circular storm sewer piped east along Dee from Fair Meadow until it discharges into Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for the first 100 feet of the profile. There are approximately two structures within the zero-to-one-foot-depth floodplain. The City has not received any flooding complaints along or in the vicinity of profile CB-23.

(Appendix D/E detail map page: 19)

CB-25: from Park Ave to Bayou

CB-25 originates as a 24" storm sewer just north of Park between cross-streets Drake Manor and South Perkins and is piped south parallel to South Perkins. After about 900 feet, the sewer size increases to 30" and is piped southwest until it discharges into Cherry Bayou

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are approximately two structures within the zero-to-one-foot-depth floodplain. The City has received two flooding complaints in the vicinity of profile CB-25.

(Appendix D/E detail map page: 23, 28)

CB-26: from Chip to Cherry Bayou

CB-26 is a 36" circular storm sewer that originates at Chip and South Perkins and is piped northwest along South Perkins until discharging into Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile, but not greater than ground level. There are no predicted flooded structures along the profile. However, the City has received two flooding complaints along profile CB-26 and another one in the vicinity. These complaints are thought to be attributed to maintenance issues which have since been resolved.

(Appendix D/E detail map page: 23)

CB-28: from S Perkins to Cherry Bayou

CB-28 originates as a 36" circular storm sewer near South Perkins between cross-streets Spottswood and Southern and is piped in the general southwest direction. At Spottswood, the sewer size increases to 42" and the sewer heads south along Crossover. At Gladeside, the sewer size increases to 48" and again at Elmbrook to a 4.5' by 6' triangular-rectangular box culvert. About 450 feet upstream of Park, the sewer size increases to a 4.5' by 7' triangular rectangular box culvert heading west and again to a 4' by 6' box culvert heading south underneath Park. The sewer then transitions into an open channel headed south until discharging into Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than the ground level for most of the profile. There are approximately six structures within the zero-to-one-foot-depth floodplain, two structures within the one-to-two-foot-depth floodplain, and one structure within the greater-than-two-foot-depth floodplain. The City has received two flooding complaints in the vicinity of profile CB-28.

(Appendix D/E detail map page: 24, 29, 32)

4.2.12 Area 11

CB-30: from Wellville to Rustling Oaks

CB-30 originates as a 24" storm sewer at the intersection of Wilmore and Edenshire and is piped south for 155 feet along Wilmore before heading west. At Wellsville, the sewer size increases to 30" and again at White Station to a 36". At Wilbec, the sewer is piped north to Edenshire and then west along Edenshire. At Mount Moriah, the sewer size increases to 42" and is piped north to Hampshire where the sewer size increases to 48". From

Hampshire, the sewer is piped north to Welchshire and continues west along Welchshire for about 475 feet before turning northwest. The sewer size increases to 54" and continues northwest past the intersection of Kae and Ivy for about 615 feet until transitioning into a concrete open channel for 597 feet. The sewer then transitions into a 5' by 10.5' box culvert before discharging into Cherry Bayou near Colonial and Rustling Oaks.

The 10-year, 24-hour HGL is greater than the crown of pipe/top of channel for the entire profile and greater than the ground level for most of the profile. There are approximately 91 structures within the zero-to-one-foot-depth flood plain, 54 structures within the one-to-two-foot-depth floodplain, and nine structures within the greater-than-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-30, CB-30.1, CB-30.2, and CB-00 due to the extensive flooding in the area. The City has received two flooding complaints along profile CB-30.

(Appendix D/E detail map page: 24, 25)

CB-30.2.1: from Alrose to Ivy

CB-30.2.1 originates as a 24" circular storm sewer at Alrose between cross-streets Ivy and Mount Moriah and is piped west along Alrose. After about 300 feet, the sewer size increases to 30" and continues west to Ivy where the sewer turns south and connects to profile CB-30.2.

The 10-year, 24-hour HGL is greater than the crown of pipe and ground level for the entire profile. There are approximately 91 structures within the zero-to-one-foot-depth flood plain, 54 structures within the one-to-two-foot-depth floodplain, and nine structures within the greater-than-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-30, CB-30.1, CB-30.2, and CB-00 due to the extensive flooding in the area. The City has received three flooding complaints along profile CB-28.

(Appendix D/E detail map page: 24)

4.2.13 Area 12

CB-00B: from Poplar to Marion

CB-00B consists of the upstream main branch of Cherry Bayou. CB-00B extends from Poplar to Mount Moriah as closed pipe spanning from 24" to 3.5' by 9' culvert. At Mount Moriah, the branch transitions into the most upstream part of Cherry Bayou which is an open concrete channel. This portion of the profile, from Mount Moriah to Marion, contains approximately 3 bridged sections.

The 10-year, 24-hour HGL is greater than the crown of pipe/top of channel for the entire profile and greater than ground level for portions of the profile. There are approximately 91 structures within the zero-to-one-foot-depth flood plain, 54 structures within the one-to-two-foot-depth floodplain, and nine structures within the greater-than-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-30, CB-30.1, CB-30.2, and CB-00 due to the extensive flooding in the area. The City has received approximately three flooding complaints along profile CB-00B.

(Appendix D/E detail map page: 23, 24, 26, 29, 30, 31)

CB-30.1: from White Station to Kaye

CB-30.1 originates as a 30" circular storm sewer at White Station between cross-streets Flamingo and Dee and is piped west. At Wilbec and Parkside the sewer size increases to 36" and again after following Parkside west for about 700 feet to 42" and piped northwest. At Nassau, the sewer size increases to 48" and the sewer is piped west along Dee. At Bluff, the sewer size increases to 54" and the sewer is piped northwest to Ivy, turns and is piped north to the intersection of Ivy and Essexshire. The sewer size then increases to 60" and is piped northwest to profile CB-30.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than ground level for most of the profile. There are approximately 91 structures within the zero-to-one-foot-depth flood plain, 54 structures within the one-to-two-foot-depth floodplain, and nine structures within the greater-than-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-30, CB-30.1, CB-30.2, and CB-00 due to the extensive flooding in the area. The City has received six flooding complaints along profile CB-30.1.

(Appendix D/E detail map page: 20, 21, 24)

CB-30.2: from Wellsville to Ivy

CB-30.2 originates as a 24” circular pipe east of Wellsville and north of Welchshire and is piped west. At Wellsville, the sewer size is increased to 30” and again at White Station to 36”. At Mount Moriah, the sewer size increases again to 42” and is piped west along Kaye to profile CB-30.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than or equal to ground level for most of the profile. There are approximately 91 structures within the zero-to-one-foot-depth flood plain, 54 structures within the one-to-two-foot-depth floodplain, and nine structures within the greater-than-two-foot-depth floodplain. It is difficult to distinguish flooded structures resulting from CB-30, CB-30.1, CB-30.2, and CB-00 due to the extensive flooding in the area. The City has received two flooding complaints along profile CB-30.2.

(Appendix D/E detail map page: 24, 25)

CB-31: from Colonial to Marion

CB-31 originates as a 24” circular storm sewer at Colonial between cross-streets Eagle Crest and Southern and is piped southwest. At Spottswood, the sewer size increases to 27”. At the intersection of Spottswood and St. Nick, the sewer is piped south and increases to 30”. At Carnes and St. Nick, the sewer size increases to 36” and again at Marion to 42” and is piped east until discharging into Cherry Bayou.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than or equal to ground level for most of the profile. There are approximately seven structures within the zero-to-one-foot-depth floodplain. The City has received five flooding complaints near profile CB-31.

(Appendix D/E detail map page: 29)

CB-36: from Poplar to Mount Moriah

CB-36 originates as a 21” circular storm sewer at Poplar between cross-streets Mendenhall and Mount Moriah and is piped southwest. After about 70 feet the sewer size increases to 24” and again after about 20 feet to an open channel for about 8 feet. The sewer then transitions back into a 24” sewer and continues north west along Southern. At Mendenhall, the sewer size increases to 27” and is piped south. After about 500 feet the sewer size increases to a 30” and again after about 700 feet into a 36” pipe until the sewer joins profile CB-00B.

The 10-year, 24-hour HGL is greater the crown of pipe for the entire profile and greater than or equal to ground level for most of the profile. There are no structures within the floodplain. The City has received two flooding complaints in the vicinity of profile CB-36.

(Appendix D/E detail map page: 30, 34)

CB-37: from White Station to Truse

CB-37 originates as an open channel parallel to Poplar between cross-streets White Station and Estate and continues northwest. At East Gate Town Center, the sewer transitions to a 24” by 28” elliptical pipe for about 50 feet before the sewer size increases to a 36” circular pipe. At Truse, the sewer size increases to 42” for about 115 feet and then increases to 48” and is piped southwest. The last approximately 85 feet increases to a 5.5’ by 3’ box culvert heading west to profile CB-00B.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than or equal to ground level for most of the profile. There are no structures within the floodplain. The City has not received any flooding complaints along profile CB-37.

(Appendix D/E detail map pages: 30, 31)

CB-39: Eastgate Shopping Center

CB-39 originates as a 24” circular storm sewer at the Eastgate Shopping Center and is piped west. After about 350 feet, the sewer size increases to 27” and continues west until it reaches profile CB-00B.

The 10-year, 24-hour HGL is greater than the crown of pipe for about half of the profile and less than ground level for most of the profile. There are no structures within the floodplain. The City has not received any flooding complaints along profile CB-39.

(Appendix D/E detail map page: 30)

CB-40: from Estate to CB-00

CB-40 originates as a 30” circular pipe west of the intersection of Estate and Wrens Roost and is piped northwest. After about 125 feet, the sewer transitions into an open channel and continues northwest until it reaches CB-00B.

The 10-year, 24-hour HGL is greater than the crown of pipe for the entire profile and greater than or equal to ground level for most of the profile. There are no structures within the floodplain. The City has not received any flooding complaints along profile CB-40.

(Appendix D/E detail map page: 26)

4.3 FLOODPLAIN DELINEATIONS

Appendices D and E include enlarged floodplain delineations for the 10-year, 24-hour and 100-year, 24-hour design storm events, respectively. The floodplains are presented with three color-coded depth classifications to help identify the severity of the flooding. The three classifications are:

- Green - Zero to one foot in depth
- Yellow - One to two feet in depth
- Red - Greater than two feet in depth.

The following tables (Table 4.2 and Table 4.3) provide the number of structures within each depth classification in each watershed for the existing 10-year and 100-year, 24-hour design events.

Table 4.2: Cherry Bayou Flooded Structures

Flooding Depth (feet)	Existing 10-year, 24-hour Floodplain	Existing 100-year, 24-hour Floodplain
0 – 1	398	579
1 - 2	122	204
> 2	17	39
Total	537	783
Total > 1	139	243

Table 4.3: Goodwin Flooded Structures

Flooding Depth (feet)	Existing 10-year, 24-hour Floodplain	Existing 100-year, 24-hour Floodplain
0 – 1	125	166
1 - 2	20	46
> 2	21	37
Total	166	249
Total > 1	41	83

5.0 ALTERNATIVES EVALUATION

5.1 APPROACH TO EVALUATING ALTERNATIVES

An evaluation of alternatives was performed to identify and quantify opportunities to increase system performance and reduce the frequency or severity of flooding. The two primary alternatives evaluated were increased detention storage to attenuate peak flows, and increased conveyance to remove isolated hydraulic contractions ("bottlenecks") and reduce system HGLs. The City's overarching goal was to determine if the system could be retrofitted with these types of measures to increase capacity enough to handle the 10-year, 24-hour design event.

The first step during the evaluation of alternatives was to identify significant hydraulic restrictions and areas of significant flooding. Localized hydraulic restrictions were removed and sites were identified for potential storage facilities based on available land parcels owned by the City. The storage capacities of each site were then maximized based on allowable footprints and site constraints. Even with these measures in place, several locations continued to experience significant flooding. Therefore, additional system conveyance improvements (upsizing channels/pipes) were identified to help alleviate flooding. The objective was to eliminate as many structures as possible from the greater-than-one-foot-depth floodplain of the 10-year, 24-hour design event floodplain. For this study, a structure is the main dwelling of each parcel. Secondary structures such as garages, sheds, and trailers were not included in the analysis. Appendix F includes project location maps that show the recommended conceptual improvements in each project area.

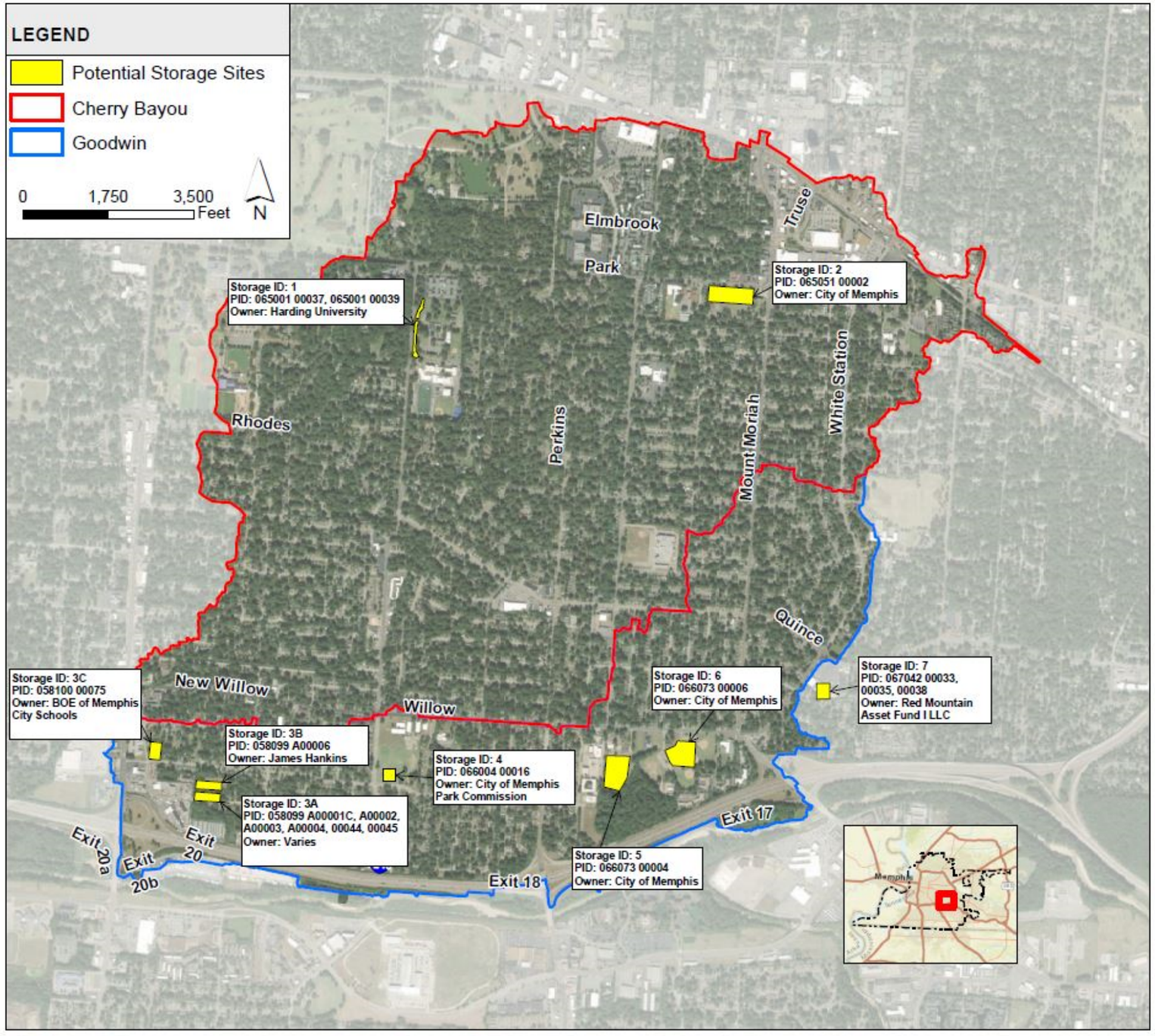
Planning-level opinions of probable cost were also developed for the recommended drainage improvements. The cost opinions are based on contemporary costs from similar projects, Tennessee Department of Transportation Average Unit Prices data (2020 awarded contracts), and engineering judgement. In general, a 35% markup was included in the adjusted unit costs for mobilization/demobilization, maintenance of traffic, bonds and insurance, contingency, engineering, and permitting. In addition, a standard 25% contingency was included for planning purposes.

The planning-level cost opinions are summarized in Table 6.2. Appendix B includes more detailed planning-level opinions of probable construction costs for each alternative project.

5.2 STORAGE ALTERNATIVES

A meeting was held on February 7, 2020 with representatives from the City to review the status of model development activities and potential alternatives that could be evaluated to reduce flooding. A total of seven potential storage locations were initially presented to the City for consideration (refer to Figure 5.1). The sites that were presented are larger open areas adjacent to major components of the storm drainage system in areas of significant flooding. Of the seven sites reviewed, four (three alternatives with two options for alternative 3) were chosen to be viable options based on the location and current property ownership. These four locations were then analyzed to determine the maximum storage capacity at the site. The storage basins were modeled with the 100-year, 24-hour design storm event to ensure that the available volume could contain a large event without causing additional adverse flooding conditions. Storage basin outlets were adjusted to maximize the available storage capacity. A 15-inch diameter outlet pipe is the smallest allowable size to prevent maintenance issues, in accordance with the Memphis and Shelby County Storm Water Management Manual. The evaluation showed that storage was not needed at Sites 4, 5, 6, and 7. The following is a description of the four storage basin locations chosen for analysis.

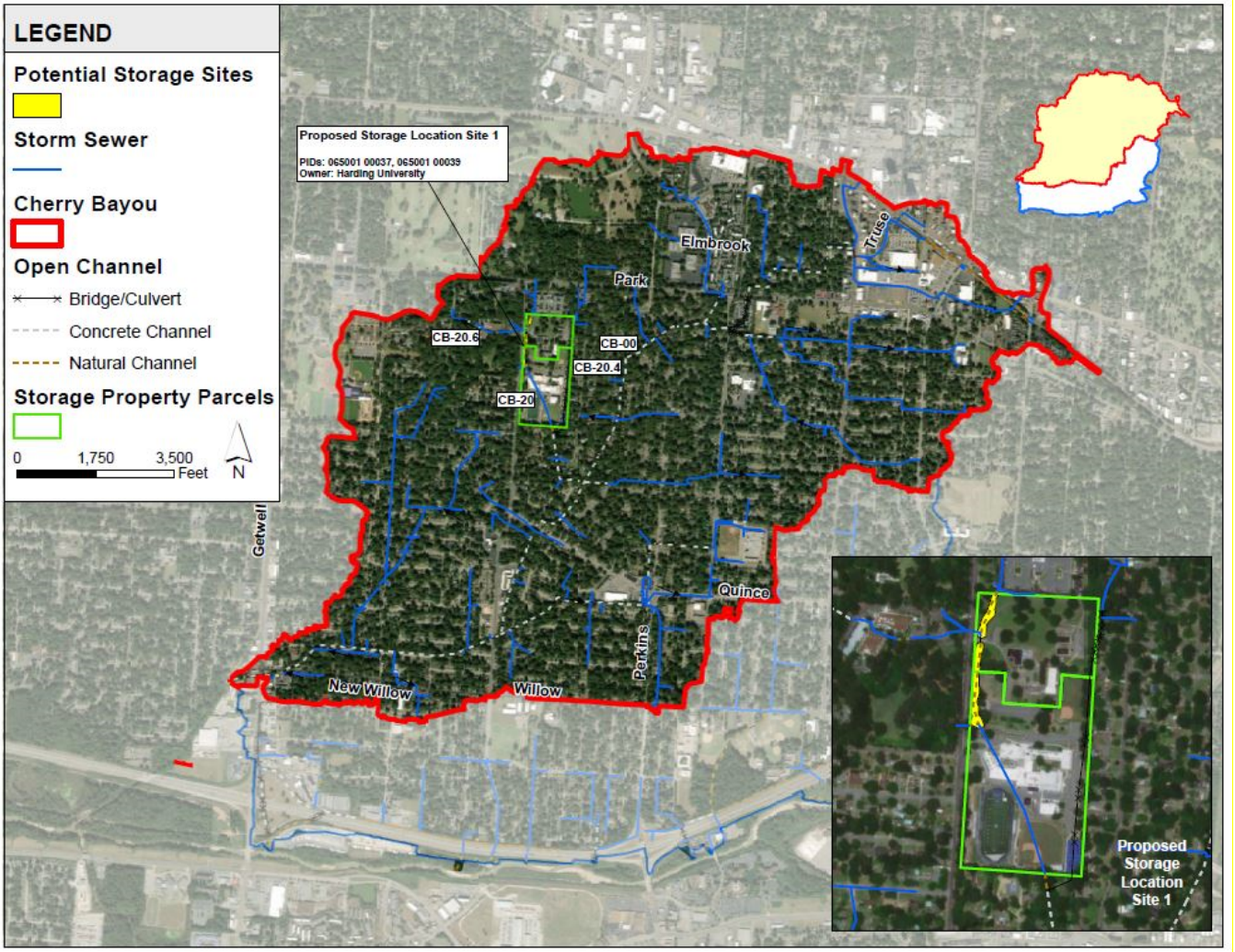
Figure 5.1: Areas Evaluated for Potential Storage Sites



5.2.1 Site 1 – Harding Academy Storage Alternative

Site 1 – Harding Academy: This site is located on the Harding Academy campus near the intersection of Cherry Road and Haverhill Road in the Cherry Bayou drainage area (CB-20). Storage at this location was provided by enhancing the open channel cross sections throughout this reach of the model to increase the cross-sectional flow area. The open storage for this alternative involves widening approximately 943 LF of channel to 50 feet wide. The planning-level cost opinion for the Site 1 storage alternative is $1,620,000. Figure 5.2 presents the conceptual planning improvements proposed at Site 1: Harding Academy.

Figure 5.2: Conceptual Harding Academy Storage Alternative

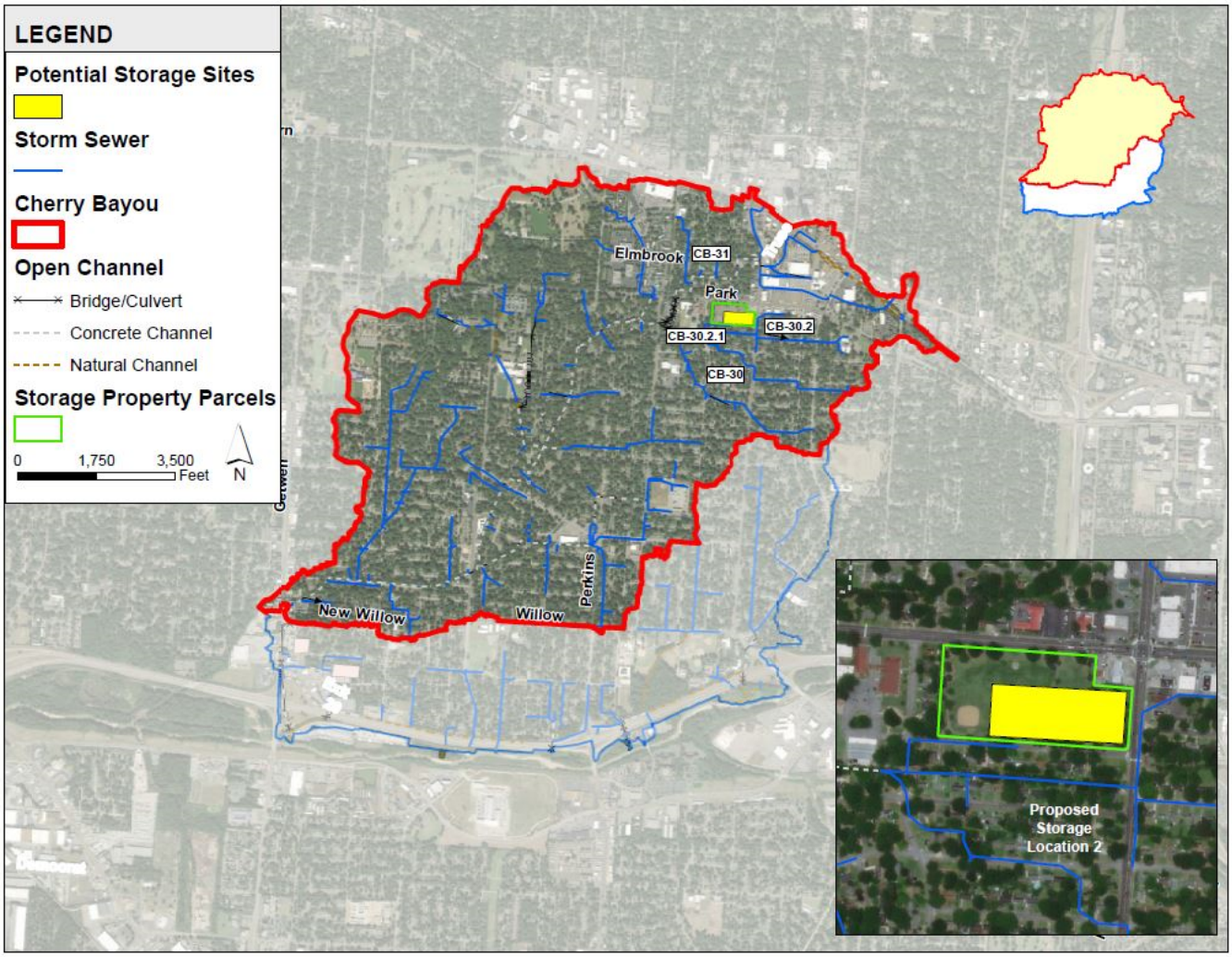


The proposed open channel storage decreases the HGL and reduces the extents of the floodplain, but storage alone is not enough to eliminate Harding Academy from the 10-year design storm floodplain. The total planning-level cost opinion for the recommended storage and associated capacity improvements (discussed in Section 5.3) is $7,590,000.

5.2.2 Site 2 – Marquette Park Storage Alternative

Site 2 – Marquette Park: This site is located at Marquette Park near the intersection of Alrose Avenue and Mt. Moriah Road in the Cherry Bayou drainage system. For the 10-year, 24-hour design storm approximately 688,000 cubic feet of storage is required for the 10-year, 24-hour design storm. Based on existing site conditions, the storage basin at this location was modeled as a 7-foot-deep open basin fed by a 54-inch pipe with a maximum footprint of 189,000 square feet and total potential capacity of 1,100,000 cubic feet. Using a 15-inch outlet pipe, the maximum depths obtained during the 10-year and 100-year design events are 4.7 feet and 6.6 feet, respectively. The planning-level cost opinion for the Site 2 storage alternative is $3,650,000. Figure 5.3 presents the conceptual planning improvements proposed at Site 2: Marquette Park.

Figure 5.3: Conceptual Marquette Park Alternative



The proposed storage basin decreases the HGL and reduces the extents of the floodplain, but storage alone is not enough to eliminate the majority of the homes from the 10-year design event floodplain. The total planning-level cost opinion for the recommended storage and associated capacity improvements (discussed in Section 5.3) is $5,660,000.

5.2.3 Site 3 – Memphis Board of Education Storage Alternative

Site 3 – Memphis Board of Education: This site was modeled at multiple locations. Site 3C was the initially selected location for storage and is located at an empty parcel adjacent to South Park Elementary School near the intersection of East Mallory Road and Getwell Road in the Goodwin drainage system. In addition, storage was modeled at potential FEMA buyout properties (3A) and a low-lying vacant parcel (3B).

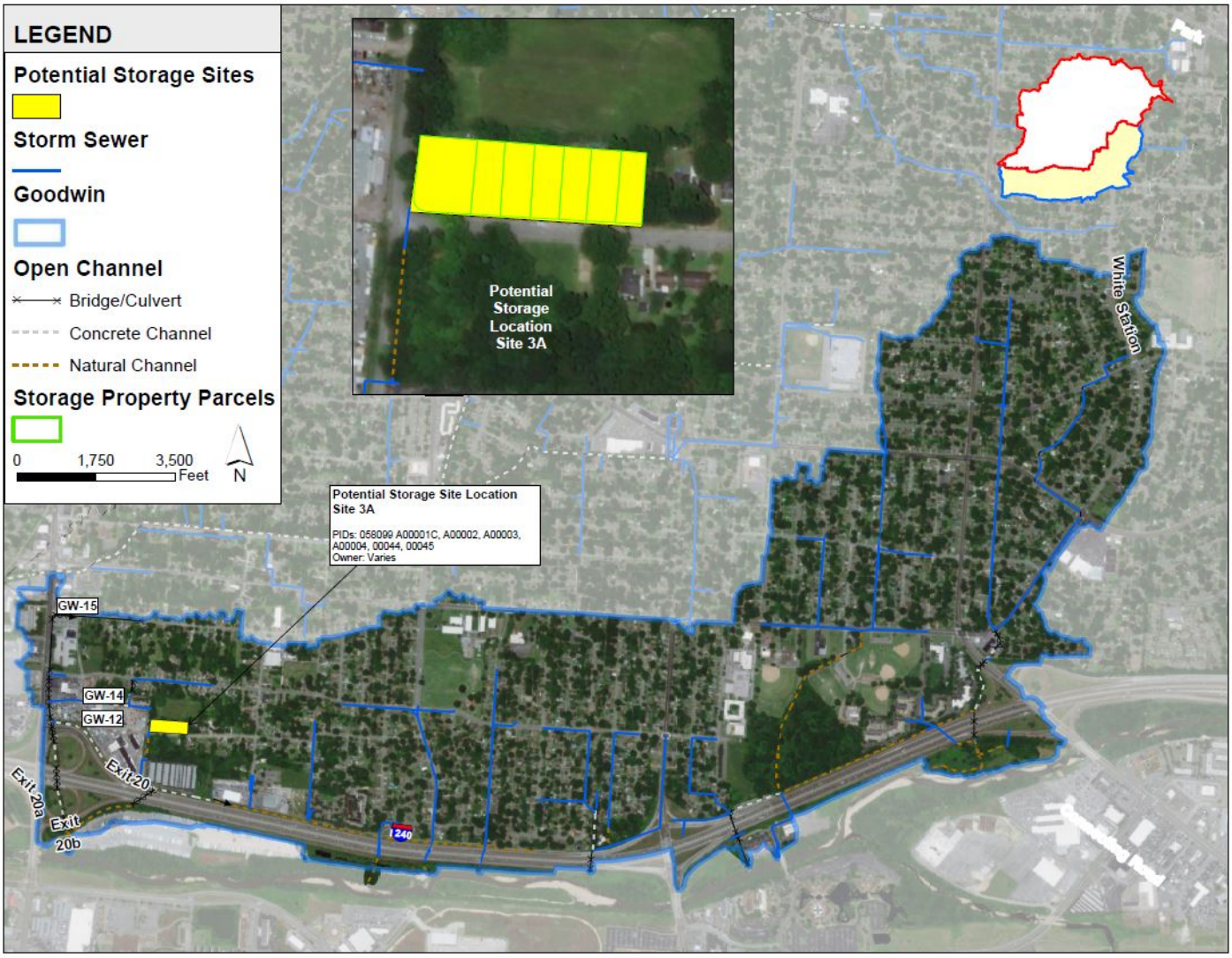
3A/3B:

For the 10-year, 24-hour design storm approximately 290,000 cubic feet of storage is required for the 10-year, 24-hour design storm. Based on existing site conditions, the potential storage basin at these two locations was modeled as a 6-foot-deep open basin with a maximum footprint of 83,000 square feet and total capacity of 395,000 cubic feet. The basin is fed by 24-inch, 36-inch, and 48-inch pipes. Using a 24-inch outlet pipe, the maximum depths obtained during the 10-year and 100-year design events are 4.6 feet and 5.9 feet, respectively. The planning-level cost opinion for Site 3A/3B is $5,220,000. Figures 5.4 and 5.5 present the conceptual planning improvements proposed at Site 3A/3B.

3C:

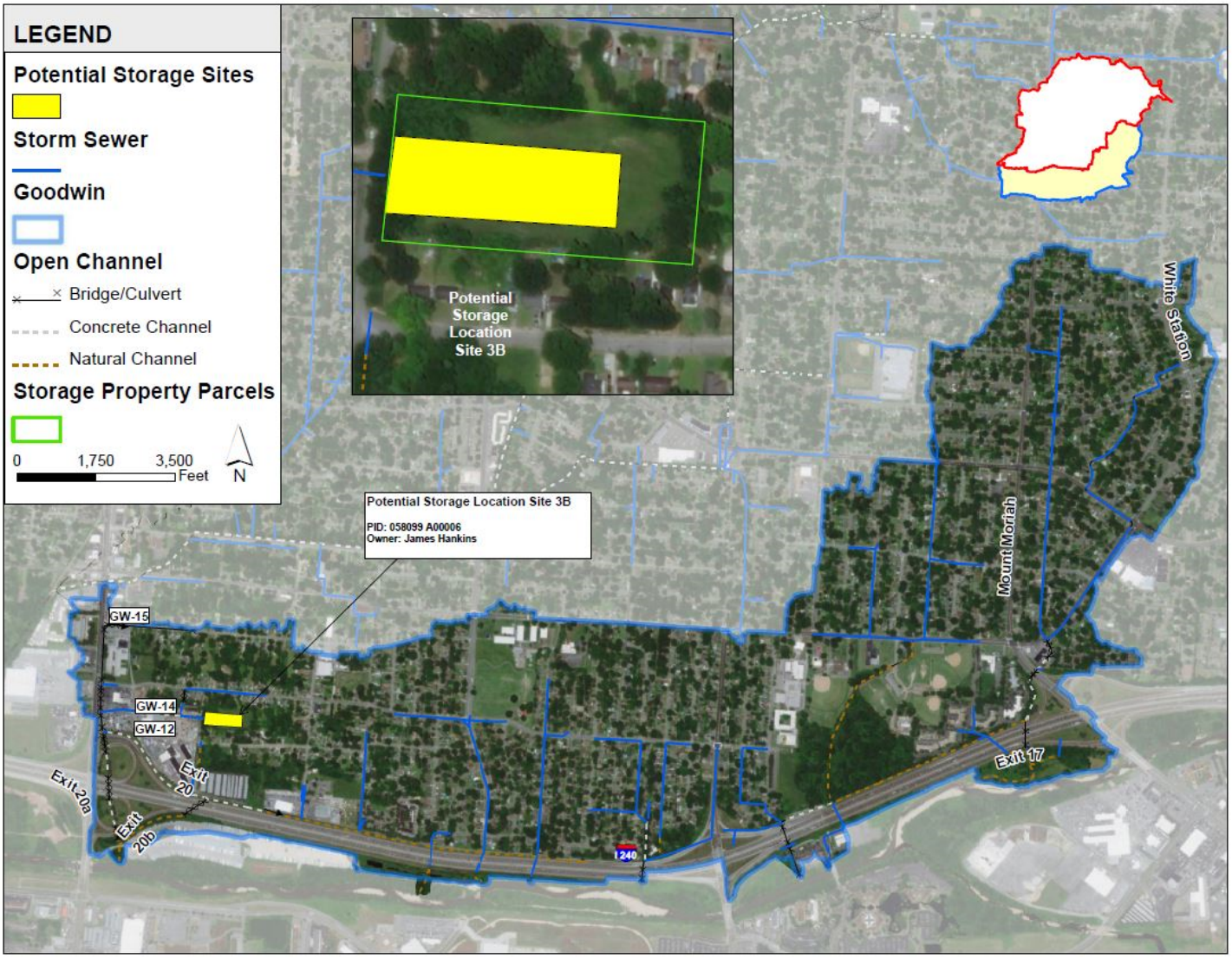
For the 10-year, 24-hour design storm approximately 112,000 cubic feet of storage is required for the 10-year, 24-hour design storm. Based on existing site conditions, the potential storage basin at this location was modeled as a 12-foot-deep open basin fed by a 42-inch and 54-inch pipe with a maximum footprint of 60,000 square feet and total capacity of 418,000 cubic feet. Using a 15-inch outlet pipe, the maximum depths obtained during the 10-year and 100-year design events are 5.1 feet and 5.8 feet, respectively. The planning-level cost opinion for Site 3C is $3,440,000. Figure 5.6 presents the conceptual planning improvements proposed at Site 3C: Memphis Board of Education.

Figure 5.4: Conceptual Memphis Board of Education Alternative 3A



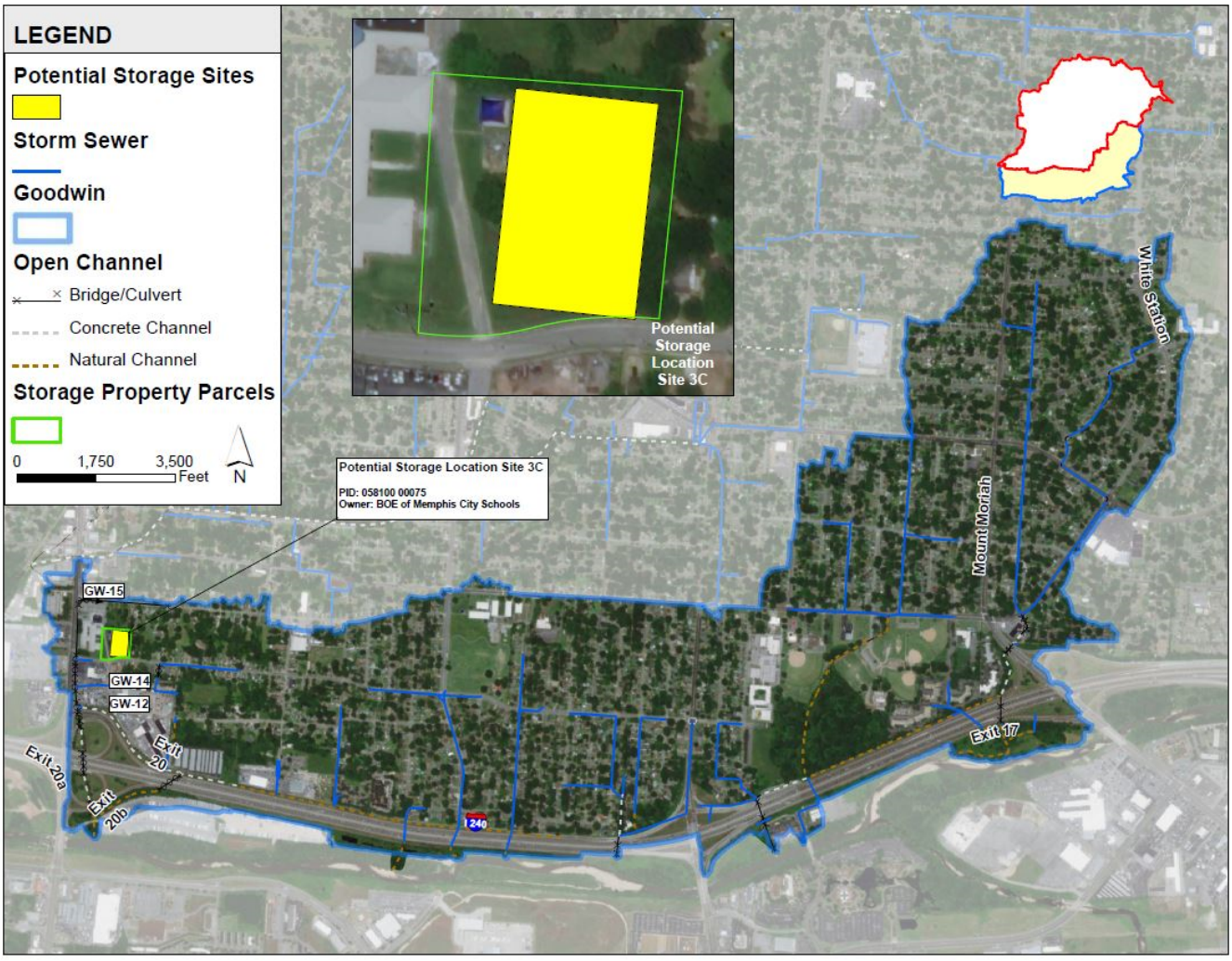
The proposed storage basins decrease the HGL and reduce the extents of the floodplain, but storage alone is not enough to eliminate the majority of the homes from the 10-year design event floodplain. The total planning-level cost opinion for the recommended storage and associated capacity improvements (discussed in Section 5.3) is $6,250,000.

Figure 5.5: Conceptual Memphis Board of Education Alternative 3B



The proposed storage basins decrease the HGL and reduce the extents of the floodplain, but storage alone is not enough to eliminate the majority of the homes from the 10-year design event floodplain. The total planning-level cost opinion for the recommended storage and associated capacity improvements (discussed in Section 5.3) is $6,250,000.

Figure 5.6: Conceptual Memphis Board of Education Alternative 3C



The proposed storage basins decrease the HGL and reduce the extents of the floodplain, but storage alone is not enough to eliminate the majority of the homes from the 10-year design event floodplain. The total planning-level cost opinion for the recommended storage improvements is $4,470,000.

5.3 SYSTEM CAPACITY ALTERNATIVES

This section provides details on each of the evaluated alternatives that are recommended for the Cherry Bayou Study Area. The recommended improvements are summarized by watershed and branch ID, which is also tied to the hydraulic profiles. Appendix C includes hydraulic profiles of the main branches in each watershed and all branches with a recommended improvement. Therefore, not every minor branch from the model will have a hydraulic profile in Appendix C. Appendices G and H include detailed floodplain delineations of the 10-year and 100-year proposed improvements, respectively. Appendix F provides enlarged plan-view figures of the proposed improvements including location and size. The planning-level costs opinions are summarized in Table 6.2. Appendix B includes a more detailed breakdown of planning-level cost opinions for each project. For budgeting purposes, the removal and replacement of pipes was assumed. Providing parallel relief pipes should be evaluated when projects are moved into a design phase to analyze routes and utility conflicts.

Figure 5.7: Example Appendix C Figure

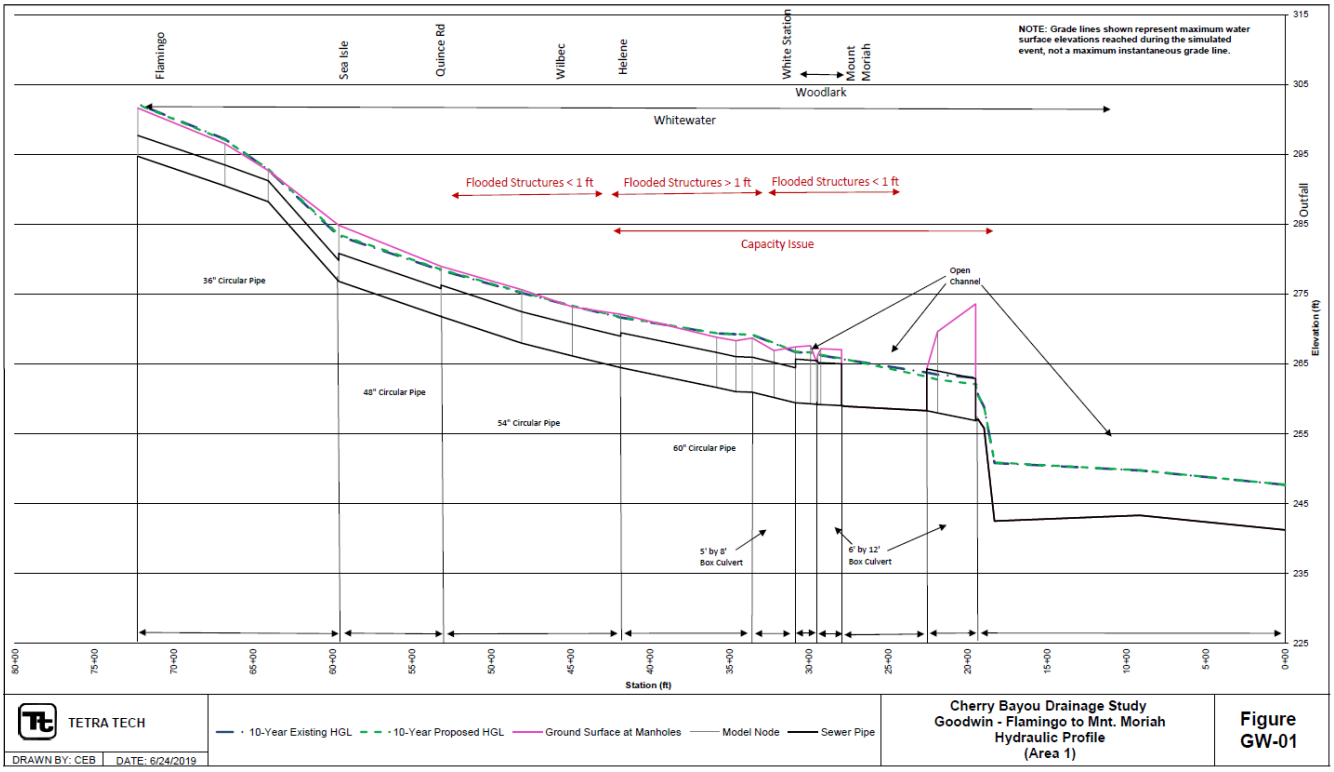


Figure 5.8: Example Appendix G Figure

Figure 5.9: Example Appendix H Figure

5.3.1 Cherry Bayou Watershed Capacity Alternatives

CB-02 Alternative

The CB-02 network area of concern includes flooding along New Willow Avenue. The flooding is due to limited capacity within the existing system. There are no existing sewers in the vicinity with excess capacity or viable storage locations that can provide relief to the area. Therefore, the available option is to provide a new adequately sized sewer system.

The CB-02 alternative consists of upsizing 87 LF of 24-inch pipe to 36-inch pipe, upsizing 376 LF of 24-inch pipe to 42-inch pipe, and upsizing 255 LF of 30-inch pipe to 54-inch pipe along New Willow Avenue.

By increasing the conveyance capacity at these locations, one (1) structure will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Thirteen (13) structures are removed from the zero-to-one-foot-depth floodplain and zero (0) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $960,000.

(Appendix F/G/H map page: 7)

CB-03 Alternative

The CB-03 network area of concern includes flooding along Willowview Avenue.

The CB-03 alternative consists of installing 124 LF of 30-inch pipe from CB-03 across Willowview Avenue to Cherry Bayou (CB-00).

By increasing the conveyance capacity at these locations, twelve (12) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. One (1) structure is removed from the zero-to-one-foot-depth floodplain and zero (0) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $140,000.

(Appendix F/G/H map page: 7)

CB-05 and CB-05.04 Alternative

The CB-05 and CB-05.04 network has flooding that begins at Dunn Road and continues upstream to Audubon Drive. Severe flooding areas include properties along Rebecca Street, Fredericks Avenue, Fizer Road, Meadow Drive, Briarwood Road, Oakridge Drive, Broadmoor Street, Wedgewood Street, Carolyn Drive, Cherrydale Road, Cherrydale Cove, Rhodes Avenue, Woodcrest Drive, and Amber Lane.

The CB-05 and CB-05.04 alternative consists of the following improvements (listed upstream to downstream):

a. Upsizing 1038 LF of 36-inch pipe to 42-inch pipe on Merrycrest Drive.
b. Upsizing 1315 LF of 30-inch pipe to 42-inch pipe on Audubon Drive.
c. Upsizing 200 LF of 30-inch pipe to 54-inch pipe from Oakridge Drive along Rhodes Avenue.
d. Upsizing 131 LF of 30-inch pipe to 60-inch pipe from Rhodes Avenue to Broadmoor Street.
e. Installing 875 LF of 60-inch pipe from Rhodes Avenue at Broadmoor Street to Barron Avenue at Broadmoor Street.
f. Upsizing 383 LF of 24-inch pipe to 60-inch pipe from Barron Avenue at Broadmoor Street to Cherrydale Road at Broadmoor Street.
g. Upsizing 35 LF of 30-inch pipe to 60-inch pipe near Broadmoor Street at Cherrydale Road.
h. Upsizing 290 LF of 36-inch pipe to 60-inch pipe from Broadmoor Street at Cherrydale Road to Wedgewood Street at Cherrydale Road.
i. Upsizing 43 LF of 30-inch pipe to 60-inch pipe near Wedgewood Street at Cherrydale Road.
j. Upsizing 438 LF of 42-inch pipe to 60-inch pipe from Wedgewood Street at Cherrydale Road to Merrycrest Drive at Cherrydale Road.
k. Installing 3,418 LF of 66-inch pipe from Merrycrest Drive at Cherry Dale Road to Dunn Road at Merrycrest Drive, from Dunn Road at Merrycrest Drive to Michael Street at Dunn Road, from Michael

Street at Dunn Road to Boyce Avenue at Michael Street, and from Boyce Avenue at Michael Street to Cherry Bayou (CB-00).

By increasing the conveyance capacity at these locations, five (5) structures will be removed from the greater-than-two-foot-depth floodplain and thirty-five (35) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. One hundred and nineteen (119) structures are removed from the zero-to-one-foot-depth floodplain and eight (8) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $9,560,000.

(Appendix F/G/H map pages: 7, 12, 13, 17, 18, 22)

CB-07 Alternative

The CB-07 network has flooding near the intersection of New Willow Avenue and South Goodlett Street. The flooding is due to limited capacity within the existing system.

The CB-07 alternative consists of installing 794 LF of 30-inch pipe from CB-07 at Goodlett Street to Cherry Bayou (CB-00).

By increasing the conveyance capacity at these locations, two (2) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Twelve (12) structures are removed from the zero-to-one-foot-depth floodplain and four (4) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $670,000.

(Appendix F/G/H map page: 8)

CB-12.6 and CB-12.8 Alternative

The CB-12.6 and CB-12.8 network areas of concern include flooding along Sea Isle Drive, Marcia Road, and Verne Drive.

The CB-12.6 and CB-12.8 alternative consists of upsizing 18 LF of 27-inch to 36-inch pipe, 139 LF of 27-inch pipe to 42-inch pipe, and 324 LF of 36-inch pipe to 42-inch pipe from Verne Avenue to Colonial Road at Quince Road and installing 120 LF of 24-inch pipe from CB-12.6 to CB-12.8 at Sea Isle Road at Colonial Road.

By increasing the conveyance capacity at these locations, seven (7) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Twenty (20) structures are removed from the zero-to-one-foot-depth floodplain and seventeen (17) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $660,000.

(Appendix F/G/H map pages: 14, 15, 20)

CB-20, CB-20.04, and CB-23 Alternative

The CB-20 network is flooding along Cherry Road near the east side of the Harding Academy property, west of Cherry Road along CB-20.06, along CB-20.04 on the west side of the Harding Academy property, along Dee Road, and an open channel portion that affects properties off of Fairmeadow Road.

The CB-20, CB-20.04, and CB-23 alternative consists of the following improvements (listed upstream to downstream):

a. Widening the existing open channel on the west side of the Harding Academy property to approximately 50’ wide.
b. Installing 850 LF of 3.5’ x 5.5’ box culvert from Cherry Road east toward Fairmeadow Road.
c. Upsizing 731 LF of 3.5’ x 5.5’ box culvert to 4’ x 8’ box culvert along the east side of the campus.
d. Installing 380 LF of 4’ x 8’ box culvert from Dee Road to Dee Road at Fairmeadow Road.
e. Upsizing 628 LF of 30-inch pipe to 4’ x 8’ box culvert from Dee Road at Fairmeadow Road to CB-00 at Dee Road.

By increasing the conveyance capacity at these locations, two (2) structures will be removed from the greater-than-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Eleven (11) structures are removed from the zero-to-one-foot-depth floodplain and three (3) remain within the zero-to-one-foot-depth floodplain for the

10-year, 24-hour design storm event. In addition, one (1) structure remains within the one-to-two-foot-depth floodplain and two (2) structures remain in the greater-than-two-foot-depth floodplain. These structures are office buildings near Harding Academy. This flooding appears to be on private property and improvements on these properties were not investigated. The planning-level cost opinion for this alternative is $7,590,000.

(Appendix F/G/H map pages: 19, 22, 23, 27, 28)

CB-21 Alternative

The CB-21 network is flooding along Dearing Avenue, South Perkins Road, Mockingbird Lane, Hummingbird Lane, Colonial Lane, and Flamingo Road.

The CB-21 alternative consists of installing 1,176 LF of 30-inch pipe from CB-21 at Colonial Road to Dearing Road at Flamingo Road, 652 LF of 36-inch pipe on Flamingo Road, 570 LF of 42-inch pipe at West Perkins Road along Flamingo Road, and 162 LF of 54-inch pipe from Flamingo Road to Cherry Bayou (CB-21).

By increasing the conveyance capacity at these locations, one (1) structure will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Twenty-one (21) structures are removed from the zero-to-one-foot-depth floodplain and nine (9) will remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $2,230,000.

(Appendix F/G/H map pages: 19, 20)

CB-28 Alternative

The CB-28 network areas of concern include flooding along Towering Oaks Drive, Colonial Street, and Colonial Road.

The CB-28 alternative consists of upsizing 86 LF of 4’ x 6’ box culvert to 4.5’ x 7.5’ box culvert.

By increasing the conveyance capacity at these locations, one (1) structure will be removed from the greater-than-two-foot-depth floodplain and two (2) structures are removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Three (3) structures are removed from the zero-to-one-foot-depth floodplain and three (3) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $210,000.

(Appendix F/G/H map pages: 29, 33)

CB-30, CB-30.1, CB-30.2, and CB-00 Alternatives

The CB-30, CB-30.1, CB-30.2, and CB-00 network areas of concern include flooding along Alrose Avenue, Kaye Avenue, Welchshire Avenue, Hampshire Avenue, Edenshire Avenue, and Ivy Road. Due to the significance of Marquette Park to the area, two alternatives have been developed.

The Option A alternative consists of the following improvements (listed upstream to downstream):

a. Installing 735 LF of 48-inch pipe from CB-00 at Mt. Moriah Road near the Eastgate Shopping Center entrance to near Alrose Avenue at Mt. Moriah Road.
b. Installing 300 LF of 60-inch pipe near Alrose Avenue at Mt. Moriah Road to near Kaye Avenue at Mt. Moriah Road.
c. Installing 3,499 LF of 72-inch pipe from Kaye Avenue at Mt. Moriah along Welchshire Avenue and Colonial Road to CB-00 near Kaye Avenue at Colonial Road.
d. Installing 25 LF of 36-inch pipe from CB-30.2.1 near Alrose Avenue at Mt. Moriah Road to the new 60-inch pipe on Mt. Moriah Road.
e. Installing 115 LF of 30-inch pipe from CB-30.2 at Mt. Moriah Road to the new 72-inch pipe on Mt. Moriah Road.
f. Upsizing 1,188 LF of 36-inch pipe to 42-inch pipe from Edenshire Avenue at Wilbec Road to Edenshire Avenue at Mt. Moriah Road.
g. Upsizing 587 LF of 42-inch pipe to 48-inch pipe from Edenshire Avenue at Mt. Moriah Road to Hampshire Avenue at Mt. Moriah Road.

By increasing the conveyance capacity at these locations, nine (9) structures will be removed from the greater-than-two-foot-depth floodplain and fifty-four (54) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Seventy-five (75) structures are removed from the zero-to-one-foot-depth floodplain and sixteen (16) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $7,970,000.

(Appendix F/G/H map pages: 21A, 24A, 25A)

The Option B alternative consists of the following improvements (listed upstream to downstream):

a. Storage Site 2 at Marquette Park (refer to Section 5.2.2).
b. Installing 735 LF of 48-inch pipe from CB-00 at Mt. Moriah Road near the Eastgate Shopping Center to Storage Site 2 at Marquette Park.
c. Installing 25 LF of 36-inch pipe from CB-30.2.1 near Alrose Avenue at Mt. Moriah Road to Storage Site 2 at Marquette Park.
d. Installing 115 LF of 30-inch pipe from CB-30.2 at Mt. Moriah Road to the new 54-inch pipe on Mt. Moriah Road.
e. Installing 1,085 LF of 72-inch pipe along Welchshire Avenue.
f. Installing 372 LF of 54-inch pipe from CB-30 on Welchshire Avenue to Storage Site 2 at Marquette Park.
g. Upsizing 1,188 LF of 36-inch pipe to 42-inch pipe from Edenshire Avenue at Wilbec Road to Edenshire Avenue at Mt. Moriah Road.
h. Upsizing 587 LF of 42-inch pipe to 48-inch pipe from Edenshire Avenue at Mt. Moriah Road to Hampshire Avenue at Mt. Moriah Road.

By increasing the conveyance capacity at these locations, nine (9) structures will be removed from the greater-than-two-foot-depth floodplain and fifty-four (54) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Fifty-one (51) structures are removed from the zero-to-one-foot-depth floodplain and forty (40) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $5,660,000.

Option B removes all homes from the greater-than-one-foot-depth floodplain at a lower cost, thus it is recommended.

(Appendix F/G/H map pages: 21B, 24B, 25B)

CB-43 Alternative

The CB-43 network has flooding along Leatherwood Road. The flooding is due to limited capacity within the existing system.

The CB-43 alternative consists of upsizing 564 LF of 24-inch pipe to 30-inch pipe along Gilson Road and installing 650 LF of 54-inch pipe from near Gilson Road at Boyce Road to Cherry Bayou (CB-00). By increasing the conveyance capacity at these locations, four (4) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Five (5) structures are removed from the zero-to-one-foot-depth floodplain and three (3) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $1,240,000.

(Appendix F/G/H map pages: 8, 13)

5.3.2 Goodwin Watershed Capacity Alternatives

The White Station area of the Goodwin drainage area was originally modeled in InfoSWMM and severe flooding was predicted in this region. However, there were not enough flooding complaint tickets in the City's database to believe that the predicted flooding was real. Since InfoSWMM interpolates between hydraulic grade lines and assumes an infinite supply of water, Tetra Tech decided to further investigate this area via 2D PCSWMM modeling that accounts for the exact volume of water expelled from the flooding system.

This investigation significantly reduced the predicted flooding to approximately 5 homes existing in the > 1 foot floodplain depth. After extensive attempts to rectify the flooding near the intersection of Whitewater Road and South White Station Road where the homes are flooding, it was apparent that the cost benefit ratio to remove the five homes from the floodplain was unfeasible. As a result, additional surveying was completed to ensure the flooding predicted by the model was not an inappropriate interpolation of hydraulic grade lines. The survey results showed that the finished floor elevations of the five homes in question were above the maximum water surface elevation and were not actually flooding. No alternatives are proposed in this area.

GW-11 Alternative

The GW-11 network areas of concern include flooding along East Mallory Road and Titus Road.

The GW-11 alternative consists of upsizing 151 LF of 1.8' x 2.8' horizontal ellipse pipe to 36-inch pipe along South Goodlett Street to Barr Avenue at South Goodlett Street, upsizing 456 LF of 2.4' x 2.8' horizontal ellipse pipe to 42-inch pipe at Barr Avenue at South Goodlett Street along South Goodlett Street, upsizing 542 LF of 2.4' x 2.8' horizontal ellipse pipe to 48-inch pipe along South Goodlett Street to GW-13.

By increasing the conveyance capacity at these locations, six (6) structures will be removed from the greater-than-two-foot-depth floodplain and twelve (12) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Fifteen (15) structures are removed from the zero-to-one-foot-depth floodplain and nine (9) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $1,280,000.

(Appendix F/G/H map page: 2)

GW-14 and GW-15 Alternative

The GW-14 and GW-15 network is flooding along South Goodlett Street and Bar Avenue.

After the initial selection of the Board of Education storage site, the City notified Tetra Tech of potential FEMA property buyouts on Barr Avenue. If these buyouts are finalized, a storage site could be developed in this area. Another potential location on a nearby vacant parcel was also identified. Thus, two options were developed.

The Option A/B alternative consists of the following improvements (listed upstream to downstream):

a. Installing 512 LF of 30-inch pipe from Elliston Road at Getwell Road to Cherry Bayou (CB-00).
b. Storage Site 3 at two possible locations: 3A at FEMA buyout property lots or 3B at a low-lying private property parcel.
c. Installing 524 LF of 48-inch pipe near Titus Road at East Mallory Road to Storage Site 3A/3B.
d. Installing 484 LF of 36-inch pipe from Barr Avenue at Titus Road to Storage Site 3A/3B.
e. Regrading the 24-inch (20 LF) and 30-inch portion of GW-14 on East Mallory Road (922 LF).
f. Upsizing 197 LF of 24-inch pipe to 38-inch x 60-inch horizontal elliptical pipe at Getwell Road and East Mallory Road.
g. Installing 800 LF of 38-inch x 60-inch horizontal elliptical pipe along East Mallory Road from South Park Elementary School to GW-14.
h. Removing sediment/debris from the natural channel that begins near Barr Avenue at Titus Road.
i. Upsizing 61 LF of 24-inch pipe to 30-inch pipe east to west across Titus Road.
j. Upsizing 268 LF of 27-inch pipe to 36-inch pipe along Titus Road to GW-12.

By increasing the conveyance capacity at these locations, fifteen (15) structures will be removed from the greater-than-two-foot-depth floodplain and eight (8) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Twenty-one (21) structures are removed from the zero-to-one-foot-depth floodplain and six (6) remain within the zero-to-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $6,250,000.

The Option C alternative consists of the following improvements (listed upstream to downstream):

a. Installing 512 LF of 30-inch pipe from Elliston Road at Getwell Road to Cherry Bayou (CB-00).
b. Storage Site 3C at the Memphis Board of Education property.
c. Installing 735 LF of 54-inch pipe from GW-14 at East Mallory Road to Storage Site 3C.
d. Upsizing 197 LF of 24-inch pipe to 48-inch pipe at Getwell Road and East Mallory Road.
e. Installing 500 LF of 48-inch pipe from the existing segment of pipe at Getwell Road and East Mallory Road to Storage Site 3C.
f. Upsizing 20 LF of 24-inch pipe to 36-inch pipe on East Mallory Road.
g. Upsizing 460 LF of 30-inch pipe to 42-inch pipe on East Mallory Road.
h. Upsizing 462 LF of 30-inch pipe to 48-inch pipe on East Mallory Road.
i. Removing sediment/debris from the natural channel that begins near Barr Avenue at Titus Road.
j. Upsizing 60 LF of 24-inch pipe to 30-inch pipe east to west across Titus Road.
k. Upsizing 268 LF of 27-inch pipe to 36-inch pipe along Titus Road to GW-12.

By increasing the conveyance capacity at these locations, fifteen (15) structures will be removed from the greater-than-two-foot-depth floodplain and five (5) structures will be removed from the one-to-two-foot-depth floodplain for the 10-year, 24-hour design storm event. Eighteen (18) structures are removed from the zero-to-one-foot-depth floodplain. Nine (9) remain within the zero-to-one-foot-depth floodplain and three (3) remain in the greater-than-one-foot-depth floodplain for the 10-year, 24-hour design storm event. The planning-level cost opinion for this alternative is $4,470,000.

Option C does not remove all structures from the greater-than-one-foot-depth floodplain, thus Option A/B is recommended.

(Appendix F/G/H map pages: 1, 7)

5.4 FLOODPLAIN DELINEATIONS

The existing and proposed alternatives floodplain delineations are shown in Appendices D and E (Existing conditions 10-year and 100-year floodplains, respectively) and Appendices G and H (Proposed conditions 10-year and 100-year floodplains, respectively). The floodplains are presented with three depth classifications to help identify the severity of the flooding. The three classifications are:

- Green - Zero to one foot in depth
- Yellow - One to two feet in depth
- Red - Greater than two feet in depth.

The following tables indicate the number of structures within each depth classification for the proposed 10-year and 100-year design storm events per drainage area.

Table 5.1: Cherry Bayou Flooded Structures with Recommended[1] Improvements

Flooding Depth (feet)	Proposed 10-year, 24-hour Floodplain	Proposed 100-year, 24-hour Floodplain
0 – 1	120	303
1 - 2	2	32
> 2	2	2
Total	124	337
Total > 1	4	34

Table 5.2: Goodwin Flooded Structures with Recommended[1] Improvements

Flooding Depth (feet)	Proposed 10-year, 24-hour Floodplain	Proposed 100-year, 24-hour Floodplain
0 – 1	89	164
1 - 2	0	21
> 2	0	1
Total	89	186
Total > 1	0	22

Footnotes:

1 – Structure counts included for the recommended project when more than one alternative is provided.

6.0 RECOMMENDATIONS

A series of alternatives have been developed and evaluated for the purpose of providing options to help alleviate flooding within the study area. These alternatives were based on the hydrologic and hydraulic model developed using survey, as-built data, and calibrated to water level and precipitation data. The alternatives provide the City with planning-level cost opinions for Capital Improvement Plan budgeting. The sizing and effectiveness of improvements assumes that all the projects are implemented. For example, if an upstream project is completed prior to the constructing recommended downstream improvements, the downstream system may not have sufficient capacity which could lead to adverse impacts in those areas.

The recommended improvements have been prioritized based on constructability and the effectiveness of reducing residential flooding. Projects were prioritized as follows: areas with flooding complaints, followed by cost-benefit ratios. The number of homes within and removed from the 10-year and 100-year design storm events floodplains are independent of each other. Therefore, the number of primary structures removed for the 100-year event could be less than the 10-year event due to the location of specific structures within each floodplain and the floodplain reductions from each improvement. Table 6.1 summarizes the costs by priority and the total number of primary structures removed from all projects in each priority grouping.

Table 6.1 summarizes each of the recommended improvements including prioritization, project cost and number of primary structures removed from the 10-year and 100-year floodplain. The Priority 1 improvements provide the most benefit and would remove approximately 128 total primary structures from the 10-year floodplain at a cost of approximately $29.1M (or $228,000 per home removed). These projects are in areas with significant predicted flooding and structure or land flooding complaints. The Priority 2 projects category contains projects with street or maintenance complaints. Priority 3 projects are projects in areas with no reported flooding complaints and a significantly higher cost benefit ratio, which is the primary reason for their lower priority ranking.

The cumulative anticipated project costs for Priority 1, 2 and 3 improvements are $36.2M. To optimize the City's capital expenditure for the greatest positive impact, we recommend a phased implementation approach. We recommend implementing the Priority 1 projects and then evaluating the remaining system to determine if isolated flooding continues to persist. If isolated flooding does continue to occur, the City can implement specific Priority 2 and/or 3 projects as needed to address specific issues.

Table 6.1: Summary of Improvement by Priority

Priority Level	Project IDs	Total Cost Opinion, $[1]	Primary Structures[2] Removed from 10-Year Floodplain	Primary Structures[2] Removed from 100-Year Floodplain
1	CB-05 & CB-05.04, CB-20, CB-20.04, & CB-23, CB-30, CB-30.1, CB-30.2, & CB-00 (Option B), GW-14 & GW-15 (Option A)	$29,060,000	128	199
2	CB-03, CB-12.6 & CB-12.8, CB-21, CB-28, GW-11	$4,520,000	41	59
3	CB-02, CB-07, CB-43	$2,870,000	7	11

Footnotes:

1 – See Appendix B for breakdown cost opinions for each project, with explanatory notes.

2 – Primary structures do not include out-buildings, garages, or sheds.

Table 6.2: Prioritization of Recommended Improvements

Watershed	Priority	Project ID	Description	# of Primary Structures[2] in Existing 10-Year Floodplain Flooding > 1'	# of Primary Structures[2] Removed from 10-Year Floodplain Flooding > 1'	Cost-Benefit Ratio ($/Primary Structure[2] Removed from > 1' 10-Year Floodplain)	# of Primary Structures[2] in Existing 100-Year Floodplain	# of Primary Structures[2] Removed from > 1' 100-Year Floodplain	Cost-Benefit Ratio ($/Primary Structure[2] Removed from > 1' 100-Year Floodplain)	Planning-Level Project Cost Opinion, $[1]
Cherry Bayou	1	CB-05 & CB-05.04	Capacity Improvements for CB-05 & CB-05.04	40	40	$239,000	70	66	$145,000	$9,560,000
Cherry Bayou	1	CB-20, CB-20.04, & CB-23	Capacity Improvements for CB-20, CB-20.04, & CB-23	5	2[3]	$3,795,000	7	2	$3,795,000	$7,590,000
Cherry Bayou	1	CB-30, CB-30.1, CB-30.2, & CB-00	Capacity Improvements (Option A) for CB-30, CB-30.1, CB-30.2, & CB-00	63	63	$127,000	101	91	$88,000	$7,970,000
Cherry Bayou	1	CB-30, CB-30.1, CB-30.2, & CB-00	Capacity & Storage Improvements (Option B) for CB-30, CB-30.1, CB-30.2, & CB-00	63	63	$90,000	101	73	$78,000	$5,660,000
Goodwin	1	GW-15	Capacity & Storage Improvements (Option A/B) for GW-14 & GW-15	23	23	$272,000	48	40	$157,000	$6,250,000
Goodwin	1	GW-15	Capacity & Storage Improvements (Option C) for GW-14 & GW-15	23	20	$224,000	48	36	$125,000	$4,470,000
Cherry Bayou	2	CB-03	Capacity Improvements for CB-03	12	12	$12,000	16	16	$9,000	$140,000
Cherry Bayou	2	CB-12.6 & CB-12.8	Capacity Improvements for CB-12.6 & CB-12.8	7	7	$95,000	11	5	$132,000	$660,000
Cherry Bayou	2	CB-21	Capacity Improvements for CB-21	1	1	$2,230,000	14	12	$186,000	$2,230,000
Cherry Bayou	2	CB-28	Capacity Improvements for CB-28	3	3	$70,000	6	5	$42,000	$210,000
Goodwin	2	GW -11	Capacity Improvements for GW-11	18	18	$72,000	30	21	$61,000	$1,280,000
Cherry Bayou	3	CB-02	Capacity Improvements for CB-02	1	1	$960,000	8	8	$120,000	$960,000
Cherry Bayou	3	CB-07	Capacity Improvements for CB-07	2	2	$335,000	5	3	$224,000	$670,000
Cherry Bayou	3	CB-43	Capacity Improvements for CB-43	4	4	$310,000	4	0	N/A	$1,240,000

Footnotes:

1 – See Appendix B for breakdown cost opinions for each project, with explanatory notes.

2 – Primary structures do not include out-buildings, garages, or sheds.

3 – Three remaining structures are private office buildings that improvements were not investigated for.

APPENDIX A: PUBLIC OUTREACH MATERIALS

Cherry Bayou Drainage Master Plan

Neighborhood Meeting – March 29, 2018

ALLWORLD
Project Management, LLC

TETRA TECH

Meeting Agenda

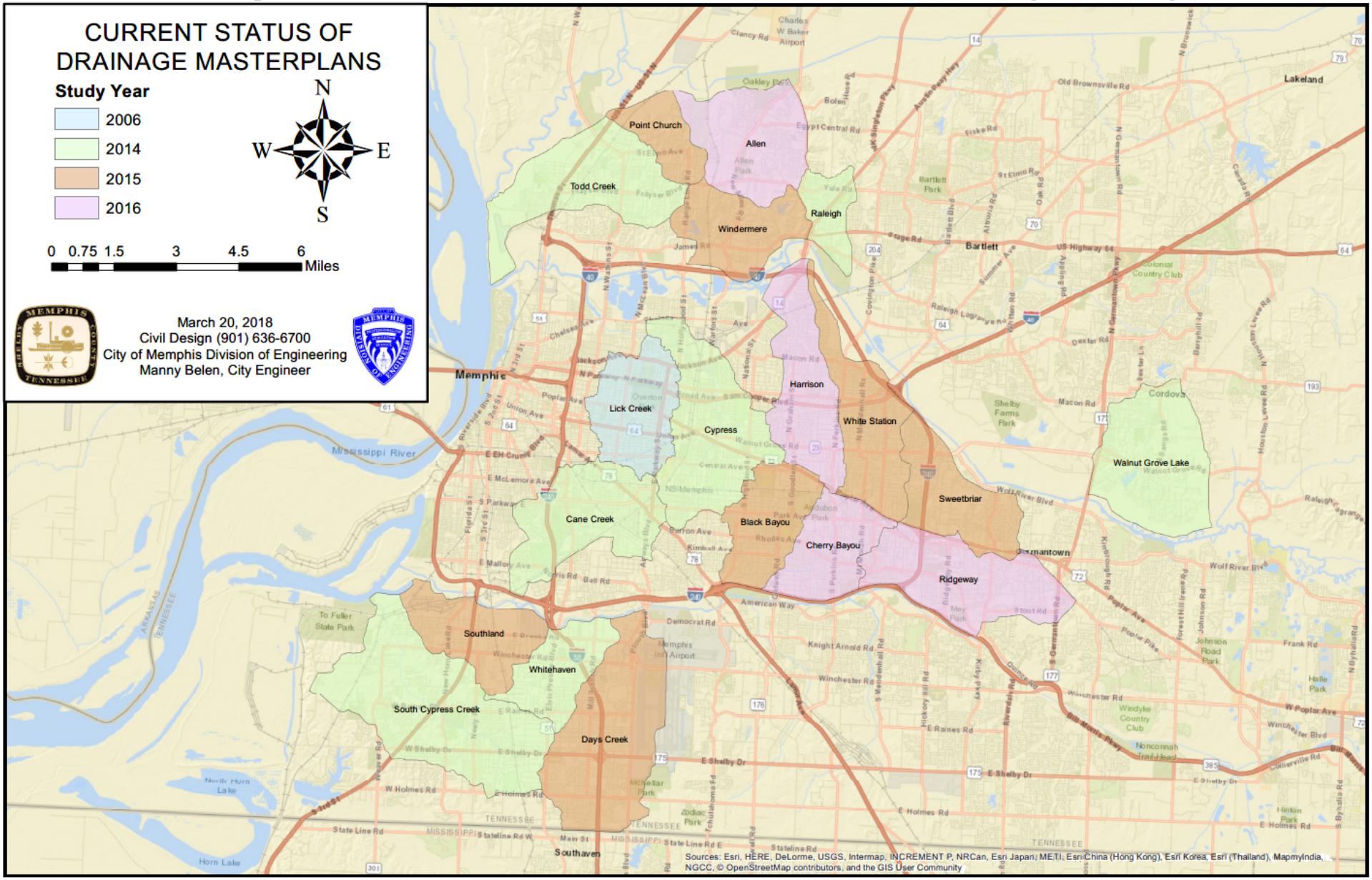
- Welcome / Sign-in
- Introduction to Project Team
- City Program Overview
- Project Scope and Purpose
- Schedule
- Requested Feedback
- Questions and Answers

Background on the City of Memphis Stormwater Master Planning Program

Lick Creek Area - 2012

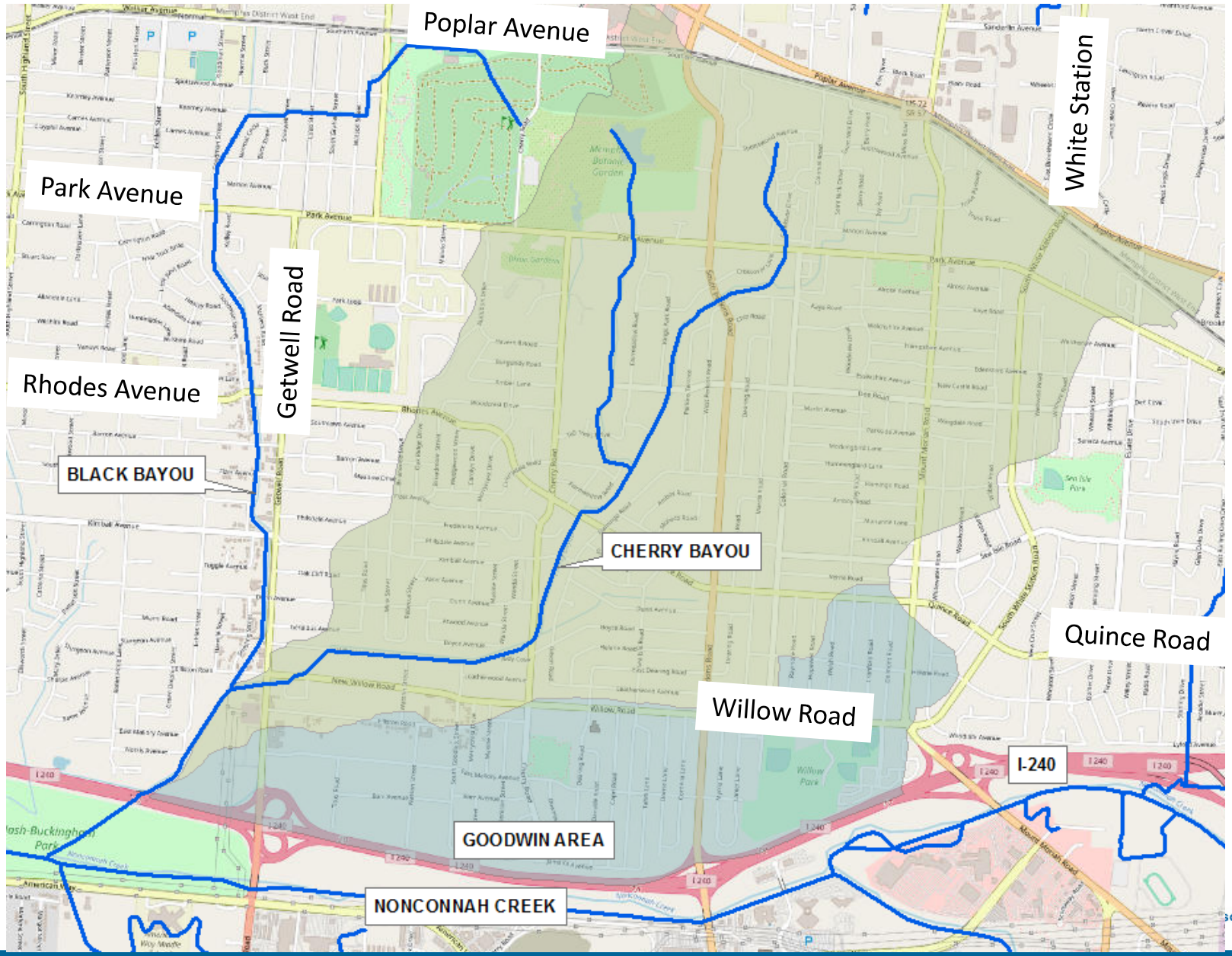
TETRA TECH

City Stormwater Master Planning Program



TETRA TECH

Cherry Bayou Study Area



SOLUTIONS™

Project Scope of Work

- Public engagement
- Survey
- Rain and Stream Data Collection
- GIS mapping
- Assessment of existing drainage system
- Recommended improvements
- Summary report

Public Participation

- Two public neighborhood meetings
  - One initial meeting to introduce the project and gather information on flooding locations
  - One meeting near the end of the project to review the outcomes and next steps

Inventory Existing Drainage System

- Field survey
- Photographs
- GIS mapping
- Record drawings
- Public input on flooding locations

Alternatives Development

- Cost effective means to reduce flooding
- Potential improvements
  - Upsize storm sewer and culverts
  - Detention/ retention ponds
  - Green infrastructure