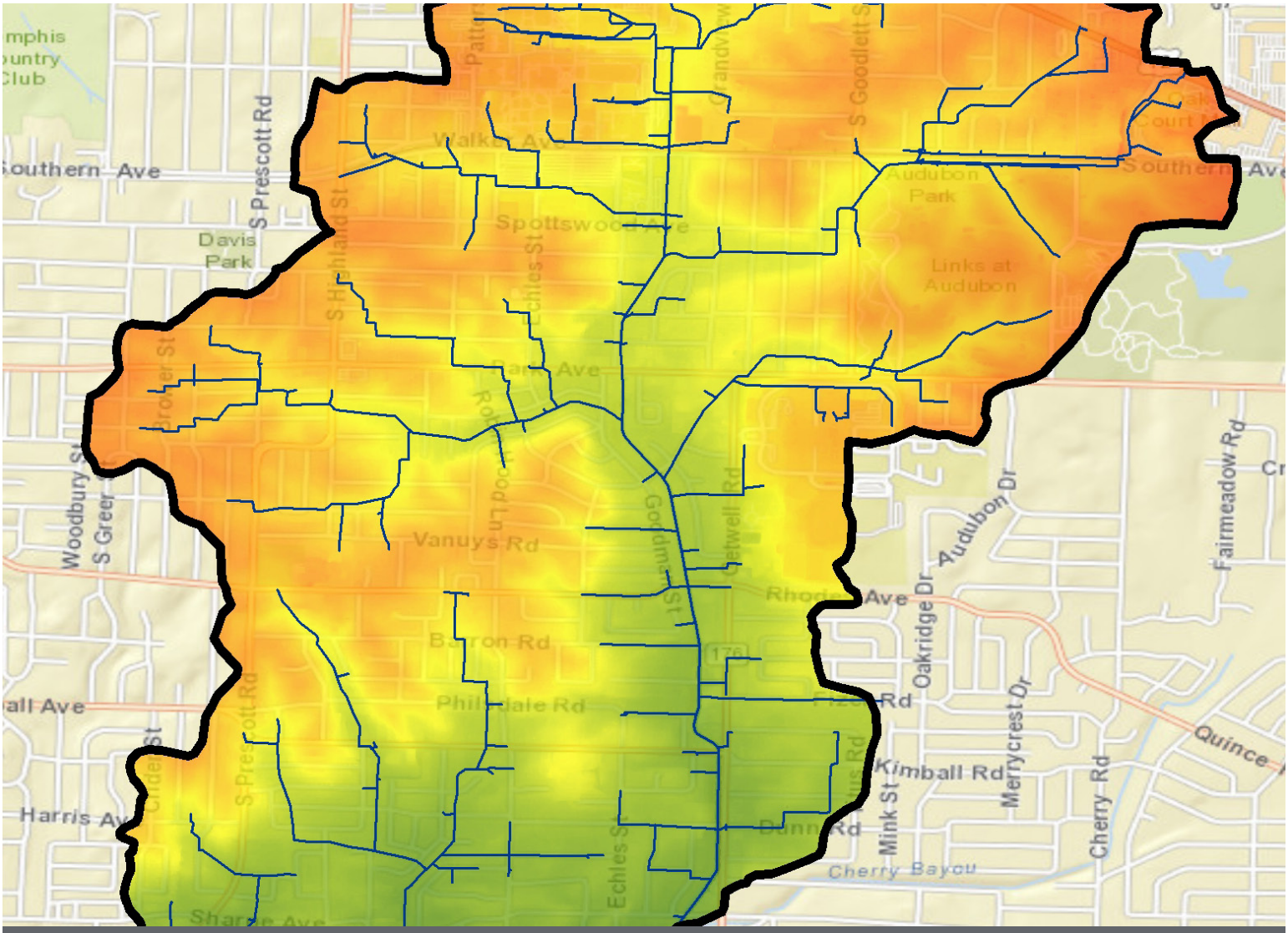

Comprehensive Drainage Report

BLACK BAYOU DRAINAGE BASIN STORMWATER MASTER PLAN

VOLUME ONE

City of Memphis, Tennessee

APRIL 2020

BARGE DESIGN SOLUTIONS

20180172

BLACK BAYOU DRAINAGE BASIN
STORMWATER MASTER PLAN

VOLUME I

CITY OF MEMPHIS, TENNESSEE

March 2020

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EXECUTIVE SUMMARY

To address stormwater drainage problems affecting the growing City of Memphis, the City implemented a stormwater program and began to collect stormwater fees. As fees accrued, the City has begun to study individual drainage basins in each of the seven council districts to evaluate the existing stormwater infrastructure and identify solutions to drainage problems. The study presented in this report evaluated the Black Bayou Drainage Basin.

The Black Bayou Drainage Basin was developed in the early to mid-1900's. Drainage has been previously managed by straightening natural channels and installing vertical wall concrete channel linings. The outfall of Black Bayou is into Nonconnah Creek. The area is primarily small lot residential with some commercial development. Two pre-study public meetings have been held in the area to hear residents' concerns. Two additional meetings will be held after improvements have been proposed.

This study utilized InfoSWMM to comprehensively model the Black Bayou Drainage Basin. Consistent with City of Memphis stormwater modeling standards, the Environmental Protection Agency's – Stormwater Management Model (EPA-SWMM)'s Non-linear reservoir runoff model and the Green Ampt infiltration model were the specific hydrologic options used. Previous studies conducted for portions on the Black Bayou Drainage Basin were reviewed and provided details useful for developing the model. The model was developed in conformance with the draft *Memphis Drainage Mapping and Modeling Analysis Standards Manual (06-24-2015)*, as provided by the City of Memphis, and City of Memphis / Shelby County Stormwater Management Manual.

Basin characteristics were compiled in the model including precipitation, topography, soils data, and land use. Point precipitation frequency estimates were retrieved from Atlas 14. Memphis receives about 48 inches of rainfall annually; the highest rainfall occurs in late fall and early spring. Soils classification data was obtained from the Natural Resources Conservation Service (NRCS) Soil Survey. Roughly 87% of the soil in the Black Bayou Drainage Basin is udorthent land, implying that this soil has been backfilled after the removal of the native surface. The remaining area is composed of various types of silt loam with moderate infiltration rates when thoroughly wet. The land usage data for the project area were retrieved from the National Land Cover Database (NLCD) 2011 by the Multi-Resolution Land Characteristics Consortium. These data show that most of the land in the Black Bayou Drainage Basin is classified as "Developed Low Intensity" or "Developed Open Space".

The stormwater infrastructure data was first obtained from the City of Memphis stormwater inventory geodatabase. A field survey was then conducted to update the stormwater inventory and add details such as pipe diameter or channel dimensions. The Black Bayou Drainage Basin contains more than 1000 pipe/channel segments for a total of 40 miles of conveyance. Segments less than 130 feet are most common, and the median length is approximately 140 feet. As is typical for Memphis, the Black Bayou Drainage Basin contains extensive lengths of concrete-lined channels as the primary conveyance structure throughout the basin.

The stormwater system analysis for the Black Bayou Drainage Basin was performed using a stormwater model that includes both hydrologic (rainfall runoff) calculations as well as hydraulic (system capacity/performance) calculations. The compiled model was calibrated against measured stream and rain gauge data and model parameters were modified until a good match was achieved. The existing drainage infrastructure system was evaluated for 24-hour duration storm events having National Oceanic and Atmospheric Administration (NOAA) rainfall amounts for theoretical return frequencies of 2, 5, 10, 25, 50 and 100 years.

The existing conditions analysis identified several areas where the existing drainage infrastructure was not adequate to prevent above-ground ponding for the design storm with a 10-year return frequency although the system as a whole performed relatively well. Within the Black Bayou Basin under existing conditions, the model showed that more than 300 stormwater structures would be considered undersized. Additionally, the 10-year 24 hour design storm model produced flooding impacting more than 100 locations along roadways. When compared to the survey of finished floor elevations for buildings at risk of inundation, 331 buildings were affected. A total of five individual areas were identified to develop remedial measures to alleviate the drainage deficiencies.

The first area identified is located along Southern Avenue near the University of Memphis main campus. The existing conditions analysis indicated 41 of the 52 drainage structures within this location flooded during the 10-year event due to being undersized . The proposed improvement includes increasing the size of drainage conduit and installation of additional drainage conduits acting as parallel conveyance to adequately convey the stormwater and prevent flooding during the 10-year event within Area 1. Three underground detention facilities are also proposed. The estimated cost for improvements in Area 1 is $13,820,000 and the benefit-cost ratio is 0.34.

The second area identified is located in the upper reaches of the Black Bayou watershed near the Audubon park and golf course. The existing conditions analysis indicated flooding of 29 of the 63 drainage structures within this location during the 10-year event due to being undersized . Additionally, flooding occurred over Southern Avenue and Village Road near the intersection with Williamsburg Lane and over the railroad tracks that run between Southern Ave and Village Road. The proposed improvement includes increasing the storage capacity of an above ground storage area along the park and golf course to detain some of the flooding. It then includes rerouting drainage conduit, adding new conduit to divert drainage from upstream of the railroad tracks directly to the storage area, and adding new conduit near Audubon Park. The estimated cost for improvements in Area 2 is $2,047,000 and the benefit-cost ratio is 8.35.

Area 3 is located from the intersection of Marion Avenue and Patterson Street South to the Main Black Bayou Canal at Robin Hood Lane. The existing conditions analysis indicated flooding of 25 of the 45 drainage structures within this location during the 10-year event due to being undersized. The proposed improvement includes increasing the size of conduit and adding new conduit down Robin Hood Lane. Additionally, a new underground detention facility is proposed. The estimated cost for improvements in Area 3 is $3,634,000 and the benefit-cost ratio is 4.7.

Area 4 is located from Brower Street at Park Avenue East to South Highland Street. The existing conditions analysis indicated flooding of 43 of the 56 drainage structures within this location during the 10-year event due to being undersized as well as some flooding at the intersection of Carrington Road and South Prescott Road. The proposed improvement includes increasing the size of conduit and adding new conduit as well as three new underground detention areas. The estimated cost for improvements in Area 4 is $9,263,000 and the benefit-cost ratio is 1.40.

Area 5 is located from just north and east of Rhodes Avenue and Will Scarlet Road to just south of Kimball Road and Robin Hood Lane. The existing conditions analysis indicated flooding of 31 of the 37 drainage structures within this location during the 10-year event due to being undersized as well as some flooding over Robin Hood Land near Philsdale Road and over Tyne Street near Deerwood Avenue. The proposed improvement includes increasing the size of conduit and adding a new route down Robin Hood Lane. A detention area would also be included in the open field near Sherwood Elementary to divert and store backwater from the canal. The estimated cost for improvements in Area 5 is $1,346,000 and the benefit-cost ratio is 12.36.

A benefit-cost analysis on was performed for the proposed improvements. The benefit cost analysis evaluated benefits that would be provided by proposed improvements including reduction in loss of service of roads, reduction in amount of property damage and reduction in rental costs for displaced families. The combined benefit-cost ratio for the five areas proposed for improvements is 2.28. Individual benefit-cost ratios for the five areas ranged from 0.35 to 12.36. The total cost for all improvements is estimated to be $30,109,000.

1 PROJECT INTRODUCTION AND BACKGROUND

1.1 Project Purpose

The City of Memphis was founded in 1819 on the fourth Chickasaw Bluff south of the confluence of the Wolf and Mississippi Rivers. The city proceeded to grow over the years, and given the boundaries presented by the Mississippi River to the west and the Mississippi State line to the south, this growth occurred mainly to the east away from the river bluffs and to a lesser degree to the north. Logically, the predominant drainage patterns of the area generally flowed from the east to the west toward the Mississippi River. As development moved east, more and more impervious surfaces were added to the drainage areas of the streams and, consequently, runoff was continually added to the existing downstream drainage systems to the west which had been designed for drainage areas with much less runoff. For years, the City of Memphis and Shelby County primarily dealt with drainage problems with a site-by-site approach using different drainage design criteria. In 2006 the City of Memphis and Shelby County jointly adopted a new and updated drainage design manual along with other significant policy changes including the institution of stormwater management fees. As monies accrued from the stormwater fees, the stormwater program was reviewed. In 2012 seven major study districts, approximating the seven city council districts, were delineated (See Figure 1-1) allowing multiple studies to be done concurrently to more equitably distribute the stormwater improvements across the extents of the City. Each of the major study districts was further subdivided into individual drainage basins to allow for efficient modelling and study of the existing infrastructure. The study presented in this report evaluated the Black Bayou Drainage Basin. Survey data was collected beginning in the fall of 2015 through the summer of 2016 within the Black Bayou Drainage Basin. After completion of the field survey numerous developments within the basin were built that potentially altered the stormwater infrastructure. These developments, specifically near the University of Memphis, are not included in this study. The City's intent is to study and develop drainage master plans for each of the basins identified. Under this program, Barge Design Solutions, Inc., formerly Barge, Waggoner, Sumner and Cannon, Inc. was selected to study the Black Bayou Drainage Basin which is described in more detail below.

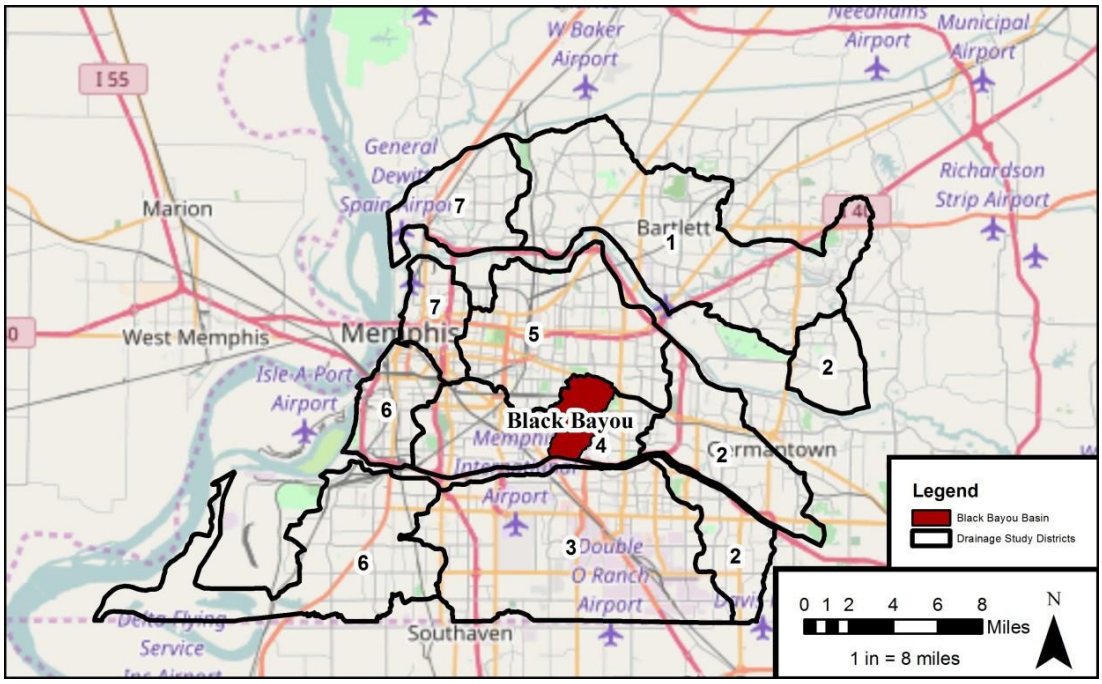


Figure 1-1 City of Memphis Study Districts

1.2 Memphis's Stormwater Drainage History

Drainage system design criteria in Memphis have evolved over the almost 200 years that the City has been incorporated. Intuitive and trial-and-error sizing techniques were replaced by simple design flow calculations based purely on the size of the contributing drainage area such as using one, and later two, cubic feet per second per acre of drainage area. As upstream areas continued to urbanize and impervious areas increased producing more runoff per unit of drainage area, downstream systems which had once performed adequately became insufficient. In many cases this inadequacy was addressed by straightening the natural channels and installing vertical wall concrete channel linings to maximize channel capacity without drastically increasing the "footprint" of the drainageway. There are over 12,000 linear feet of these channels within the Black Bayou basin.

In the 1980's, the advent of the desktop computer and design software such as the United States Environmental Protection Agency (USEPA)'s Stormwater Management Model (SWMM) platform, the United States Army Corps of Engineers (USACE)'s Hydrologic Engineering Center (HEC)-1 and HEC-2 packages and others allowed the designer to more easily and more accurately evaluate the adequacy of existing drainage systems using inputs including basin soil types, topography, and land cover, in addition to drainage area. In 1987, recognizing that some existing structures had inadequate capacities, the City released an updated Drainage Design Manual instituting stormwater detention requirements at new developments for the first time. At this time, detention requirements were limited to maintaining post-project peak flows to no more than pre-project values for the designated design storms.

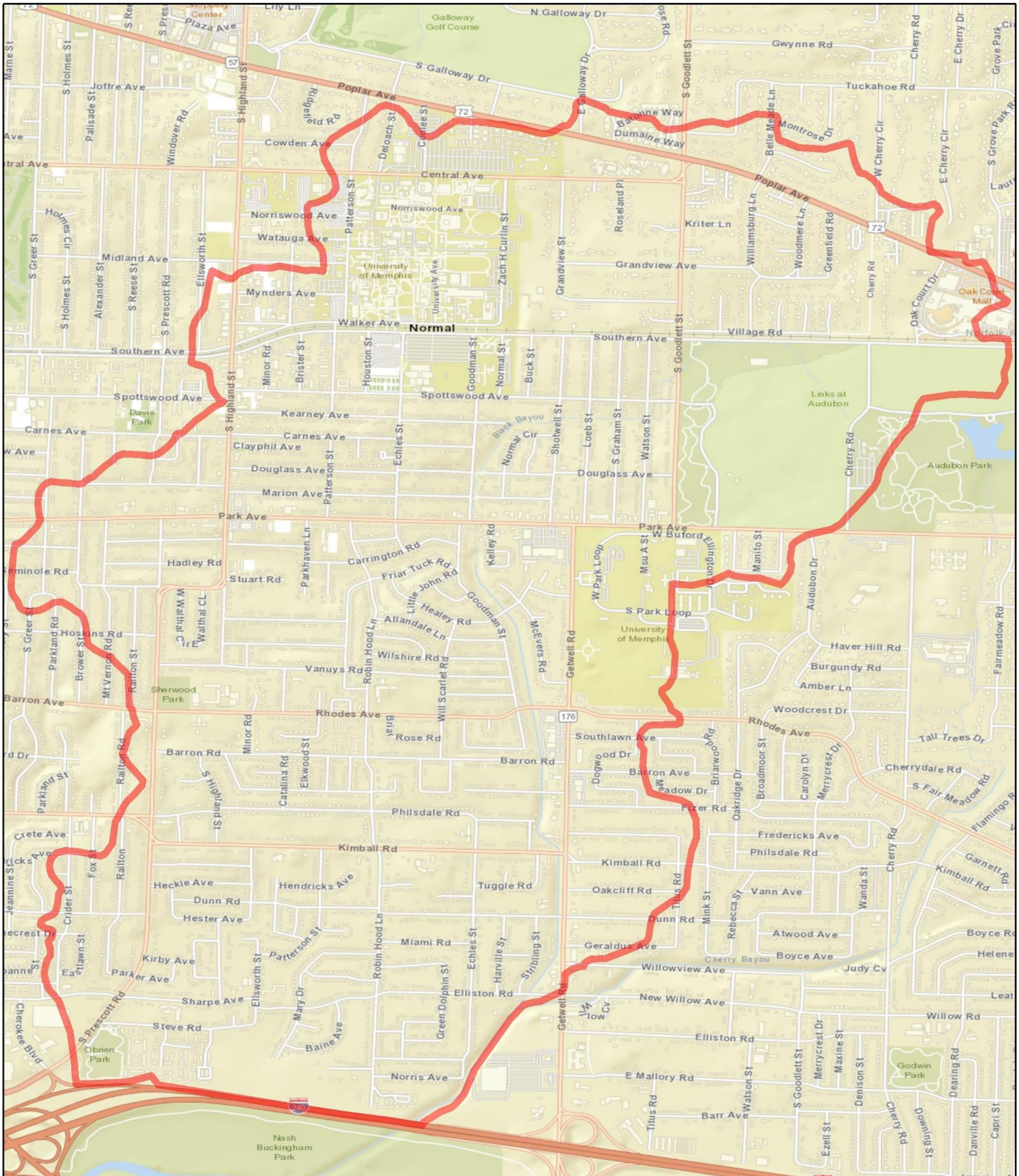
In June 2006 the City of Memphis and Shelby County Public Works Department jointly adopted an updated and renamed Stormwater Management Manual. The new manual continued the post-project peak flow limitation requirements of the previous manual and added the requirement to limit the post-project outflow volume during a designated seven-hour window of the 24-hour design storm to no more than the pre-project outflow volume during that same seven-hour window. This Manual is currently in place and governs drainage system designs in Memphis and Shelby County.

1.3 Overview of Project Area

The Black Bayou Drainage Basin, shown in Figure 1-2, is located in the southeastern quadrant of the I-240 loop and is a relatively older portion of the City with the area having been developed in the early to mid-1900's. The Black Bayou outfall is into Nonconnah Creek approximately 0.7 miles upstream of Lamar Avenue. The Basin lies north of I-240 and is generally bounded on the west by Prescott and Highland Streets, on the east by Getwell Road and Audubon Park, and on the north by Poplar Avenue. The Basin encompasses 2,961 acres (4.63 sq. mi.) and is primarily small lot residential in nature with some commercial development adjacent to the major thoroughfares. In addition, the north and south campuses of the University of Memphis, and Audubon Park and Golf Course are located within the basin.

Beginning at Nonconnah Creek and going upstream, the first 4,000 feet of the Bayou is a natural channel which changes to a vertical-walled concrete lined channel for the next 11,500 feet, or up to Southern Avenue. There are significant tributaries entering the main Bayou channel from the east and from the west downstream of Park Avenue and also between Southern Avenue and Park Avenue. In addition, the outfall from the Cherry Bayou Basin (2,261 ac., 3.53 sq. mi.), located to the east of Black Bayou, enters Black Bayou just downstream of New Willow Road, but it is the subject of a separate study and is not discussed herein.

There are also three drainage areas (595 acres, 118 acres and 34 acres) located at the southwest corner of the Basin which flow under I-240 and directly into Nonconnah Creek without entering the Black Bayou channel. These areas are a part of the Black Bayou Basin and have been included in the modeling efforts for this project.



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1 inch = 2,000 feet
Tennessee State Plane (feet) 4100fips
North American Datum 1983

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Figure 1-2
Black Bayou Drainage Basin
Memphis, Tennessee

Legend

Black Bayou Drainage Basin

1.4 Public Involvement

It was the intent of the City of Memphis from the outset that stakeholders, residents, and business owners of the Black Bayou Basin be aware of the ongoing study and have the opportunity to provide input concerning drainage problems they have encountered. The opportunity for public involvement was provided in the form of public meetings as well as a website accessible to the general public for receiving or providing information about drainage in the basin.

The four public meetings will be held in two stages, two during the data collection phase to hear residents' concerns and two after approval of the study by the City to present the findings to the residents.

- The two pre-study meetings were held on the following dates and locations:
- Thursday, October 22, 2015 – Freedom's Chapel Christian Church
- Thursday, October 29, 2015 – Freedom's Chapel Christian Church

Once the improvements proposed for the Black Bayou Basin have been identified and approved by the City, two post-study presentation meetings will be held to present the findings and make the basin stakeholders aware of the proposed improvements to be pursued.

1.5 Model Software Description

To comprehensively model the Black Bayou Drainage Basin, Innovyze's InfoSWMM (Version 14.0, Service Pack 1, Update #3) simulation software was used. This software is integrated into the geographic information system (GIS) software ArcGIS and allows users to model the entire hydrologic cycle with a variety of land use and soil specific stormwater runoff equations. Consistent with City of Memphis stormwater modeling standards, the EPA-SWMM/Non-linear reservoir runoff model and the Green Ampt infiltration model were the specific hydrologic options selected. Existing spatial data and geodatabases can be pulled into InfoSWMM via ArcGIS to easily begin the modeling process. The software accurately depicts the hydrologic conditions of a drainage system by accounting for time-varying rainfall, infiltration, percolation, evaporation, groundwater flow, and any user defined flows. InfoSWMM also models the hydraulic features of a drainage system by accounting for runoff and external inflows through a network of pipes, channels, and diversion structures. After all input parameters are set and the software has completed its simulation, the results are output in a user-friendly product that allows for customization and GIS-based map production.

2 REVIEW OF PREVIOUS STUDIES AND AVAILABLE DATA

The Black Bayou Drainage Basin is similar to many of the basins inside the Memphis corporate limits, that is, a humid subtropical climate, primarily small lot residential development with some commercial/institutional areas on flat to gently rolling silty/loamy soils. The basin is essentially fully-developed with few disturbed/bare earth areas present at any given time.

Vegetative cover is well-established in the form of grass, shrubs and trees on the non-paved portions of the basin. Drainage infrastructure is extensive with curb and yard inlets intercepting stormwater runoff and delivering it via collector pipes to the major open channel drainageways of the basin. More specific basin characteristics are listed below.

2.1 Previous Studies

Numerous studies were previously conducted within the Black Bayou Drainage Basin to address specific flooding and stormwater issues. The studies were shared by the City at the onset of this project to provide background. They were helpful in providing details that would otherwise be unknown such as the underground detention configuration under athletic fields within the basin. A majority of the studies relate to the northern portion of the basin upstream of Park Avenue. For the purposes of this comprehensive analysis of the entire Black Bayou Drainage Basin, the studies were reviewed for applicable data and are summarized below:

2nd Pres Detention Goodlett and Central Ave - ETI Corp.pdf (ETI, 2005)

- Redesign of a detention pond in the upstream portion of Black Bayou Basin (near South Goodlett Street and Central Avenue)
- Invert elevation and existing and modified hydrographs for design storms
- Peak flow table
- No outlet structure details

Black Bayou Culvert Study BB5-6.pdf (ETI, 2000)

- Analysis of existing reinforced concrete box culverts (RCBC) to mitigate flooding at upstream of 2nd Presbyterian Church (preface to 2005 detention study above)
- Existing box culverts range from 6 ft by 3 ft to 10 ft by 3.25 ft, 600+ LF
- Various scenarios from upstream detention to parallel system
- Source of proposed culvert profile, capacity analysis, and 10-yr floodplain

Black Bayou Drainage Study Box Culvert Options Cost Analysis.pdf (ETI, 2002)

- Cost comparison of various existing RCBC (2000 ETI study above) improvement options
- $1.6 - $2.5 Million

Audubon Park Detention Design Report.pdf (ETI, 2003)

- Pondpack output report
- No narrative outside of title page

Black Bayou Drainage Channel Study 5-C and 5-D.pdf (ETI, 2002)

- Hydrology and flood study of the Black Bayou channels upstream of Park Avenue
- Summary of hydrology, profile, capacity issues, and flood elevations for channels upstream of Park Avenue
- Mentions surveyed channels, but survey not included
- Includes resident flood surveys and high-water mark survey

Black Bayou Drainage Channel Study.pdf (ETI, 2002)

- Same as report for 5-C and 5-D but includes all profiles, RAS output, and surveyed channels

Black Bayou Drainage Study - Stormwater Model.pdf (AFRAM, 2007)

- Detailed (500 page) report and EPA-SWMM Model report for the area upstream of Southern Avenue
- Incorporates ETI study and other detention studies information into model
- Comprehensive data and analysis for this portion of the basin
- Includes profiles, figures, results, applicable reference

Black Bayou Regional Detention Study.pdf (ETI, 2001/2005)

- Duplicate information as "2nd Pres Detention Goodlett and Central Ave - ETI Corp.pdf" plus additional pond detail and results

Solutions Recommendations for Existing Flooding Problems Summary.pdf (ETI, 2002)

- Summary of flooding solution alternatives for the area between Southern Avenue (north) and Park Avenue (south)
- Alternatives include detention, channel lowering, culvert/bridge replacement, junction modification, and inlet repair
- Includes cost estimate and recommendation for a phased order of projects

UofM Main Campus Flood Study.pdf (Allen & Hoshall, 2002)

- Mitigation of localized flooding on campus
- Source of existing stormwater conditions and infrastructure on campus

2.2 Study Area Characteristics

Existing data used for this Black Bayou Drainage Basin study included background GIS information as well as City of Memphis protocols to maintain consistency with other basin analyses. Available GIS information used for this analysis included:

- Precipitation Data

- 5-ft Contour Lines
- NRCS Web Soil Survey
- NLCD 2011 Land Use Data
- Inventory of stormwater structures

Regarding City of Memphis-specific guidelines and standards, two primary sources were referenced for this study: Hydraulics & Hydrology Modeling Protocols and City of Memphis / Shelby County Stormwater Management Manual. The drainage manual was primarily referenced to confirm the design storm standard and rainfall depths defined for the City standards. The draft *Memphis Drainage Mapping and Modeling Analysis Standards Manual (06-24-2015)* provided standard modeling practices to maintain consistency with other SWMM drainage basin analyses. Naming protocols and calculation engines within InfoSWMM software are variables that benefit from consistency within a municipality, and the document was a tool referenced for this purpose.

2.2.1 Precipitation

Average precipitation amounts for the City of Memphis are shown in Table 2-1. Annual rainfall in Memphis is about 48 inches and is generally highest in late fall and early spring. December sees the most rainfall, on average 5.13 inches, and September sees the least rainfall, on average 2.20 inches. Memphis receives an average of about 2.5 inches of snowfall annually between the months of December and March. Point precipitation frequency estimates data for the watershed was retrieved from Atlas 14 and is shown in Figure 2-1. The point frequency estimates for a 24-hour period and confidence intervals for each storm are shown in Figure 2-2.

Table 2-1 Average Precipitation Amounts in Black Bayou Drainage Basin

Month	Avg. Precipitation (in.) 1981-2010
January	3.90
February	4.09
March	4.34
April	4.89
May	4.81
June	3.55
July	4.26
August	2.75
September	2.20
October	3.73
November	4.71
December	5.13
Annual	48.36

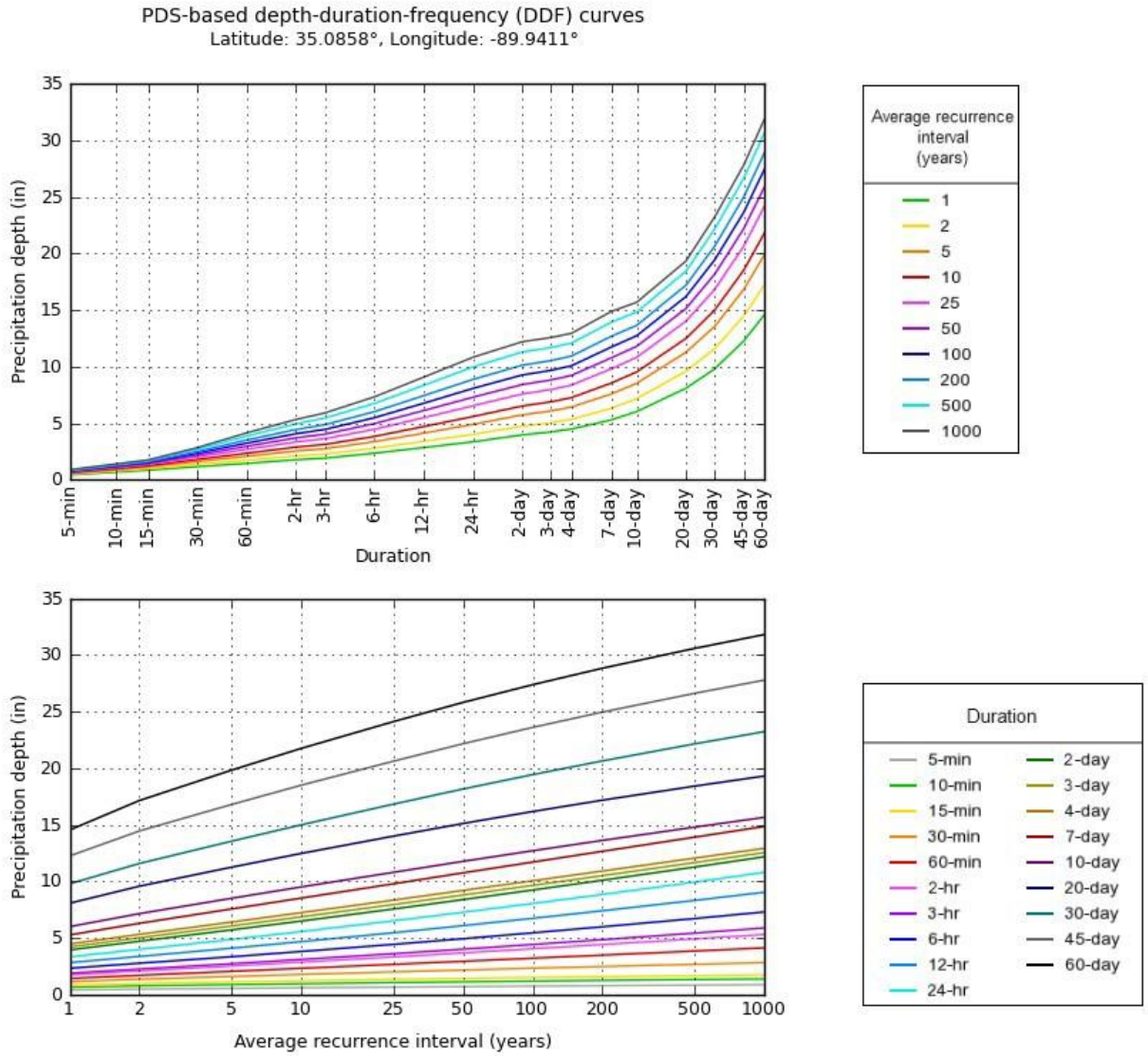


Figure 2-1 Durational Precipitation Frequency of Black Bayou Drainage Basin

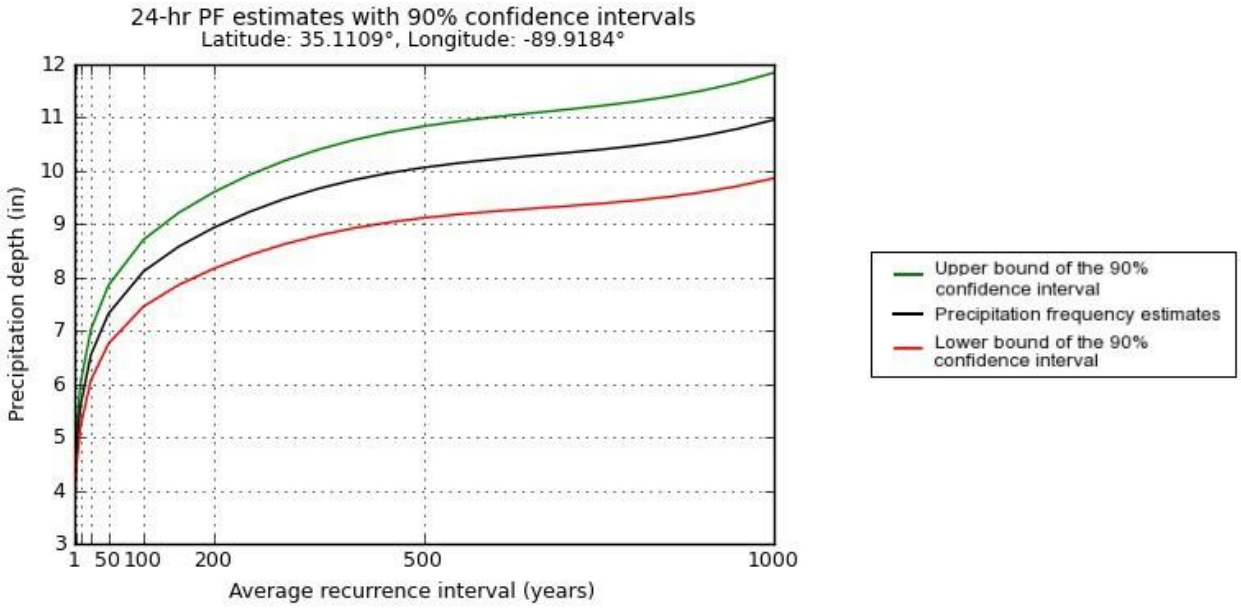
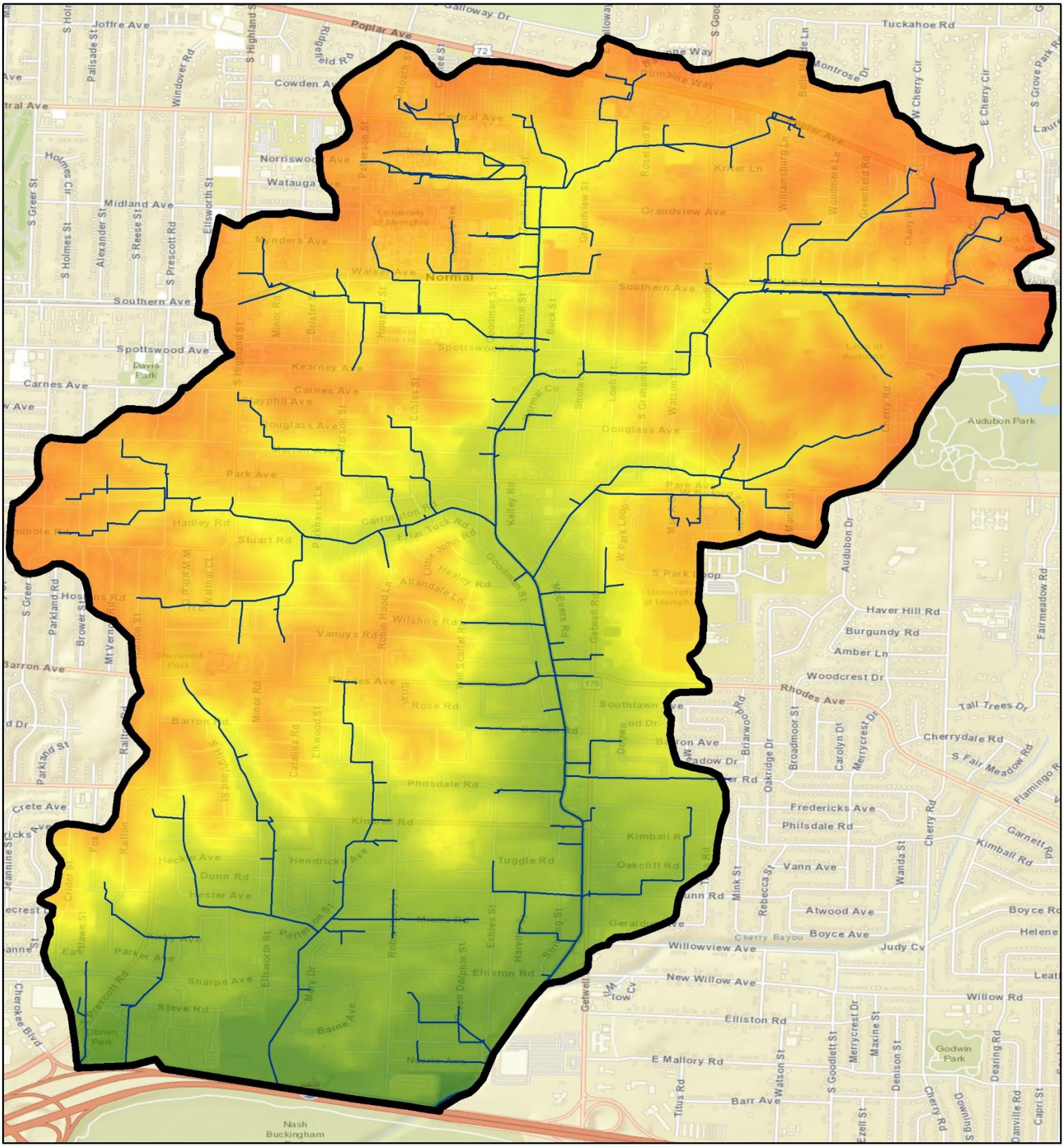


Figure 2-2 24-Hour Precipitation Frequency of Black Bayou Drainage Basin

2.2.2 Topography

As shown in Figure 2-3 the elevation in the Black Bayou Drainage Basin ranges from a high elevation of about 325 feet to a low elevation of about 230 feet. Elevation data referenced to North American Vertical Datum of 1988 (NAVD 88). The highest elevations in the basin area occur along the northern, eastern, and western basin boundary. Flow generally travels south through the hydrologic feature called Black Bayou (not to be confused with the name of the project area) to Nonconnah Creek, the lowest elevation in the basin. Slopes in the basin range from the steepest of 3% to the flattest of 1%.



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North American Datum 1983
North American Vertical Datum of 1988 (NAVD 88)

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Figure 2-3
Topography of Black Bayou Drainage Basin

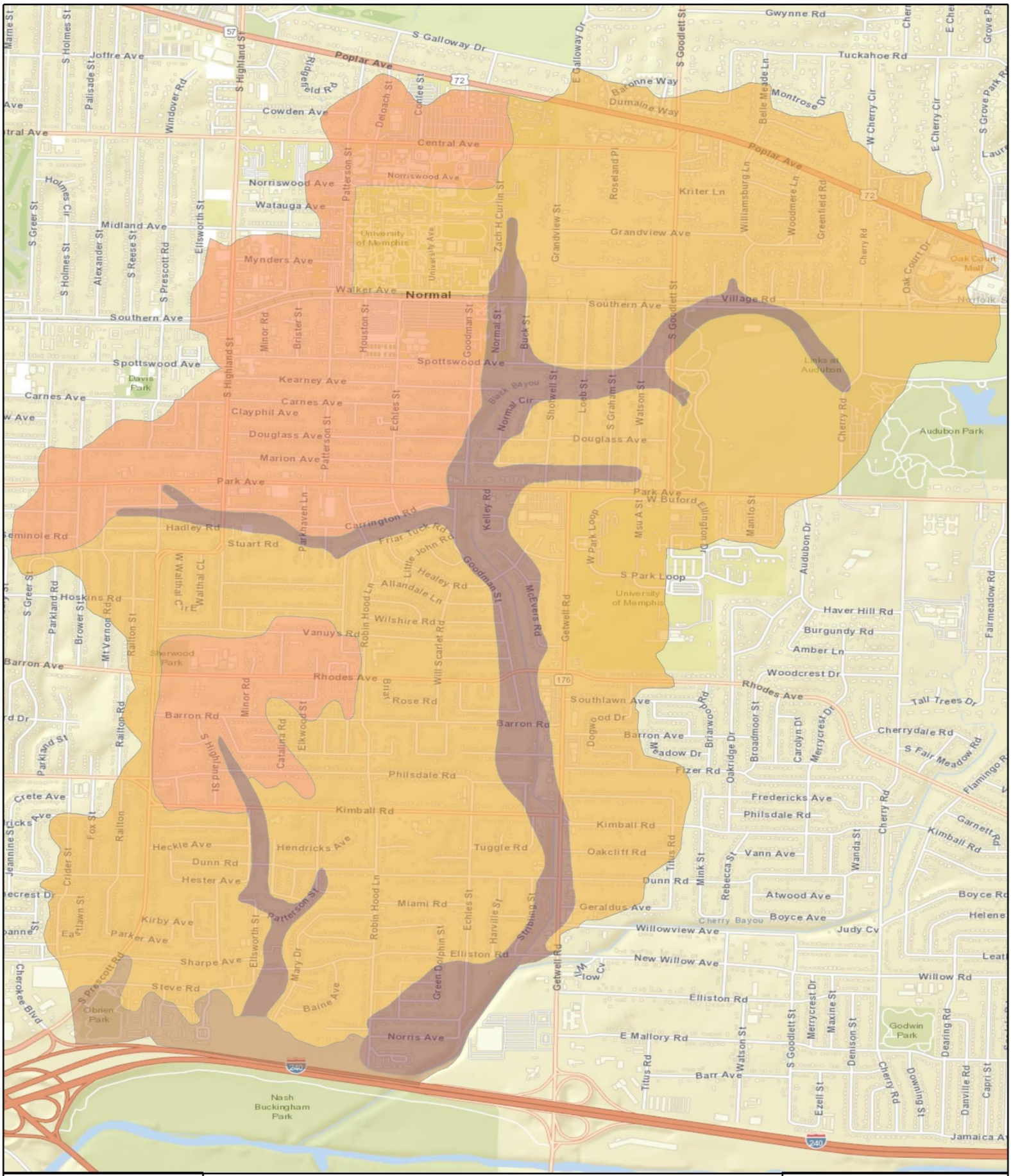
Memphis, Tennessee

2.2.3 Soils

Soil classification data for the project area was retrieved from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey. This survey shows that about 75% of the soil in the Black Bayou Drainage Basin is udorthent land, implying that this soil has been backfilled after the removal of the native surface. The remaining area is composed of various types of silt loam with moderate infiltration rates when thoroughly wet. Figure 2-4 shows the map result of the soil survey. Table 2-2 gives a summary of the soil classifications from the survey. Note that the udorthent land was not given a soil rating by the NRCS.

Table 2-2 Soil Classification in Black Bayou Drainage Basin

Map Unit symbol	Map Unit Name	Rating	Acres in AOI	Percent of AOI
Fm	Falaya silt loam	B/D	66.3	2.2%
Fs	Filled land, silty (udorthent, silty)	-	330.8	11.2%
Gr	Graded land, silty materials (udorthent, silty)	-	1,900.3	64.2%
MeB	Memphis silt loam, 2 to 5 percent slopes	B	663.7	22.4%
Totals for Area of Interest			**2,961.1**	**100.0%**



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North American Datum 1983

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Figure 2-4
Soils Classification in Black Bayou Drainage Basin
Memphis, Tennessee

USGS Soil Classifications

- Falaya Silt Loam
- Filled Land, silty (udorthent, silty)
- Graded land, silty materials (udorthent, silty)
- Memphis Silt Loam, 2 to 5 percent slopes

2.2.4 Land Use

The land usage data for the project area were retrieved from the National Land Cover Database (NLCD) 2011 by the Multi-Resolution Land Characteristics Consortium. These data show that most of the land in the Black Bayou Drainage Basin is classified as "Developed Low Intensity" or "Developed Open Space". These classifications are explained by the presence of many residential parcels. The next largest classifications of land usage are "Developed High Density" and "Developed Medium Density". These classifications occur near intersections of larger roads where there are retail businesses, Oak Court Mall, Memphis Botanic Garden, several apartment complexes, and two public schools, and also the area around the two University of Memphis campuses that are within the drainage basin boundaries. These four land classifications account for 97% of the land usage in the project area. The remaining land classifications are forests, pastures, and wetlands. Figure 2-5 shows the map result of the land use. Table 2-3 shows a breakdown of the land use classification.

Table 2-3 Land Use in Black Bayou Drainage Basin

Land Use Classification	Area (acre)	% of Total Area
Developed Open Space	1410.9	47.65%
Developed Low Intensity	919.0	31.04%
Developed Medium Intensity	398.9	13.47%
Developed High Intensity	138.9	4.69%
Deciduous Forest	54.3	1.83%
Pasture	18.3	0.62%
Woody Wetlands	14.8	0.50%
Mixed Forest	5.7	0.19%
Evergreen Forest	0.2	< 0.01%
Cultivated Crops	0.2	< 0.01%
Total	**2961.1**	**100.0%**

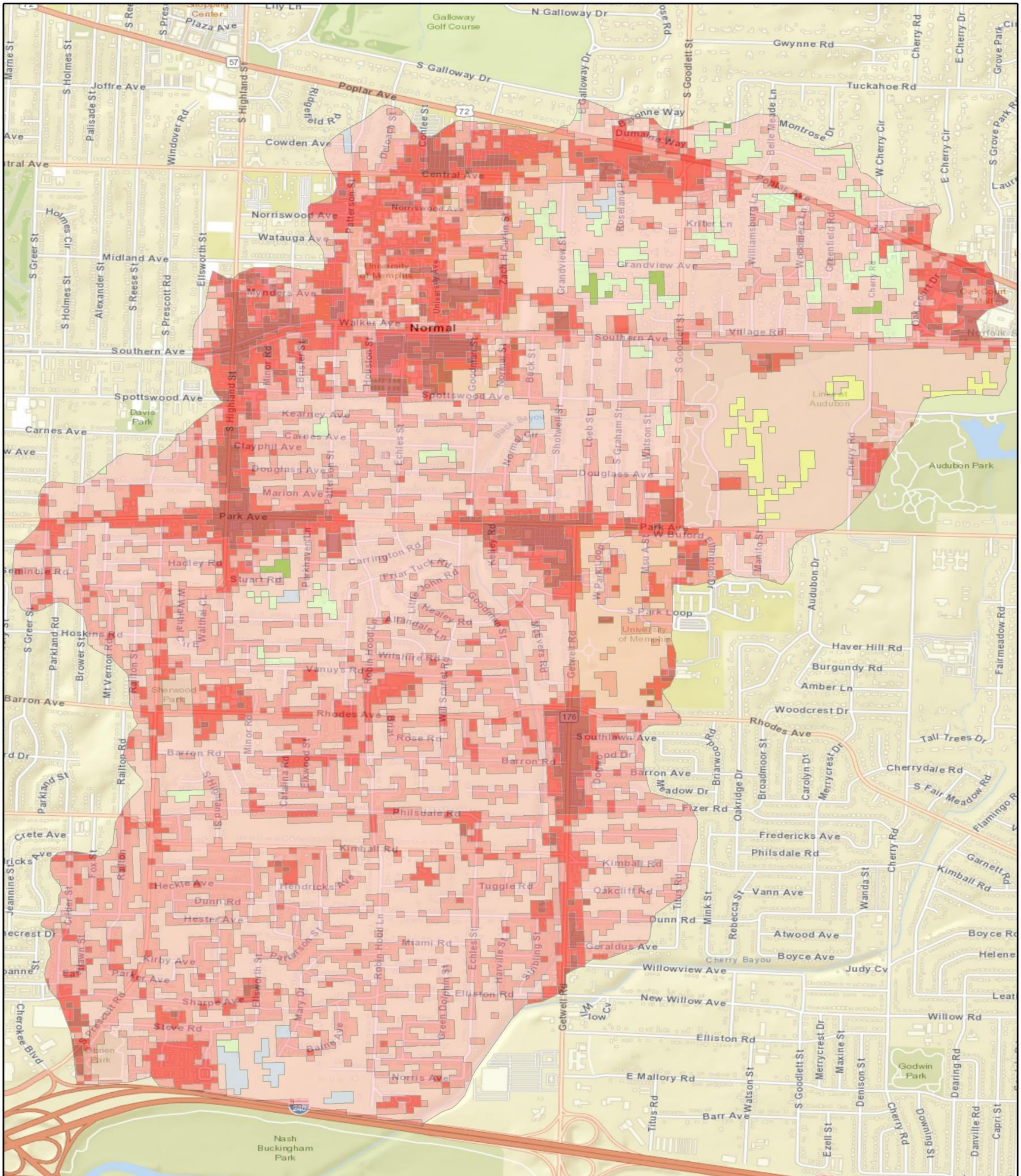

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Figure 2-5
Land Use in Black Bayou Drainage Basin

Memphis, Tennessee

National Land Cover Database (NLCD 2011)

GRIDCODE

- Developed Open Space
- Developed Low Intensity
- Developed Medium Intensity
- Developed High Intensity
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Pasture
- Cultivated Crops
- Woody Wetlands

2.3 System Inventory

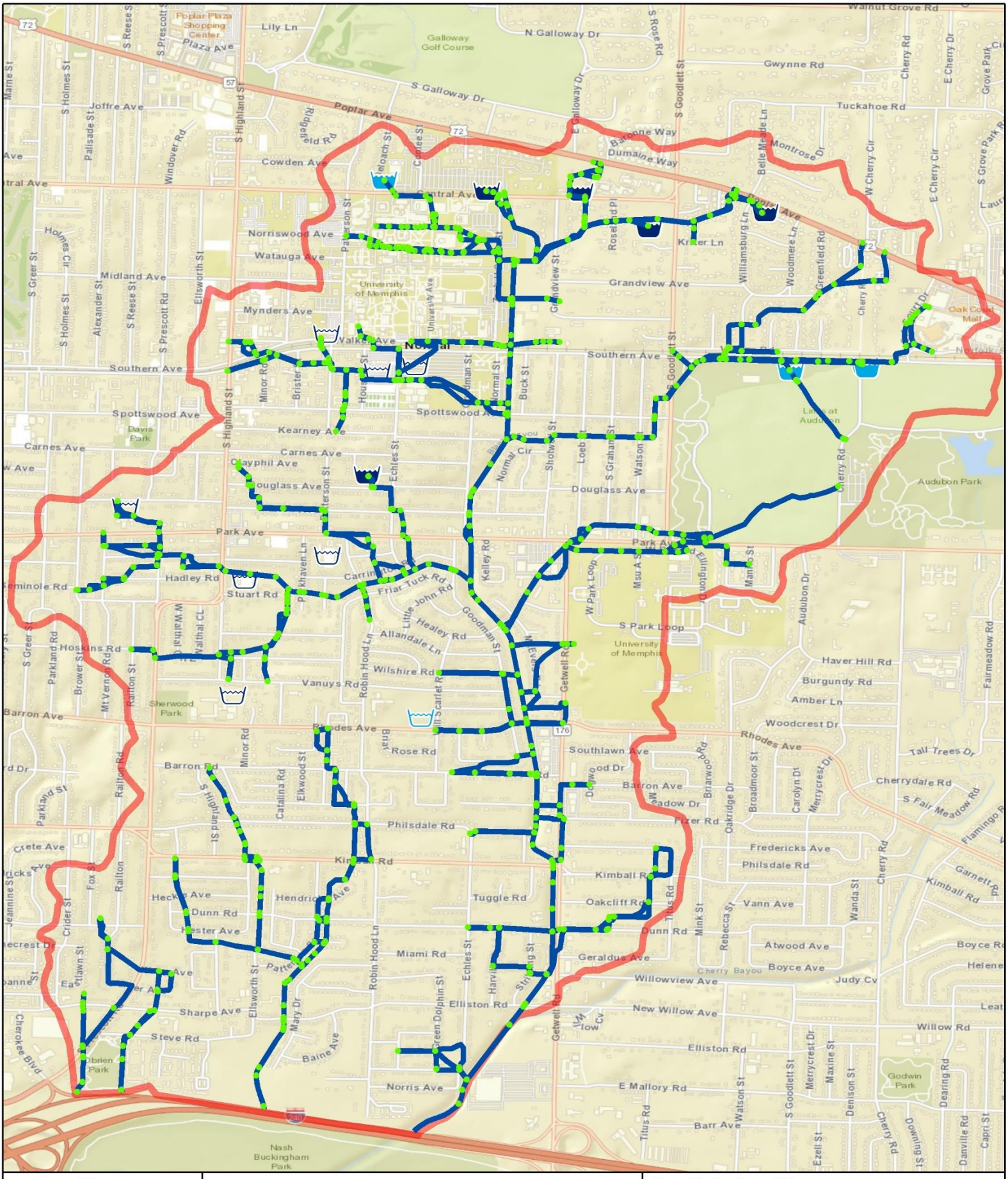
2.3.1 GIS

The existing City of Memphis stormwater inventory geodatabase was used as the starting point to establish general system connectivity and served as the location guide used by survey crews for stormwater infrastructure. This base GIS stormwater inventory was appended when new stormwater infrastructure was encountered in the field or record drawings provided updates to system information, such as underground detention.

The Black Bayou Drainage Basin contains more than 1,000 pipe and channel segments for a total of more than 40 miles of conveyance. Segments less than 130 feet are most common, and the median length is approximately 140 feet. As is typical for Memphis, the Black Bayou Drainage Basin contains extensive lengths of concrete-lined channels as the primary conveyance structure throughout the basin. These concrete-lined channels are the "backbone" of the system with a mixture of pipes and open channels collecting drainage from the neighborhoods, campuses, parks, and commercial areas. Closed pipes within the basin range in diameter from 6 in to 72 in in diameter. The concrete-lined channels most commonly have vertical sides and a triangular bottom creating a low-flow channel with a width ranging from less than 2 feet to 54 feet.

The inventory has approximately 860 drainage structures connecting the conveyance systems. Types of structures include drop inlets, catch basins, outfalls, and similar. The Black Bayou stormwater system is a relatively shallow system with prevalent surface and open-channel drainage. An overview of the drainage structures evaluated in the Black Bayou model is presented in Figure 2-6.

As described in Section 2.3.2, a field survey was conducted to update the stormwater inventory and expand the GIS geodatabase to support the modeling effort.



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Tennessee State Plane (feet) 4100fips
North American Datum 1983

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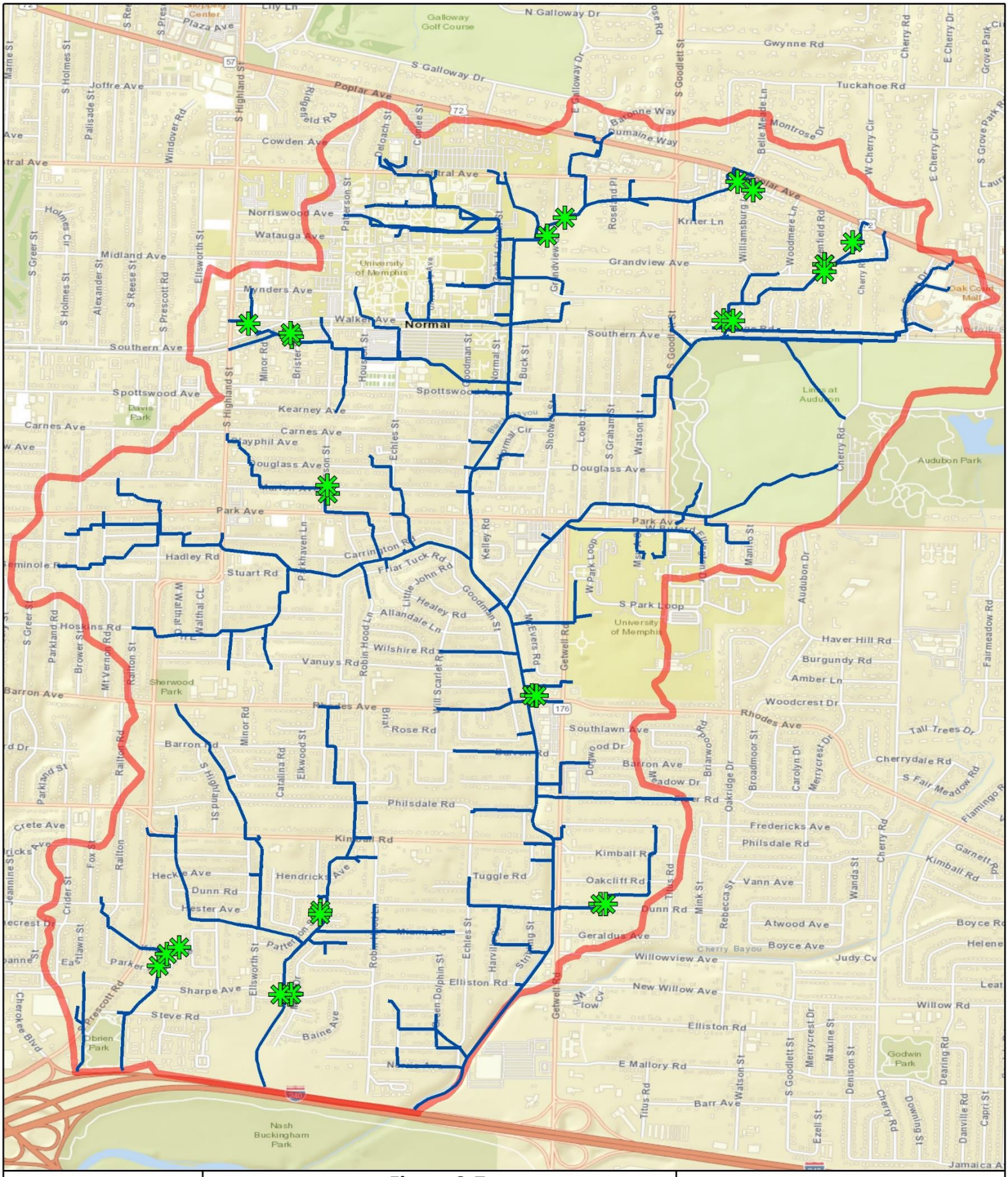
Figure 2-6
Model Overview of
Black Bayou Drainage Basin

No. of Subbasins = 144
Average Subbasin Size = 20.6 Acres

- Junctions
- Conduits
- Underground
- Surface_Pond
- Prop. Underground
- Prop. Surface Pond

2.3.2 Survey

A field survey was conducted to update the stormwater inventory. The City's inventory was used as guidance for general location and connectivity of the system, but survey-collected details were considered more accurate and replaced any City inventory information in the geodatabase inventory deliverable of this study. Photographs, also included in the study deliverables, were collected along the major concrete-lined channels of the drainage network at outfalls from the contributing systems and road crossings. In general, the survey-collected data included horizontal and vertical position data (x, y, and z) and a descriptive size and structure type for the major (greater than 24-inch diameter) stormwater system components. Data referenced to Tennessee State Plane (feet) and North American Vertical Datum of 1988 (NAVD 88). The geometry details included enough information to represent the structure type and conveyance flow area (e.g., pipe diameter, or concrete-lined channel dimensions), which applied to the stormwater modeling components of the system. Approximately 600 drainage structures were surveyed, and the City's inventory was updated accordingly. In addition to photographs and position information, applicable field notes were collected for underground storage components. The details of the notes were incorporated into the stormwater model to represent the storage components of the stormwater network. Additionally, finished floor elevations of approximately 23 buildings throughout the modeled system were surveyed (Figure 2-7) to allow comparison to predicted flood elevations.



2,000
Feet
1 inch = 2,000 feet
Tennessee State Plane (feet) 4100fips
North American Datum 1983

N

BARGE DESIGN SOLUTIONS

Figure 2-7
Finished Floor Elevations Surveyed

Memphis, Tennessee

No. of Subbasins = 144
Average Subbasin Size = 20.6 Acres

Finished Floor Survey Locations

Conduits

3 SUMMARY OF EXISTING SYSTEM ANALYSIS AND RESULTS

The stormwater system analysis for the Black Bayou Drainage Basin was performed using a stormwater model that includes both hydrologic (rainfall runoff) calculations as well as hydraulic (system capacity/performance) calculations. The hydrologic calculations in the model provide the inflow values to the stormwater system, and the survey and City infrastructure information provide the stormwater system configuration and geometry to estimate how storms are conveyed by the existing drainage system. The results of the modeling effort included velocities within pipes, streams, and channels as well as flood elevations that can be compared to structures' finished floor elevations. This section provides a summary of the existing system analysis and results. Detailed information regarding the evaluation and performance of the existing storm drainage system can be found in Volume II.

3.1 Hydrologic and Hydraulic Approach

The hydrologic model of the Black Bayou drainage basin comprises 144 sub-basins averaging 20.6 acres in size. Each sub-basin was assigned an impervious percentage, width, slope, Manning's n value, depression storage depth and soil infiltration characteristics based on its land use and soil type. The hydrologic model applied precipitation events across each sub-basin and determined the resulting runoff. The runoff was then routed to the hydraulic model input locations. The existing drainage infrastructure system was evaluated for 24-hour duration storm events having NOAA rainfall amounts for theoretical return frequencies of 2, 5, 10, 25, 50 and 100 years.

The hydraulic portion of the model analyzed the performance of the conveyance and drainage network when the design storms were applied. The model included pipes, concrete channels and stream cross-sections with individual capacity attributes such as material, slope, and geometry. The model also incorporated the few known storage facilities within the Black Bayou Drainage Basin that detain stormwater. Surveyed conveyances included all pipes 24 inches in diameter or larger. Analyses extended upstream to model inflow locations but excluded any additional upstream stormwater infrastructure from the analyses. The exclusion of conveyances upstream of model inflow locations prevents unintentional attenuation and/or storage of runoff within the model; consequently, of the approximately 850 drainage structures associated with conveyances of 24 inches in diameter or larger approximately 610 are included within the system analysis.

The compiled model was calibrated against measured stream and rain gauge data and model parameters were modified until a good match was achieved.

3.2 Existing Conditions Analysis and Results

The modeling showed that for storms up through the designated design storm (10-year return frequency) the system as a whole performed relatively well. Naturally, there were localized exceptions where the existing drainage infrastructure was not adequate to prevent above-ground ponding for the design storm.

General areas where the existing drainage system appeared to be undersized are as follows:

- North-central portion of the University of Memphis main campus south of Central Avenue east of Patterson Street.
- South of Central Avenue west of Goodlett Street.
- Southwest corner of the University of Memphis main campus near the intersection of Southern Avenue and Patterson Street.
- Vicinity of the intersection of Park Avenue and South Prescott Road.
- Sherwood Forest area near the intersection of Park Avenue and Robin Hood Lane.
- South of and parallel with Spottswood Avenue between Black Bayou and South Goodlett Street.
- Several areas in the vicinity of Rhodes Avenue Goodman Street.
- West of and parallel with Robin Hood Lane between Rhodes Avenue and I-240.
- Vicinity of Echles Street and Dunn Avenue.
- Vicinity of Echles Street and Mallory Avenue.
- East of and parallel with South Prescott between Kirby Avenue and Steve Road.

These areas, along with open space areas in Audubon Park and undeveloped areas along the north side of I-240 where inundation would occur, are shown graphically in Figure 3-1.

The next step in the analysis process was to determine if the calculated inundation threatened structures or posed a safety hazard, or if it just represented “nuisance” flooding such as short-term yard flooding which didn’t affect structures or access to buildings. This required field data collection of finished floor elevations in the suspect areas. The finished floor elevations were then compared to calculated water surface elevations to determine if remedial actions were required.

This process identified a total of five areas that warranted evaluation of remedial measures to alleviate deficiencies in the existing drainage infrastructure system. The sites identified are shown graphically in Figure 3-2.

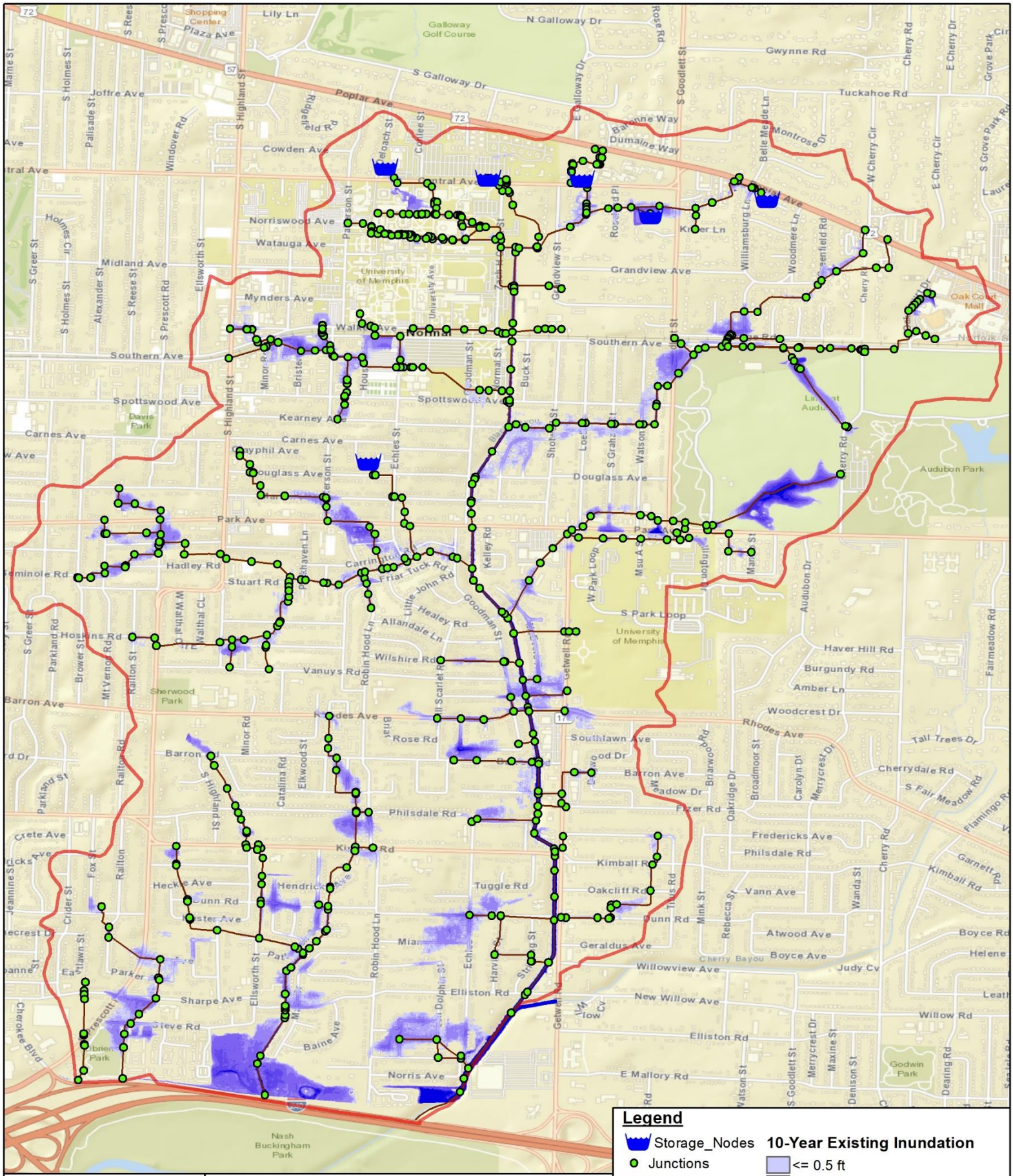


Figure 3-1
Existing 10-Year Inundation

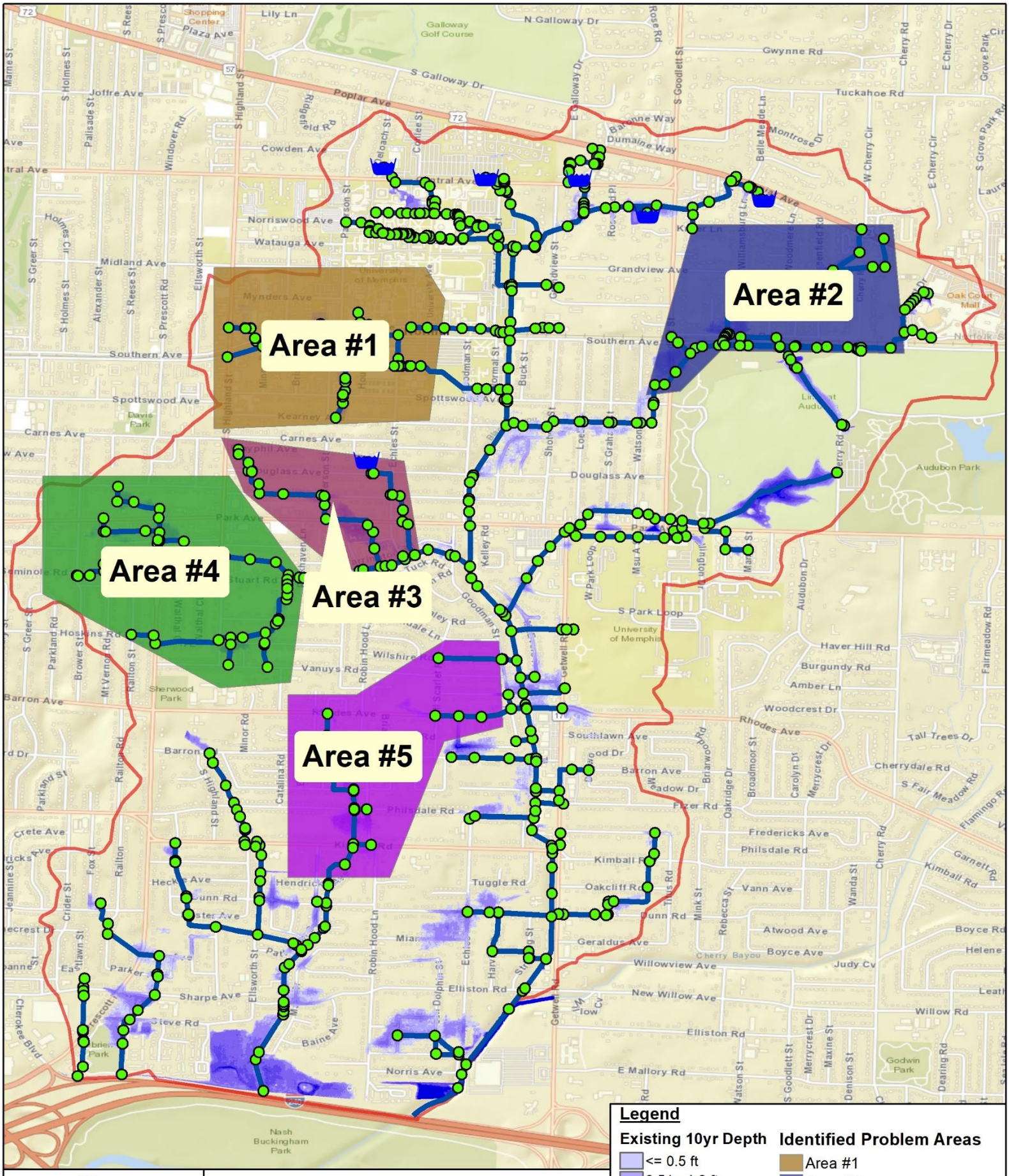


Figure 3-2

Proposed Improvement Areas

3.2.1 Flood Extent

To evaluate the flood extent both the area of inundation and the depth of flooding were considered. The InfoSWMM software includes a Risk Assessment Manager tool that generates inundation using the computed maximum hydraulic grade line (HGL) at each modeled node. The inundation produced by this tool was based on a simplistic approach of interpolating elevations between model nodes using a single line. A more detailed approach to generating inundation along the model segments was performed by creating cross-sections at model nodes. The cross-sections were assigned the computed maximum HGL. A water elevation surface was generated using the cross-sections. The computed water elevation surface was compared to the LiDAR derived ground surface data to determine a depth of inundation. Figures presented in Attachment 1 illustrate the flood inundation for each of the theoretical return frequencies evaluated during existing conditions.

3.2.2 System Assessment

The City of Memphis specifies that storm sewers shall be designed based on the 10-year 24-hour design storm. Within the Black Bayou Basin under existing conditions, the model showed that more than 300 stormwater structures are undersized. Additionally, the 10-year 24-hour design storm model produced flooding at more than 100 locations along roadways. When the 10-year 24-hour design storm elevations were compared to the survey of finished floor elevations for buildings at risk of inundation and Shelby county building footprints, 331 buildings were affected. Key facilities such as fire stations, police stations and schools were not predicted to be inundated during the simulations of the design storms however access to such facilities may be affected due to flooding on the roads.

4 FINAL RECOMMENDATIONS

4.1 Summary of Recommended Improvements

Based on the existing conditions analysis it was determined that a total of five areas required evaluation of remedial measures to alleviate deficiencies in the existing drainage infrastructure system. The proposed improvements are intended to address flooding issues only; however, water quality enhancements could be implemented into the final design. The following sections describe the improvement projects. Additional information about the improvements is presented in Volume II of this report.

4.1.1 Area 1 – Southern Ave at University of Memphis

Area 1 is located along Southern Avenue near the University of Memphis main campus. The area begins at the intersection of Southern Avenue and Highland Street and continues east to the Student Recreation Center. The area is located on the upper reaches of the Black Bayou watershed but receives the drainage from the highly impervious University of Memphis main campus. Survey data were collected beginning the fall of 2015 through the summer of 2016. After the completion of the field survey there were numerous developments built within the basin that potentially altered the stormwater infrastructure. These developments, specifically near the University of Memphis, are not included in this study. The existing conditions analysis indicated flooding of 41 of the 52 drainage structures within this location during the 10-year event due to being undersized as shown in Figure 4-1. Additionally, 27 buildings would be inundated.

The proposed improvement includes increasing the size of approximately 2,000 linear feet of drainage conduit and installation of approximately 500 linear feet of additional drainage conduits acting as parallel conveyance to adequately convey the stormwater and prevent flooding during the 10-year event within Area 1. Three underground detention facilities including more than 1,000 feet of conduit are also proposed in Area 1 to mitigate downstream flooding caused by the increase in conveyance of the improved drainage structures. The additional stormwater pipes and larger stormwater pipes in combination with the detention facilities will alleviate flooding in Area 1, and attenuate the peak flows downstream as graphically displayed in Figure 4-2. The improvements would prevent flooding in 24 buildings.

Estimated Cost for Improvements in Area 1: $13,820,000

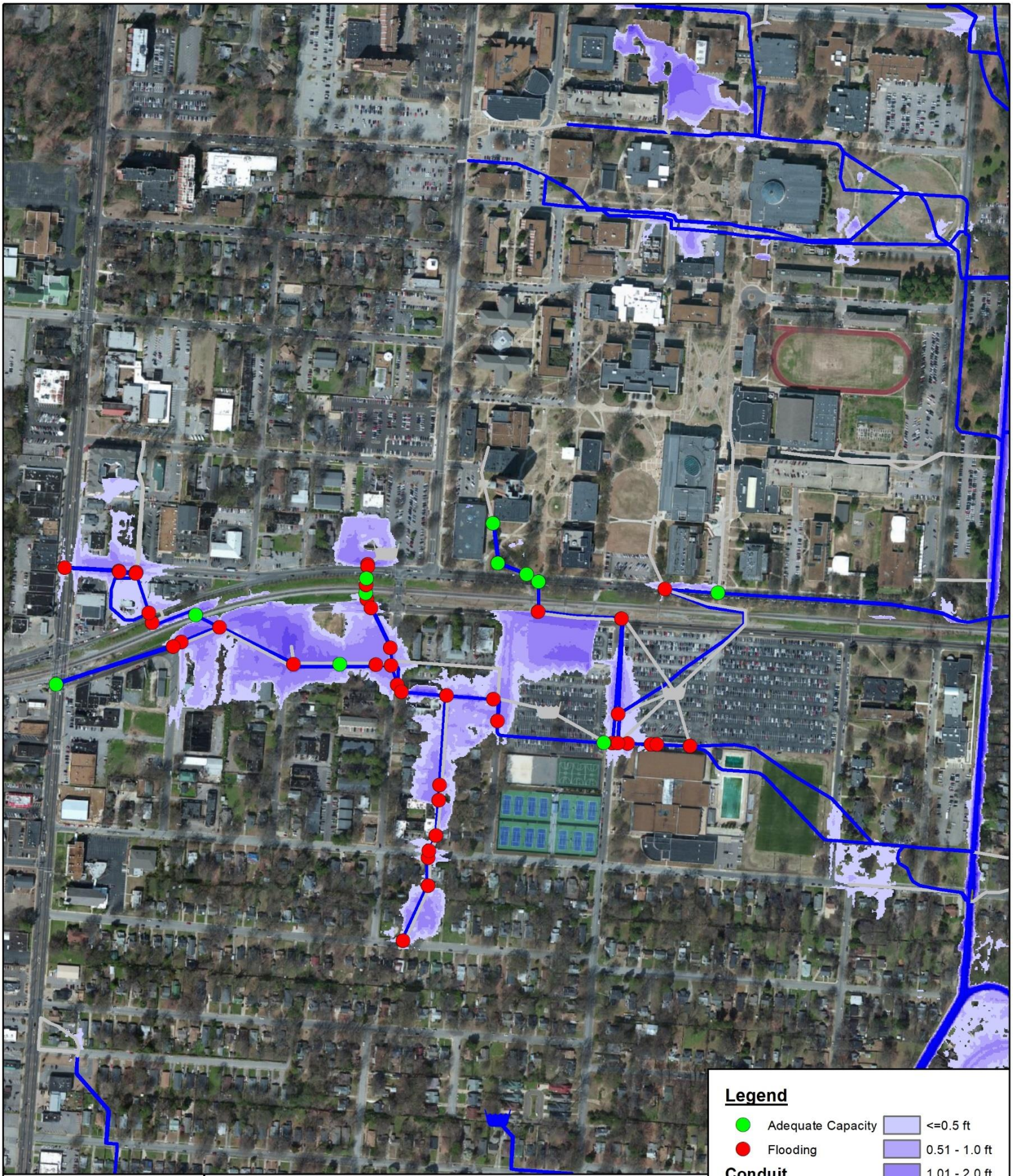


Figure 4-1
Area 1 Existing 10-Year Inundation

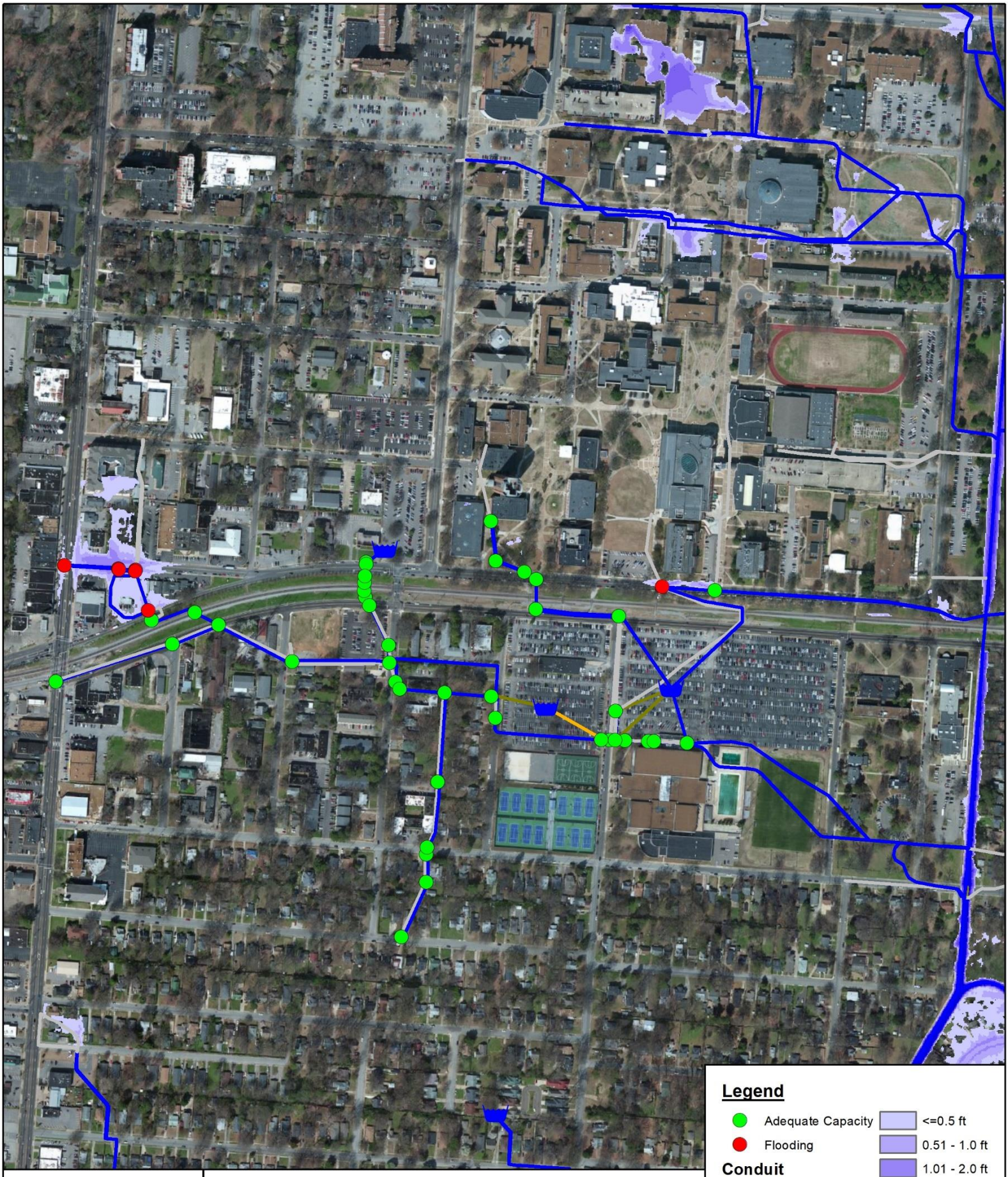


Figure 4-2
Area 1 Alternate 10-Year Inundation

4.1.2 Area 2 – Cherry Road between Poplar Ave and Southern Ave

Area 2 is located in the upper reaches of the Black Bayou watershed near the Audubon park and golf course. It receives drainage from the Oak Court Mall area as well as the residential area between S. Goodlett Street and the mall. The existing conditions analysis indicated flooding of 29 of the 63 drainage structures within this location during the 10-year event due to being undersized as well as flooding over Goodlett Street and Village Road near the intersection with Williamsburg Lane and over the railroad tracks that run between Southern Ave and Village Road as shown below in Figure 4-3. Additionally, 15 buildings would be inundated.

The proposed improvement includes increasing the capacity of an above ground storage area along the park and golf course to detain some of the flooding. It then includes rerouting approximately 500 linear feet of drainage conduit, adding approximately 1,500 linear feet of new conduit to divert drainage from upstream of the railroad tracks directly to the storage area, and adding 275 linear feet of new conduit near Audubon Park. The added storage area in combination with the stormwater diversions will alleviate flooding in Area 2 and attenuate the peak flows downstream as graphically displayed in Figure 4-4. The improvements would prevent flooding in 11 buildings.

Estimated Cost for Improvements in Area 2: $2,047,000

Figure 4-3
Area 2 Existing 10-Year Inundation

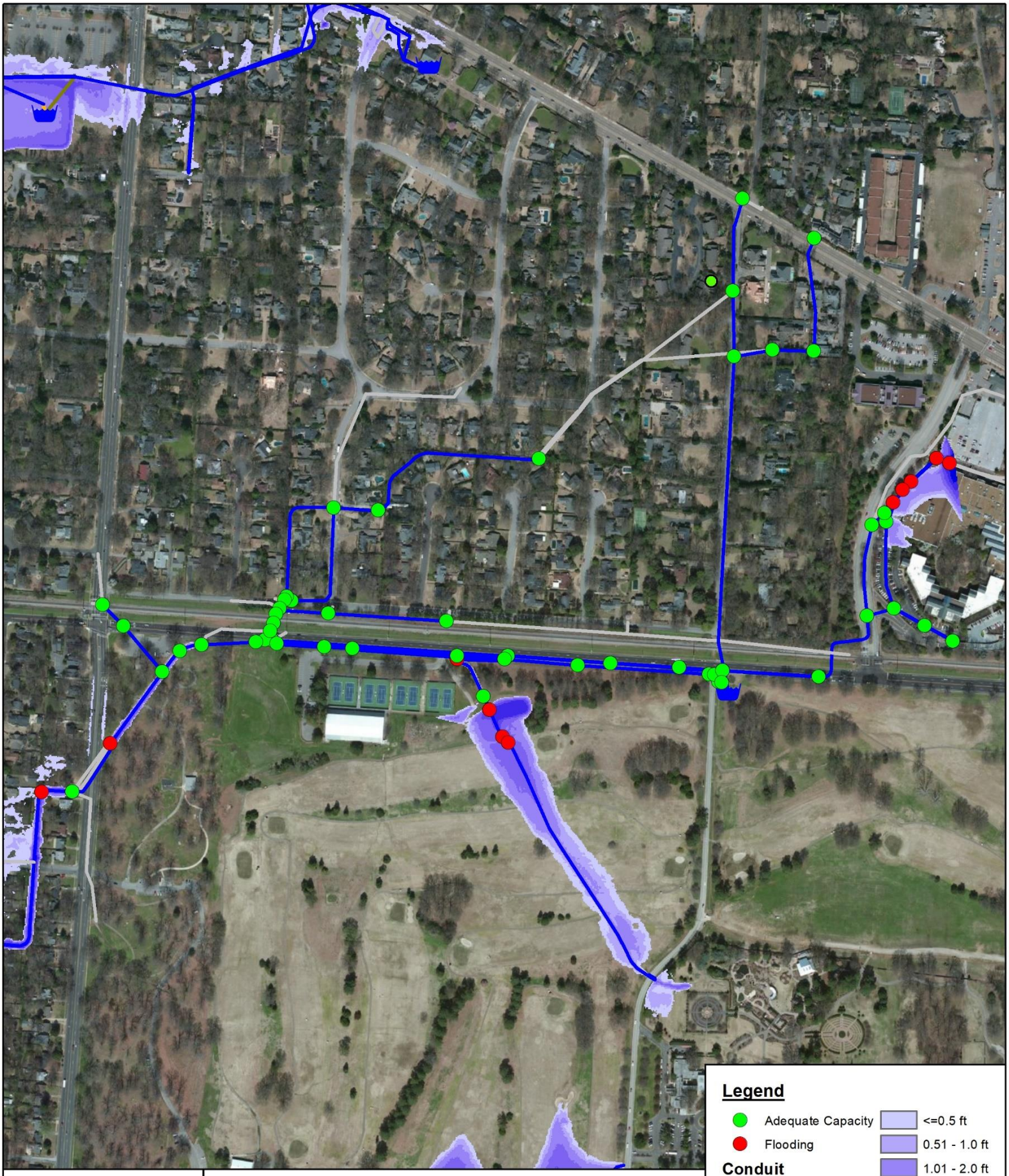


Figure 4-4
Area 2 Alternate 10-Year Inundation

4.1.3 Area 3 – Robin Hood Lane

Area 3 is located from the intersection of Marion Avenue and Patterson Street south to the main Black Bayou canal at Robin Hood Lane. The drainage area is mostly residential with some retail areas and churches. The existing conditions analysis indicated flooding of 25 of the 45 drainage structures within this location during the 10-year event due to being undersized as shown in Figure 4-5. Additionally, 35 buildings would be inundated.

The proposed improvement includes increasing the size of approximately 400 linear feet of conduit and adding approximately 670 linear feet of conduit down Robin Hood Lane. Additionally, a new underground detention facility is proposed. The increased capacity and storage will alleviate flooding in Area 3 and attenuate the peak flows downstream as shown below in Figure 4-6. The improvements would also prevent flooding in 32 buildings.

Estimated Cost for Improvements in Area 3: $3,634,000

4.1.4 Area 4 – Park Ave

Area 4 is located from Brower Street at Park Avenue East to South Highland Street. The drainage area is mostly residential with some retail areas. The existing conditions analysis indicated flooding of 43 of the 56 drainage structures within this location during the 10-year event due to being undersized as well as some flooding at the intersection of Carrington Road and South Prescott Road as shown in Figure 4-5. Additionally, 47 buildings would be inundated.

The proposed improvement includes increasing the size of approximately 1,800 linear feet of conduit and adding approximately 2,600 linear feet of conduit as well as three new underground detention areas. The increased storage capacity will alleviate flooding in Area 4 and attenuate the peak flows downstream as shown graphically in Figure 4-6. The improvements would also prevent flooding in 35 buildings.

Estimated Cost for Improvements in Area 4 $9,263,000

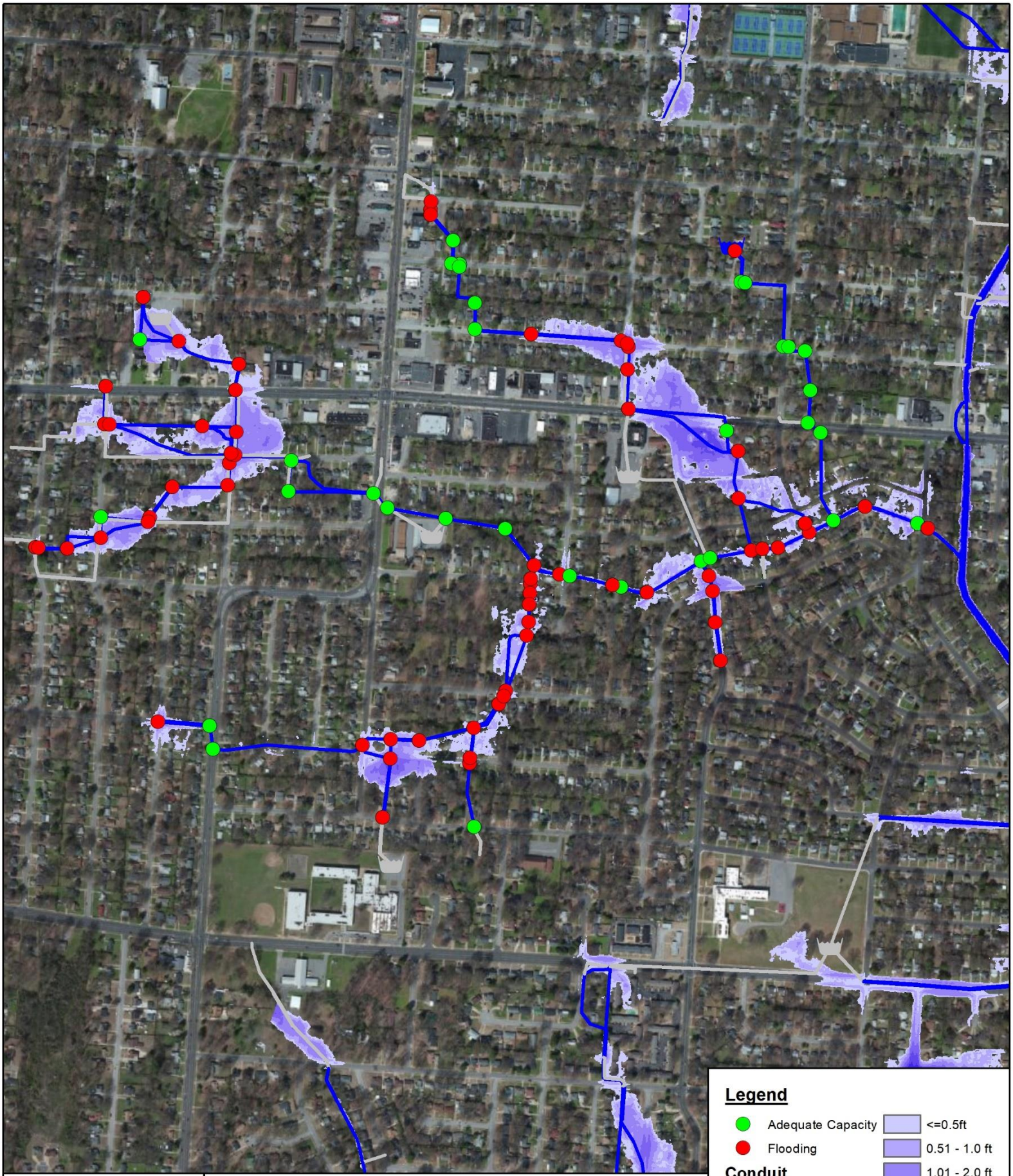


Figure 4-5
Areas 3 and 4 Existing 10-Year Inundation

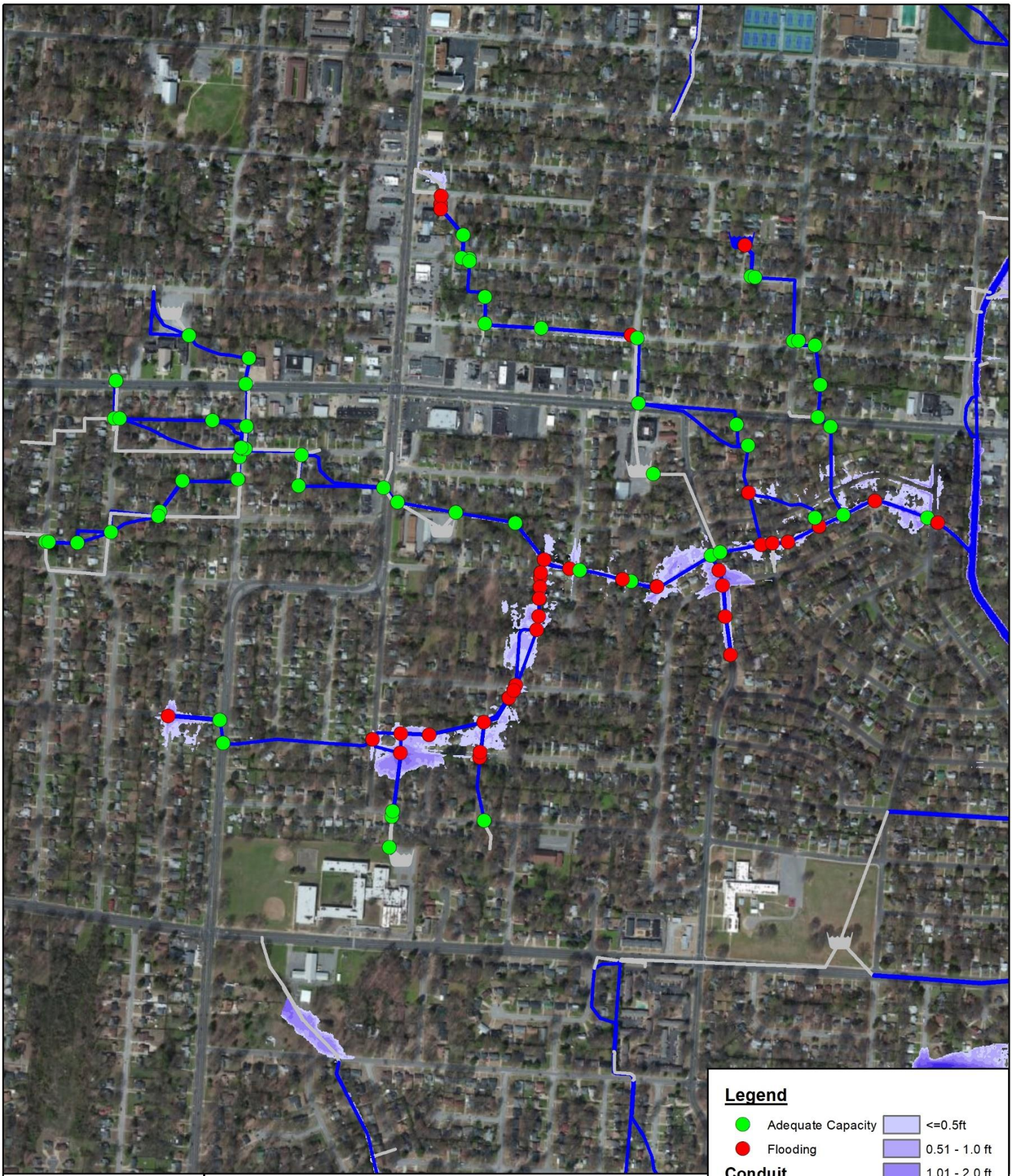


Figure 4-6
Areas 3 and 4 Alternate 10-Year Inundation

4.1.5 Area 5 – Rhodes Ave

Area 5 is located from just north and east of Rhodes Avenue and Will Scarlet Road to just south of Kimball Road and Robin Hood Lane. The drainage area is mostly residential with one school. The existing conditions analysis indicated flooding of 31 of the 37 drainage structures within this location during the 10-year event due to being undersized as well as some flooding over Robin Hood Land near Philsdale Road and over Tyne Street near Deerwood Avenue as shown in Figure 4-7. Additionally, 26 buildings would be inundated.

The proposed improvement includes increasing the size of approximately 400 linear feet of conduit and adding approximately 3,500 linear feet of conduit including a new route down Robin Hood Lane. A new detention area would also be included in the open field near Sherwood Elementary to divert and store backwater from the canal. The increased storage capacity will alleviate flooding in Area 5 and attenuate the peak flows downstream as shown graphically in Figure 4-8. The improvements would also prevent flooding in 24 buildings.

Estimated Cost for Improvements in Area 5 $1,346,000

4.2 Preliminary Planning Cost Information

Preliminary planning costs were prepared for the proposed improvements in the five areas. These costs are based on planning-level design information and comparing Tennessee Department of Transportation bid tab unit costs. These estimates are to be used for budget estimate planning purposes and benefit-cost analyses.

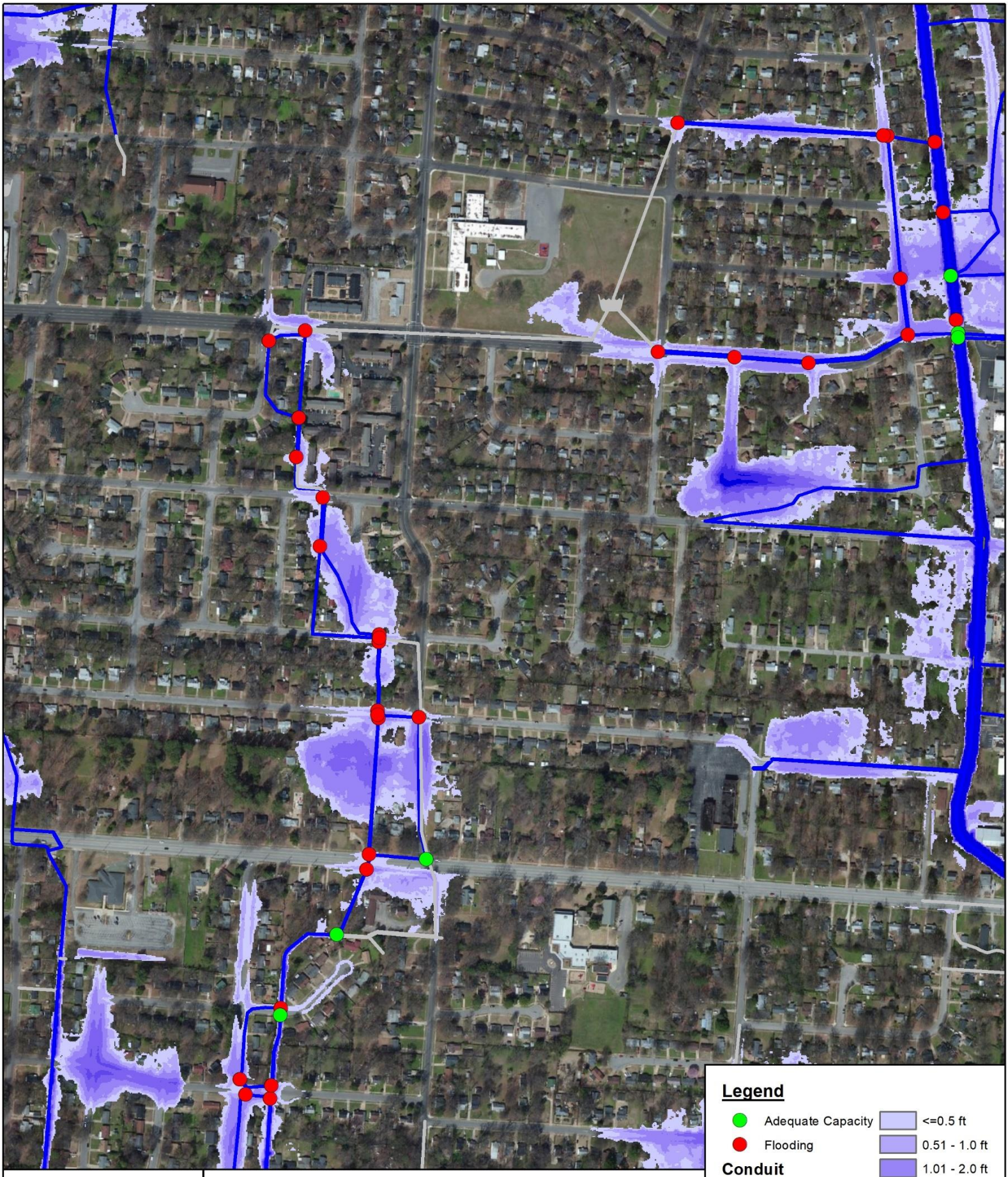


Figure 4-7
Area 5 Existing 10-Year Inundation

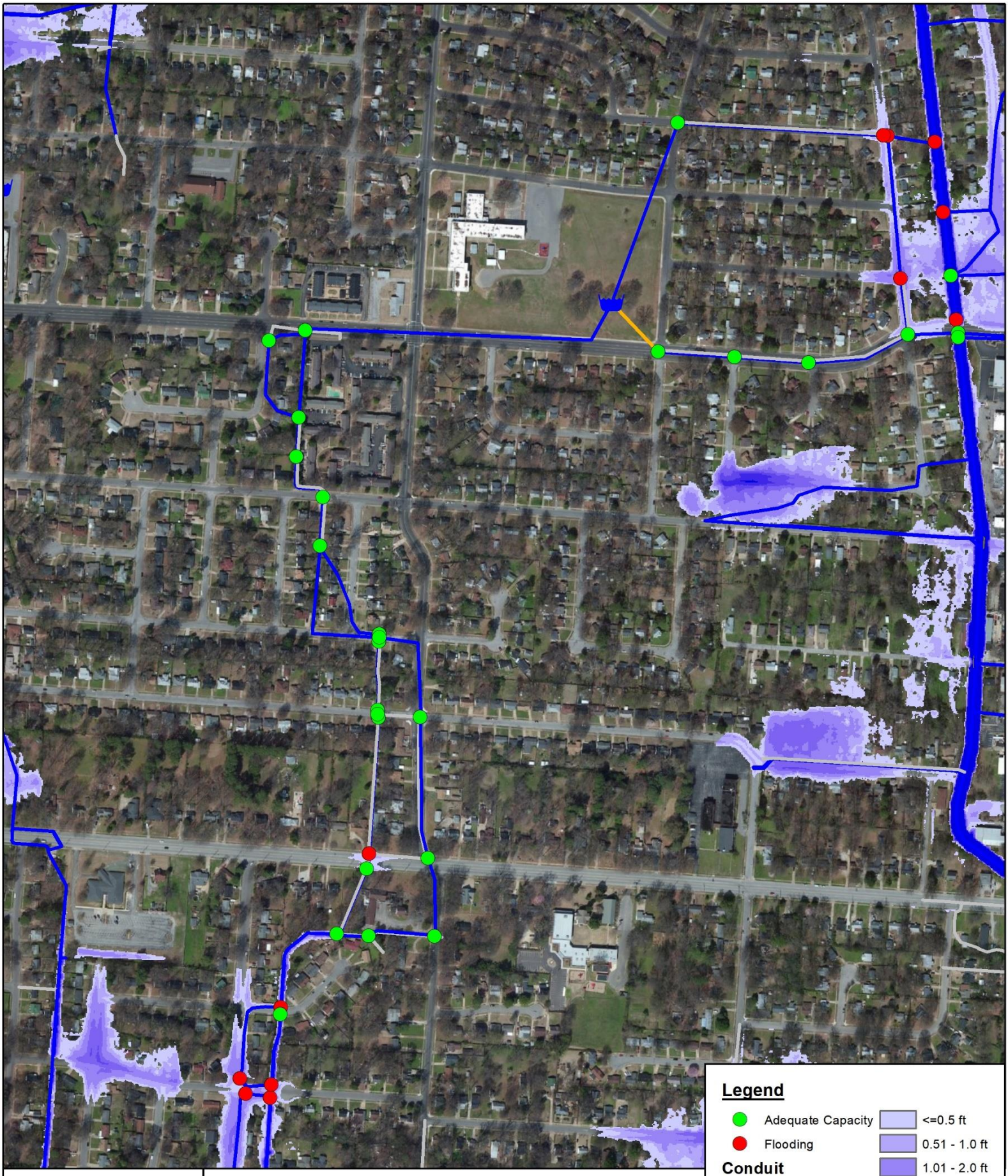


Figure 4-8
Area 5 Alternate 10-Year Inundation

5 BENEFIT-COST ANALYSIS

5.1 Summary of Benefit-Cost Analysis

A benefit-cost analysis was performed for the proposed improvements. The benefit cost analysis evaluated benefits that would be provided by proposed improvements including reduction in loss of service of roads, reduction in amount of property damage and reduction in rental costs for displaced families. The combined benefit-cost ratio for the five areas proposed for improvements is 2.28. Individual benefit-cost ratios for the five areas ranged from 0.35 to 12.36.

5.1.1 Area 1 – Southern Ave at University of Memphis

The benefit-cost ratio for Area 1 was 0.35. As shown in Figure 4-2, the proposed improvements in Area 1 would alleviate flooding on Echles Street as well as other side streets. The improvements would prevent flooding in 24 buildings; however the cost is $13, 820,000.

5.1.2 Area 2 – Cherry Road between Poplar Ave and Southern Ave

The benefit-cost ratio for Area 2 was 8.35. As shown in Figure 4-4, the proposed improvements in Area 2 would alleviate flooding on Goodlett Street a relatively high traffic street. Additionally, the improvements would prevent flooding in 11 buildings. The cost for improvements in Area 2 is $2,047,000.

5.1.3 Area 3 – Robin Hood Lane

The benefit-cost ratio for Area 3 was 4.70. As shown in Figure 4-6, the proposed improvements in Area 3 would alleviate flooding on Park Avenue and Robin Hood Lane. The improvements would also prevent flooding in 32 buildings; however the cost is $3,634,000.

5.1.4 Area 4 – Park Ave

The benefit-cost ratio for Area 4 was 1.40. As shown in Figure 4-6, the proposed improvements in Area 4 would alleviate flooding on Park Avenue. The improvements would also prevent flooding in 35 buildings. The cost for improvements is $9,263,000.

5.1.5 Area 5 – Rhodes Ave

The benefit-cost ratio for Area 5 was 12.36. As shown in Figure 4-8, the proposed improvements in Area 5 would alleviate flooding on Rhodes Avenue and Robin Hood Lane. The improvements would also prevent flooding in 24 buildings. The cost for improvements in Area 5 is $1,346,000.