FINAL REPORT

Gayoso Bayou Drainage Master Plan

City of Memphis





CITY OF MEMPHIS | September 2022

VOLUME I

CDM Smith

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Section 1

Background

1.1 Purpose

The City of Memphis was originally founded in 1819 on the Fourth Chickasaw Bluff along the Mississippi River. Since the earliest years, several drainage criteria have been used to develop or improve infrastructure. Although well-intended, the drainage criteria implemented throughout many areas of the city were inadequate to properly characterize and manage the storm water runoff and flooding potential in Memphis. The result is numerous areas of the city having repetitive flooding and erosion problems that affect roadways and structures, particularly in the older areas of the city.

A 2012 review of the storm water program identified seven major study districts, largely corresponding to City Council Districts, which have been subdivided into approximately 70 smaller study areas. The intent of the Division of Engineering is to complete one storm water master plan (SWMP) in each of the study districts each year, starting in fiscal year 2014. This document provides a SWMP for the Gayoso Bayou watershed located in southern Memphis. The eventual goal is to study each drainage basin in the City and undertake projects in each basin to mitigate existing flooding and erosion problems and the impacts of future storm events on the public infrastructure and private property.

While water quality is also a focal point of the City's comprehensive storm water management program, the primary purpose of this study is to address flooding concerns. However, potential water quality improvement options should be considered during detailed design of the flood reduction projects included herein.

1.2 Memphis' Storm Water Drainage System History

The City of Memphis encompasses a total land area of approximately 325 square miles. Storm water drainage in the city is directed to the Mississippi River, either directly or via one of three major water bodies: the Nonconnah Creek, the Wolf River, or the Loosahatchie River. Because of urbanization and channelization of numerous water bodies over the years, stream flow in the city can have extreme fluctuation. The storm water drainage system in the urban area generally proceeds as follows: inlets along the streets collect runoff during storms and direct it into underground pipes, which connect with larger trunk lines. The trunk lines connect with primarily concrete-lined open channels (although some natural sections still exist), which follow the former route of natural streams before development. The open channels flow into one of the three large streams mentioned above or directly into the Mississippi River.

For years, Memphis has been addressing storm water quantity issues (drainage and flooding) through ordinances and internal policies, which are approved by the City Council. However, Memphis has experienced numerous flooding and stream bank erosion problems associated with rapid increases in urban development and rainfall runoff. In 1994, 2007, and 2013, Flood Insurance Rate Maps for Shelby County were updated.

In 1997, the U.S. Army Corps of Engineers (USACE), Memphis District, conducted a study (The Memphis Metro Study) to determine the need for flood control improvements in the Memphis metropolitan area, which cited the sources of area flooding as flash flooding from heavy rainfalls, backwater flooding from inadequate drainage channels or bridge/culvert constrictions, and backwater flooding from a combination of high water surface elevation on the Mississippi River and high water on the headwater tributary streams. In addition to significant flooding events in 1996, 1997, 1998, and 2001 that caused secondary road closures and localized urban flooding, a historic flood occurred in 2011 that further raised concerns about flooding in Memphis and the need to address the issue in a more comprehensive way.

1.3 Overview of Project Area

The Gayoso Bayou watershed is 2,100 acres (3.28 square miles) and is located completely within the limits of the City of Memphis. The USGS hydrologic unit code (HUC) is 0801-0100-0703. Gayoso Bayou is located within the Lower Mississippi-Memphis Hydrologic basin and discharges to Wolf River Harbor, a direct tributary of the Mississippi River and is therefore strongly influenced by the Mississippi River stage. During moderately high stages of the Mississippi River, water from Wolf River Harbor can back up through the open gate of the drainage system and flood the open pools in the downstream portion of the watershed.

See ***Figure 1-1*** for the location of the Gayoso Bayou watershed within the City of Memphis.

1.4 Model Software Description

The City of Memphis chose InfoSWMM as the required modeling platform for all of its drainage basin study efforts. InfoSWMM is a dynamic hydrologic and hydraulic model capable of performing continuous or event simulations of surface runoff and groundwater base flow, and subsequent hydraulic conveyance in open channel and pipe systems. CDM Smith chose to use a similar product, PC-SWMM, to develop the baseline models. The two platforms utilize the same hydraulic engines and hydrologic equations to perform simulations.

The hydrologic system operates by applying precipitation across hydrologic units (HUs), and then through overland flow and infiltration, conveying surface runoff to loading points on the user-defined primary storm water management system (PSMS). Runoff hydrographs for these loading points provide input for hydraulic routing in the downstream system.

The hydraulic flow routing routine of PC-SWMM uses a link-node representation of the PSMS to dynamically route flows by continuously solving the complete one-dimensional Saint-Venant flow equations. The dynamic flow routing allows for representation of channel storage, branched or looped networks, backwater effects, free surface flow, pressure flow, entrance and exit losses, weirs, orifices, pumping facilities, rating curves, and other special structures or links.

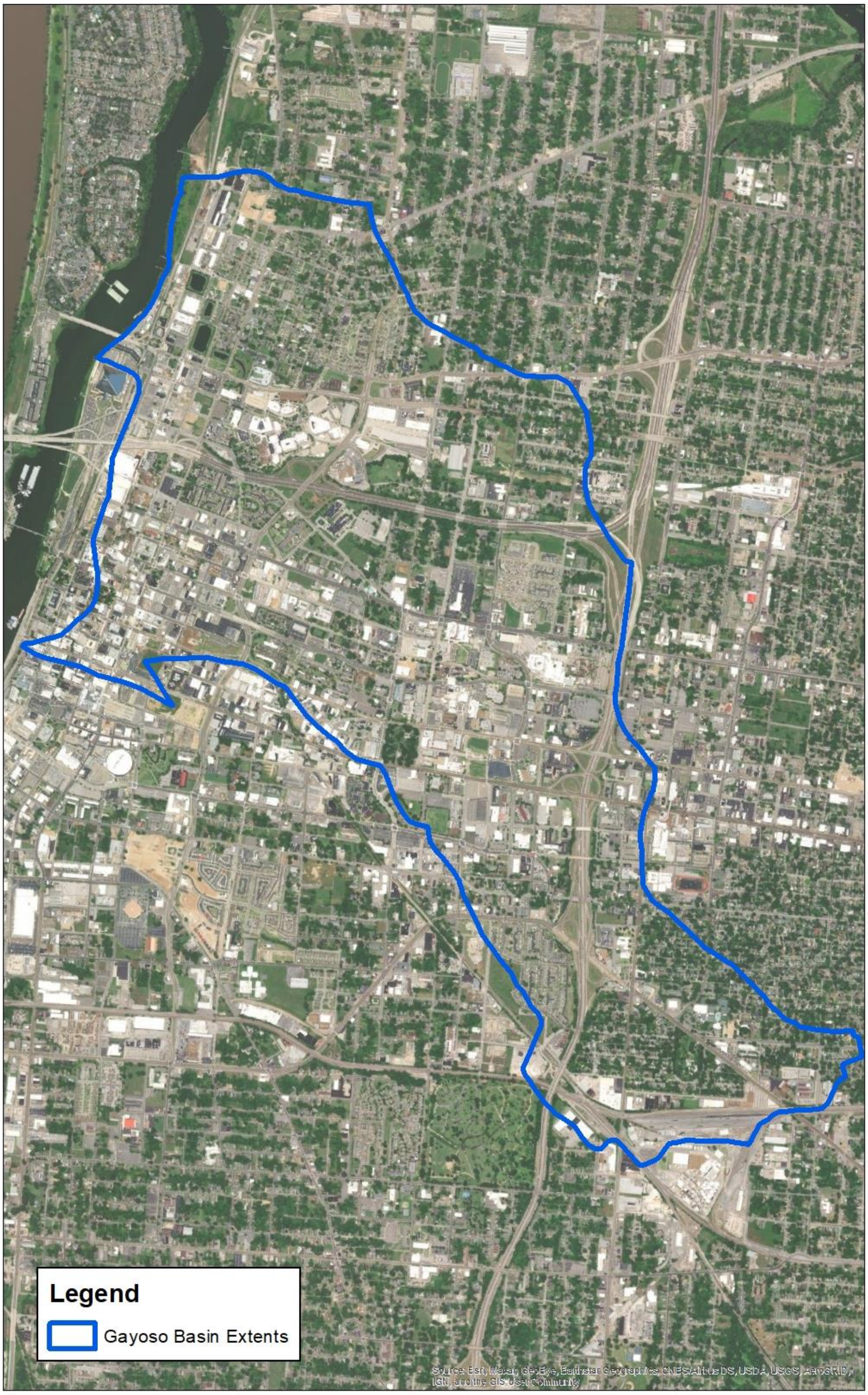

Figure 1-1
Gayoso Bayou Location

Section 2

Review of Previous Studies and Available Data

2.1 Known Problem Areas

The Gayoso Bayou drainage basin was chosen as an early priority basin for master planning due to the existence of known flooding/drainage issues. To support the development of this plan, CDM Smith began the process by collecting and reviewing available information and data about the watershed, including existing Federal Emergency Management Agency (FEMA) mapping, flooding complaints, and work orders performed by the City of Memphis Drain Maintenance staff. The following subsections summarize the information learned from this exercise.

2.1.1 FEMA Flood Insurance Study (FIS)

Gayoso Bayou is located within the Memphis Hydrologic basin and discharges to Wolf River Harbor, a direct tributary of the Mississippi River. CDM Smith acquired the FEMA FIS for Gayoso Bayou to identify areas previously designated at risk for flooding. Only Zone X, areas with reduced risk due to levee, are present from flooding sources within Gayoso Bayou. No discharges or water surface elevations for the Zone X flood zones were available for comparison with model results.

2.1.2 Heat Map Report

In 2012, CDM Smith performed the "Storm Water Program Review and Needs Assessment" report for the City. The report represented a collaborative effort between CDM Smith and the City to document the major accomplishments of the Storm Water Program since the inception of the storm water utility funding program in 2006, to evaluate the services provided by the City to its customers, and to identify future program needs. As a part of the Storm Water Program Review and Needs Assessment study, CDM Smith performed a review of customer complaints and work orders processed by the City's Drain Maintenance Division to gain an understanding of the type, quantity, and location of storm water-related issues city-wide.

For the 2012 report, City staff provided work order records from 2005 through 2011, which represented nearly 42,500 customer calls and responses by City crews. CDM Smith created a "heat map" of these work orders to identify areas that received frequent customer complaints and/or required routine maintenance to preserve the function of the storm water drainage system. This map was used to prioritize watersheds throughout the City and eventually select Gayoso Bayou for the third round of master planning. In 2020, updated data including over three hundred unique drainage requests were provided to CDM smith to create an up-to-date heat map for the watershed. That heat map is included in ***Figure 2-1***.

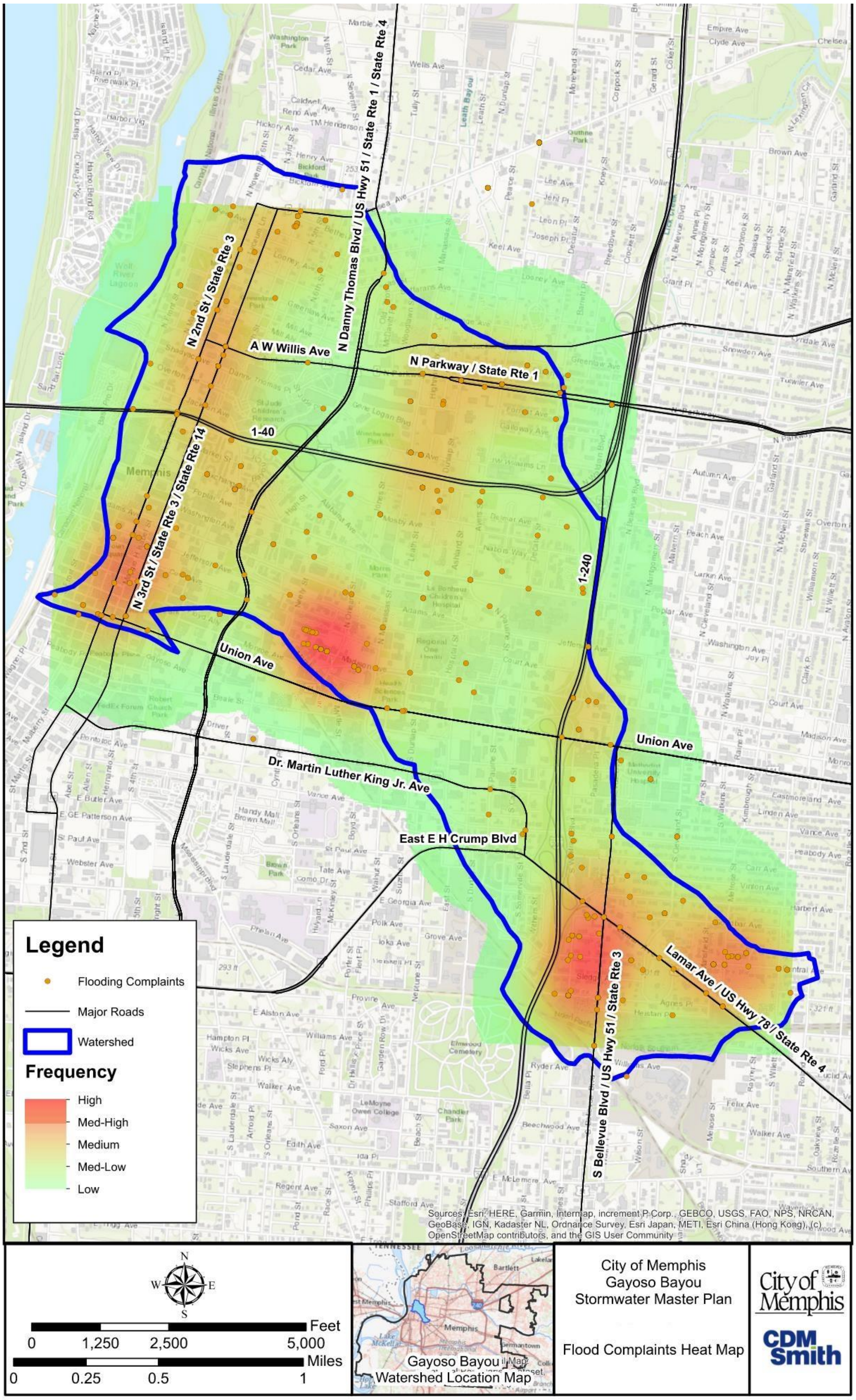

Figure 2-1
Flood Complaints Heat Map

CDM Smith noted these areas of concern during the model-build and provided additional detail in the model to evaluate potential issues/improvements for these areas.

2.2 Study Area Characteristics

2.2.1 Precipitation

The climate of the Memphis area is characterized by relatively mild winters, hot summers, and abundant rainfall. The average annual rainfall is approximately 52 inches and the average annual snowfall is approximately 3 inches. In general, winter rains are of several days duration with a large coverage, but rarely is the intensity severe. Summer rains are usually categorized as thunderstorms with high intensities over small areas. Monthly averages differ depending on the source, as shown in ***Table 2-1.***

Table 2-1 Monthly Precipitation Average Total

Month	Average Total Precipitation (Inches) (1961 – 2020) NOAA
January	4.3
February	4.4
March	5.3
April	5.5
May	5.0
June	3.5
July	4.1
August	3.3
September	3.2
October	3.3
November	4.5
December	5.2
Year	51.6

[1] Source: https://w2.weather.gov/climate/xmacis.php?wfo=meg

Overall, precipitation is heaviest during winter and early spring, a period when low-pressure systems cause widespread rains. A second period of heavy precipitation occurs late in spring and early in summer, when local showers and thunderstorms are most common. Precipitation is generally lightest late in summer and early in fall. (US Dept. of Agriculture Soil Conservation Service, 1989)

2.2.2 Topography

The City of Memphis (City) provided a LAS dataset of Light Detection and Ranging (LiDAR) point cloud data. The geodetic reference system used was Tennessee State Plane (NAD 1983, State Plane, Tennessee) and the vertical datum was in North American Vertical Datum (NAVD88) of 1988. The topography of the City of Memphis ranges from an approximate high of 380 feet NAVD in the southeast portion of the city to a low of approximately 190 feet NAVD along the Mississippi River. The Gayoso Bayou watershed is located in the central part of the city of Memphis near the Mississippi River with elevations ranging from 344 feet NAVD to 123 feet NAVD. Average slopes across the watershed range from flat to 3:1 with the steeper slopes in the downstream portions of the watershed near main stem reaches.

Figure 2-2 shows the topography across the Gayoso Bayou watershed.

2.2.3 Soils

There are 24 major soil types in the Memphis area. According to the US Department of Agriculture (USDA), Soil Conservation Service (SCS, now called the Natural Resources Conservation Service - NRCS) 1989 Soil Survey, most of Shelby County is comprised of soils containing mostly silty loam.

The three most common soil types in the project area are Memphis silt loam, Filled silt, and Graded land, silty materials. Memphis silt loam has a USDA soil classification of B. It is a deep, well-drained, silty soil on the uplands. Runoff is the main management problem. The soil is silty and erodes easily when cultivated. Erosion is often the cause for the removal of the original surface layer of soil in steeper slopes. Grass should be established in the natural watercourses. The available water capacity is high. Graded land, silty materials also has a USDA soil classification of B. It consists of areas that have been graded in preparation for residential or site development. Due to this compaction and alteration, a soil group of D was assigned. Grenada, Loring, and Memphis soils were predominant in these areas before grading. Filled silt consists of soil material that has been moved for the purpose of leveling and building up sites and is common in the downstream portions of the original channel of the bayou.

Table 2-2 Gayoso Bayou Soil Area Distribution (US Dept. of Agriculture Soil Conservation Service, 1989)

Soil Type	Area (Acres)	Percent	Hydrologic Soil Group
Graded land, silty materials	1,666	79.6%	D
Filled Silt	244	11.7%	D
Memphis silt loam	183	8.8%	B
Totals	**2,073**	**100.0%**	

Figure 2-3 shows the distribution of the soil types across the Gayoso Bayou watershed.

2.2.4 Land Use

To better understand the response of rainfall falling within the watershed, CDM Smith developed a land use map of the watershed using City GIS data and a review of aerial photography. Land uses in the Gayoso Bayou watershed can be separated into eight categories. A breakdown of each type, including total acreage is listed in ***Table 2-3. Figure 2-4*** shows the distribution of land use types across the watershed. Impervious area is commonly assigned by land use; however, CDM Smith obtained detailed impervious area from Shelby County and did not require these estimates.

Table 2-3 Gayoso Bayou Land Use Area Distribution

Land Use Type	Area (Acres)	Percent of Total
Forest or Park	29.6	2.0%
Institutional (School, Hospital)	275.4	16.7%
Open Lot	117.1	7.2%

Residential - Medium Density	312.1	18.9%
Residential - High Density	99.7	6.3%
Light Industrial	103.4	6.4%
Commercial	429.7	26.0%
Parking Lots and Highways	288.8	17.5%
Totals	**1655.8**	**100.0%**

2.3 System Inventory

2.3.1 GIS

In 2010, the City of Memphis, Department of Public Works, Stormwater Division staff initiated a joint project with the University of Memphis Center for Partnerships in GIS (CPGIS) to develop a GIS-based inventory of the City's storm drainage system. Using the City's paper maps as a base, CPGIS is creating a digital image and associated database of all documented pipes and inlets in the City. The project has involved scanning of over 30,000 map documents and incorporation of over 5,500 site grading and drainage plans. The final database will include the material, size, slope and flow direction of all pipes in the City. The information can be used to plan and prioritize work activities, as the basis for future modeling/planning projects and to assist in the identification and tracking of hazardous material spills.

While the CPGIS data is useful for many functions, it is not entirely sufficient to support the modeling effort for this project. As such, CDM Smith was tasked with providing an infrastructure inventory of the Gayoso Bayou watershed using the City's GIS data as a base. CDM Smith acquired the City's GIS for the Gayoso Bayou watershed, which included approximately 48 miles of stream/ditch/conduit sections and over 3,050 storm water drainage structures (manholes, catch basins, inlets, etc.). This data was used to develop an estimate of the additional survey required to complete the inventory as well as guide portions of the modeling effort.

2.3.2 Survey

Based on the results of the evaluation of the CPGIS data, CDM Smith directed THY Engineering, Inc. to collect field inventory and survey as described below to support master plan development and storm water inventory efforts.

- For open channel sections (natural or concrete-lined), field survey cross-sections were collected as needed depending on channel geography and transitions. Channel sections were surveyed from top of bank to top of bank, plus up to a maximum of 50-ft on each side. GIS-based topographic information provided by the City was used as the main source of topographic information beyond the top of channel banks.
- The horizontal datum for the survey work was NAD83, TN Zone 4100, as derived from the NGS National Spatial Reference System (NSRS).
- The vertical datum for all survey work shall be based on the City of Memphis Benchmark Network.
- The following features were included in the land surveying effort:
  - Open channels downstream of 24 inches pipes and larger;
  - Pipes 24 inches and larger in the tributary storm water drainage network;

- Pipes downstream from an identified flooding concern;
- Structures (headwalls, bridges, culverts) along the storm water drainage network, as well as features meeting the above criteria.

Some features smaller than 24 inches were requested to complete connectivity or further explore areas known to have local flooding issues. Based on a review of the CPGIS data and the criteria above, the following is a summary of the surveyed structures for this project:

- 953 Storm Water drainage structures (manholes, inlets, pipes, etc.)
- 11 Channel cross-sections
- 10 Road crossings
- 160 Finished Floor Elevations

Many surveyed road crossings and outfalls were photographed and geo-referenced. A GIS layer of the survey data, including appropriate photographs, was developed, and is in a separate geodatabase.

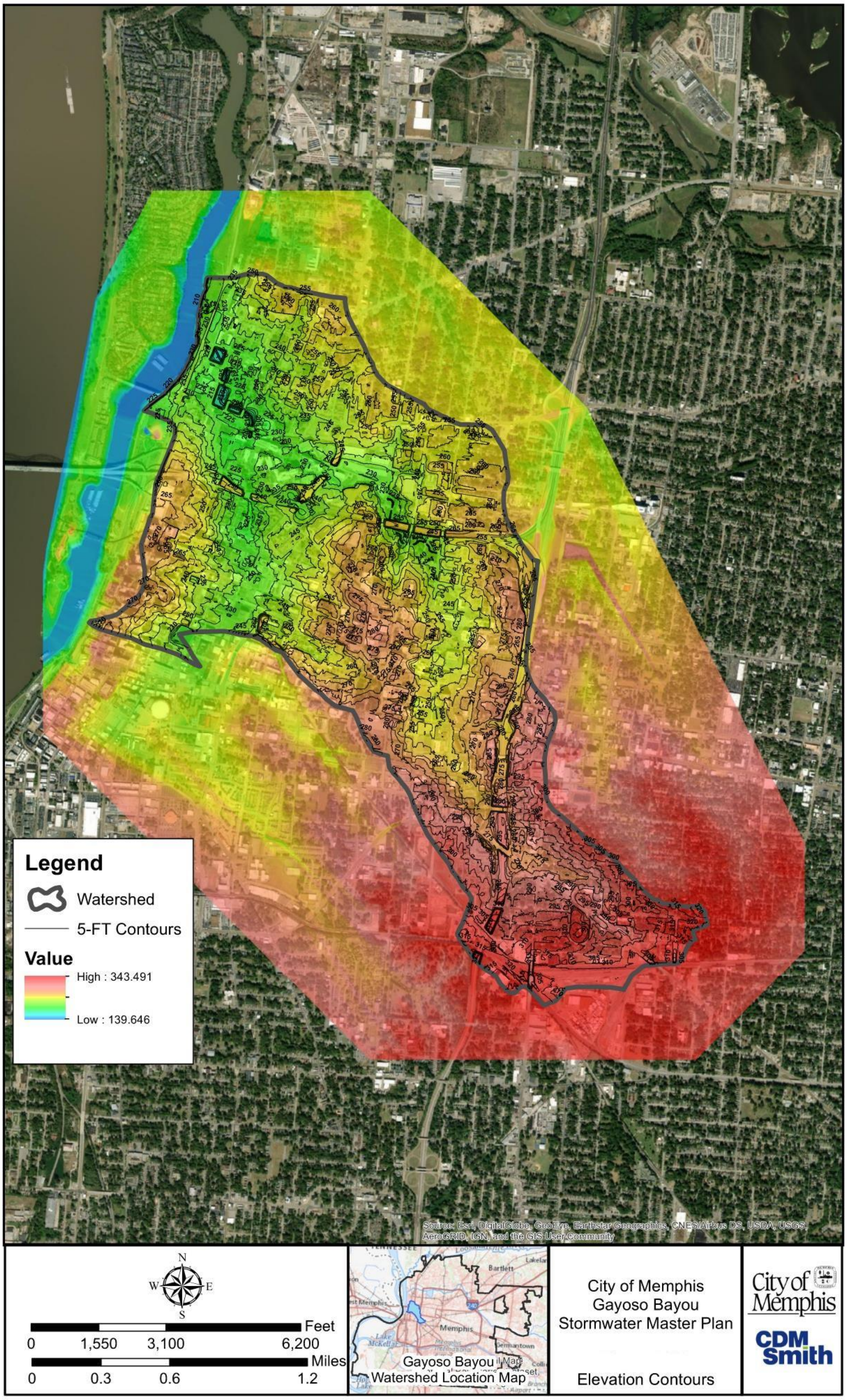

Figure 2-2
Elevation Contours and DEM

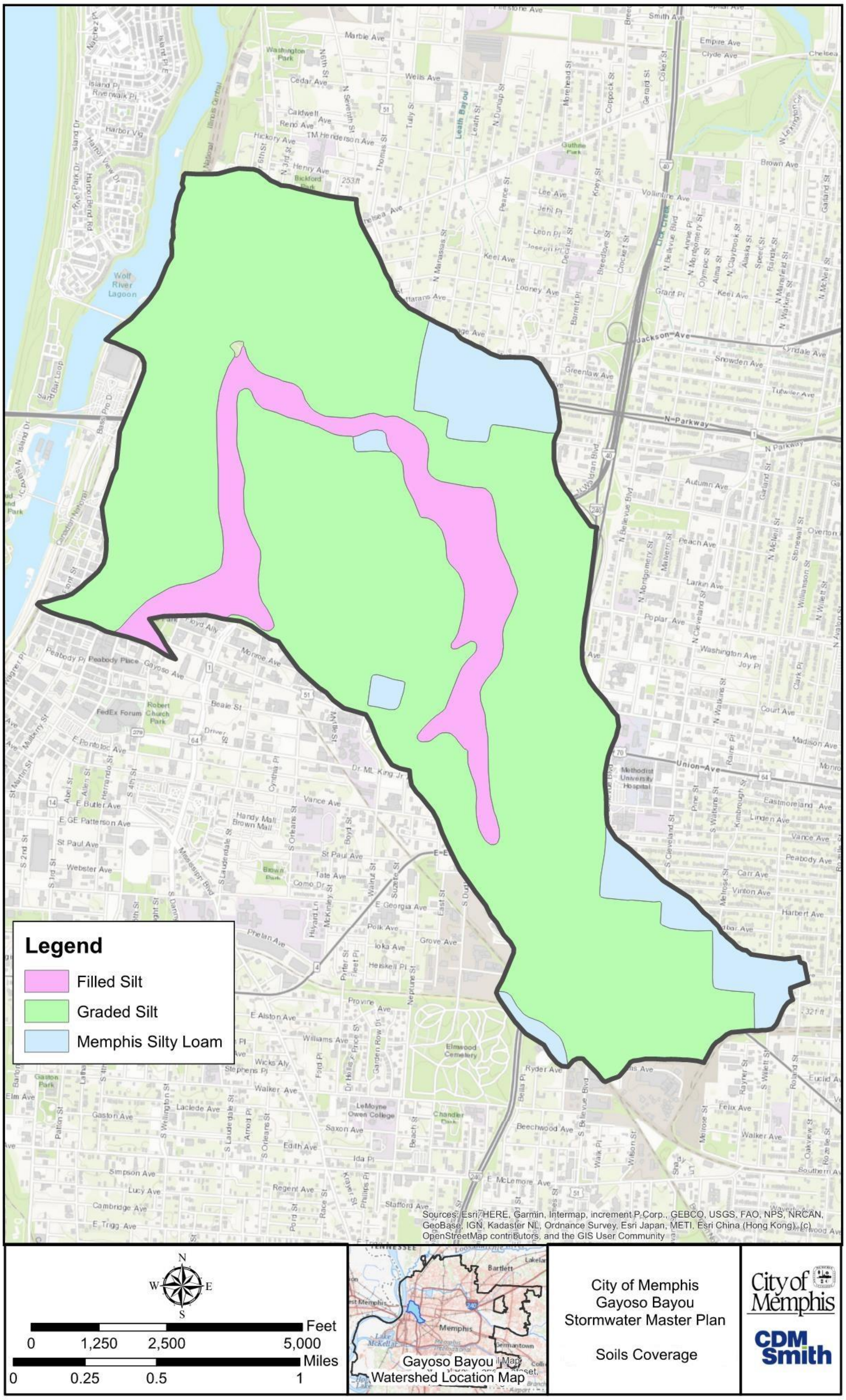

Figure 2-3
Soils Coverage

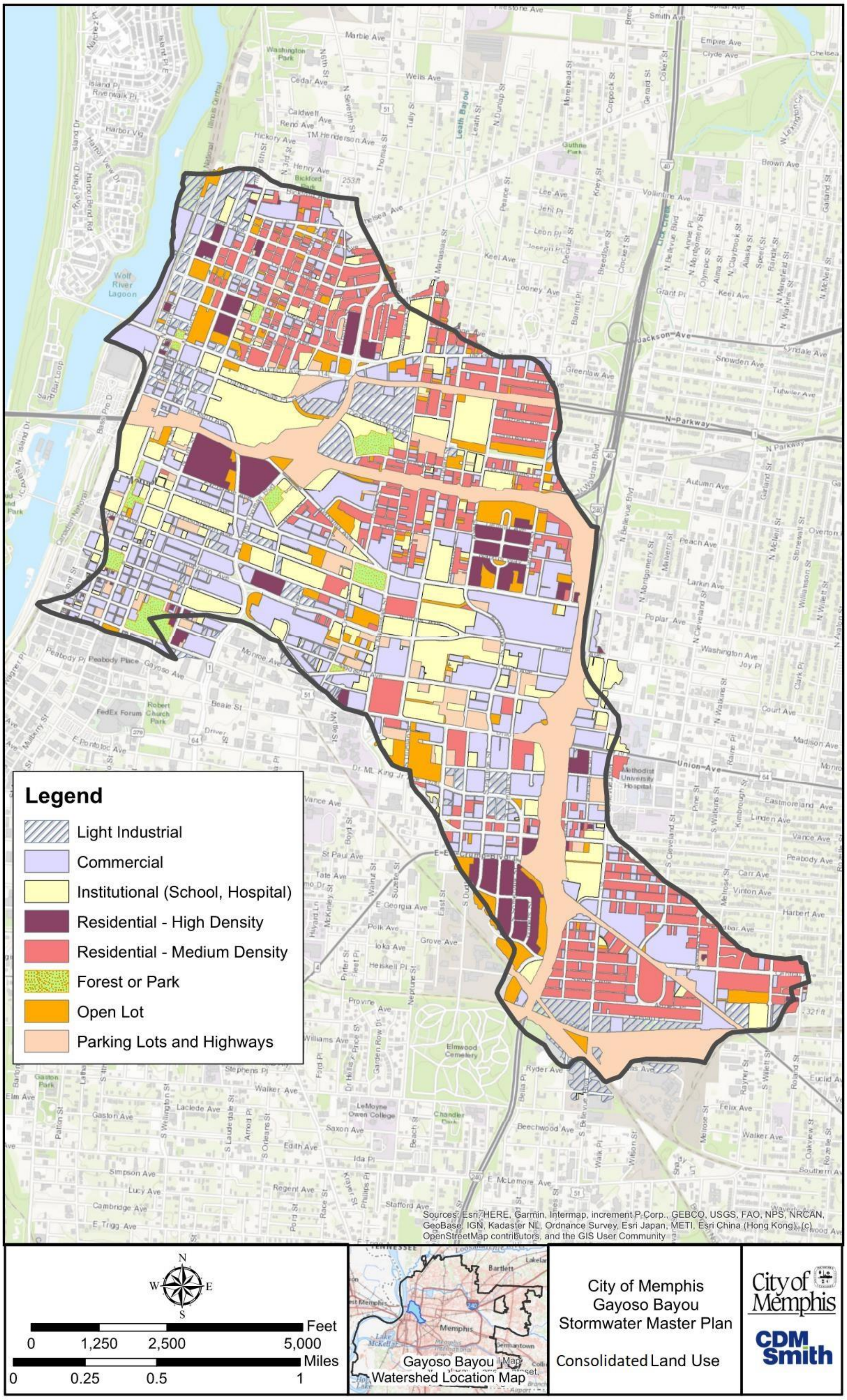

Figure 2-4
Consolidated Land Use

Section 3

Summary of Existing System Analysis and Results

This section provides a summary of the existing system analysis and results. More 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 project watershed was sub-divided into 173 hydrologically distinct catchments, or hydraulic units, based on a combination of topographic information, city storm water pipes, and aerial photography. Hydrologic parameters such as area, width, slope, impervious area, surface roughness and infiltration parameters were then assigned to each catchment based on its land use and underlying soil type. The hydrologic system operates by applying precipitation across the hydrologic units, determining the resulting runoff based on the hydrologic parameters and routing the runoff to loading points within the hydraulic system.

The hydraulic system uses a node/link (junction/conduit) representation to model the storm water system. Links are a mix of open channels (both natural and concrete lined) as well as closed conduits such as circular pipes and rectangular box culverts. Nodes are located at any transitions between conduit types or where infrastructure changes dimension or shape. Within the model only the primary storm water management system is represented including all infrastructure larger than 24-inch and any smaller segments required for connectivity. Some pipes smaller than 24-inch were included in areas with known flooding concerns. An overview of the modeled system is provided in ***Figure 3-1***.

Once the model was built, it was calibrated using water level recording devices and rainfall data collected within the watershed. During the calibration of flows and levels, model parameters were updated until the peak stage and approximate curve shape provided a best match to the monitoring data for storm events captured in October and November of 2019 and January of 2020. Figures documenting examples of calibration are included in Volume II of this report. This process confirms that the model is able to represent real-world conditions.

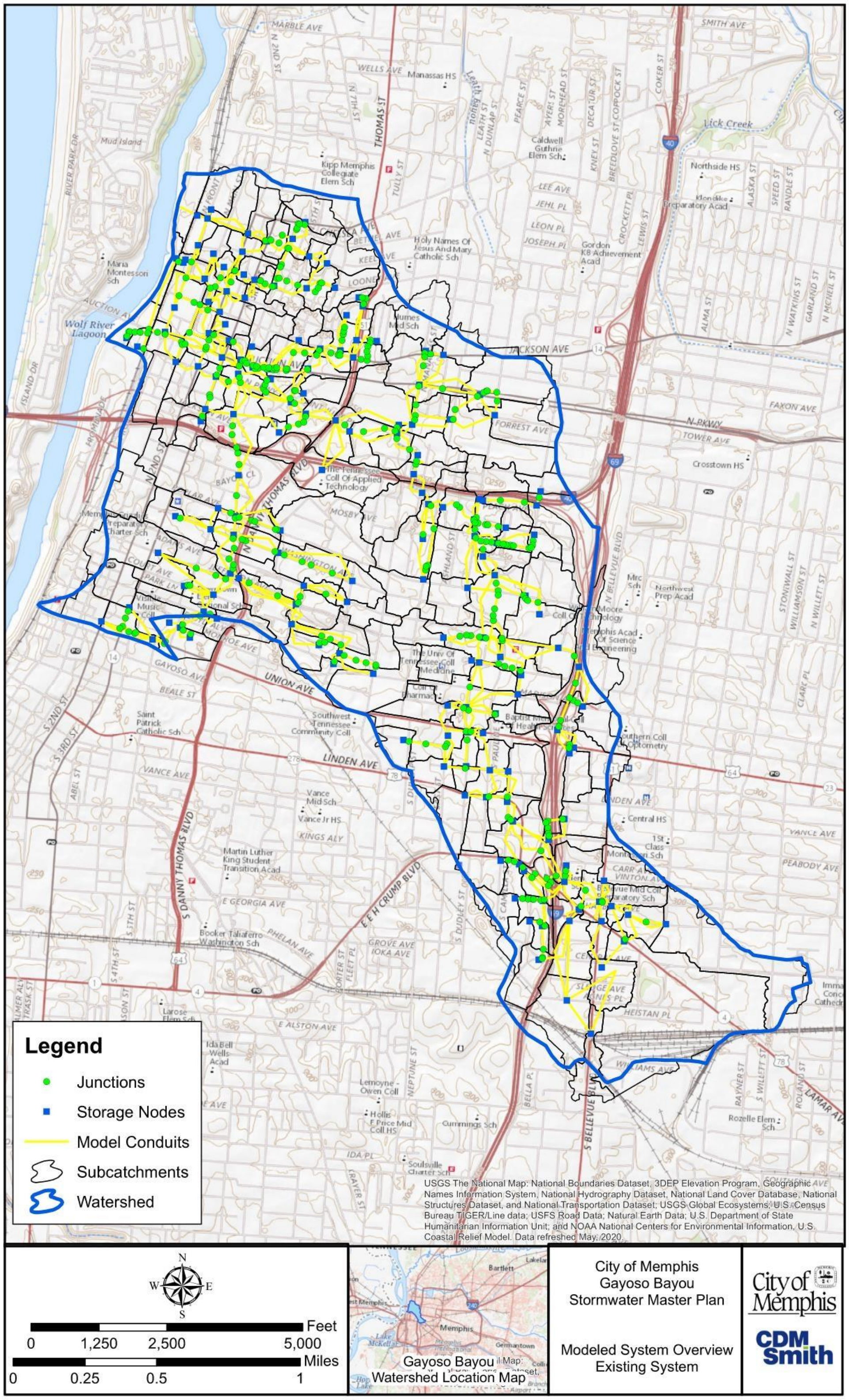

Figure 3-1
Modeled System Overview

3.2 Existing Conditions Analysis and Results

The existing system was evaluated to determine flooding extent and potential problem areas for a series of 24-hour design storms (2-yr, 5-yr, 10-yr, 25-yr, 50-yr and 100-yr). The return period signifies the chance that intensity of storm has of occurring in any given year. For example, the 25-year design storm has a 1/25 or a 4% chance of occurrence in any given year. The predicted flood extent of each design storm was compared to key infrastructure, building elevations, major roadways, and minor roadways to determine potential inundations and where level of service (LOS) targets were not met.

The primary purposes of LOS criteria are to protect public safety and property. The LOS criteria used in this study identify and define potential problem areas based on the storm water model simulations performed. The LOS criteria are then used to evaluate the effectiveness of improvements that are incorporated in the model simulating alternative solutions. Based on a review of the City's Storm Water Management Manual, the City of Memphis has established their LOS to be the following with the additional goal of all structures to remain outside of the 10-year floodplain:

- *Storm sewers shall be designed for the total intercepted flow based on the 10-year 24-hour design storm. If a portion of the storm sewer also serves as a culvert (cross drain) for a major intersection, major conveyance system, or state route — that portion must be designed to accommodate the design (50-year) flow from that drainage area.*

3.2.1 Flood Extent

Flood extents were created with GIS using the InfoSWMM Risk Assessment Manager Tool. This tool utilizes the maximum hydraulic grade line (HGL) of each node in the model along with the digital elevation model of approximate ground surface elevation to produce a map of predicted flood depths and extents. ***Figure 3-2*** through ***Figure 3-7*** shows this flood extent across the watershed for the 2-year through 100-year design storms.

3.2.2 System Assessment

Key Facilities

An analysis of key facilities (i.e. fire stations, police stations, and public schools) showed that several of the key facilities within the watershed were predicted to have inundation during the model runs, up to and including the 100-year design storm. Additionally, elementary schools may be difficult to access due to localized street flooding, including Bellevue Middle and Bruce Elementary.

Major Roads

There are 73 major road crossings included within the modeled system. Of these, 64 are predicted to have inundation during at least one of the storm events analyzed, though most of these occur only in the 100-yr storm event, and only 24 are greater than 0.5 feet in depth. A map of the crossings and the design storm during which they are first inundated is provided in ***Figure 3-8***. ***Table 3-1*** gives the number of major road crossings inundated in each of the design storms described in previous sections.

Table 3-1 Potential Road Crossings Inundated during Design Storms

Predicted Flood Depth	Number of Major Roads					
	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr
All Depths >0.5 ft	24	23	18	13	11	6
>0.5 ft	5	5	5	5	4	4
>1 ft	5	4	2	1	2	0
>1.5 ft	3	4	4	4	3	0
>2 ft	11	10	7	3	2	2

Structures with Inundation

Structures at risk for inundation were identified by examining aerial photography and other GIS basemap layers. The predicted depth of flooding at the structure was then determined for each design storm. The results of this analysis are shown in ***Table 3-2***. As part of the project, the finished floor elevation of 160 buildings were surveyed. On average, the finished floor elevation was 1.6 feet above ground level with a range of 0 to 8 feet. Thus, many of the structures identified as being inundated at the lower depths may not actually sustain any water damages. Additional survey of homes in critical areas may be performed to confirm this assumption.

Table 3-2 Potential Structure Inundation during Design Storms

Predicted Flood Depth*	Number of Structures					
	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr
All Depths	27	24	22	14	2	0
>0.5 ft	6	6	5	3	0	0
>1 ft	3	3	3	4	1	0
>1.5 ft	7	6	4	1	0	0
>2 ft	6	6	2	2	1	0

Note: *Depths based on structures located at finished floor elevation. Only the 160 structures included in the finished floor elevation survey were evaluated to create this table. Additional inundation may occur in structures not surveyed.

Minor Roads with Inundation

Besides the main channels and culverts, the model also includes above ground hydraulic elements such as overland flow and road conduits. The overland flow conduits are representative of flow perpendicularly crossing (overflowing) a roadway. In these cases, the roadway acts like a weir and water backs up behind it until the hydraulic grade line reaches the crown of the roadway. At this point, flow can move over the roadway into downstream elements. Road conduits are similar except they run parallel to the roadways and represent the road itself being used as a flow path during storm events. With the Mississippi River gate closed, during the 2-year design storm 17% of the overflow conduits are being utilized indicating some sort of minor street flooding in these locations. This increases to 88% of the overflow conduits being utilized during the 100-year design storm when the Mississippi River gate is closed. With the Mississippi River gate opened, during the 2-year design storm, 16% of the overflow conduits are being utilized indicating minor street flooding in these locations. This increases to 80% of the overflow conduits being utilized during the 100-year design storm when the Mississippi River gate is opened.

To refine the focus of these conduits to reflect real-world flood concerns, only road conduits that would leave residents without an evacuation path or that served critical structures were considered minor roads. That is, if a roadway is flooded, but a parallel road a block away could be used as an alternate route to gain access to a residence or business, that road was not considered a major or minor road.

Level of Service Evaluation

The City of Memphis specifies that storm sewers shall be designed for the total intercepted flow based on the 10-year, 24-hr design storm *when the storm gate is closed* and pumps are engaged. Within the Gayoso Basin, a total of 15.53 miles of storm sewer is shown to not meet the current level of service goal. This represents 87% of the closed conduits in the modeled system. If the storm gate to the Mississippi River is opened, 14.47 miles of storm sewer is shown to not meet current level of service goals, representing 81% of the closed conduits in the modeled system. **Table 3-3** shows the statistics for system capacity in the 2-yr 24-hr SCS Type-II, 10-yr 24hr SCS Type-II, and the 100-yr 24-hr SCS Type-II design storms with the Pump Station gate open and the river at 207 feet NAVD88. The limitations in Table 3-3 are organized by what percentage of the system is affected and for how long the pipe is surcharged. More than 70 percent of the system sees some degree of limited capacity in as little as the 2-yr 24-hr storm, though the majority of these limitations are brief, with some as short as one minute. This reflects the centrally intense nature of the SCS Type-II storm format.

Table 3-3 System Capacity in Selected Design Storms

Capacity Limitations (% of total pipes)	Design Storm		
	100-yr	10-yr	2-yr
Not Capacity Limited	5%	19%	28%
Under 1 hour	71%	65%	68%
1 – 3 hours	22%	15%	4%
>3 hours	2%	< 1%	0%

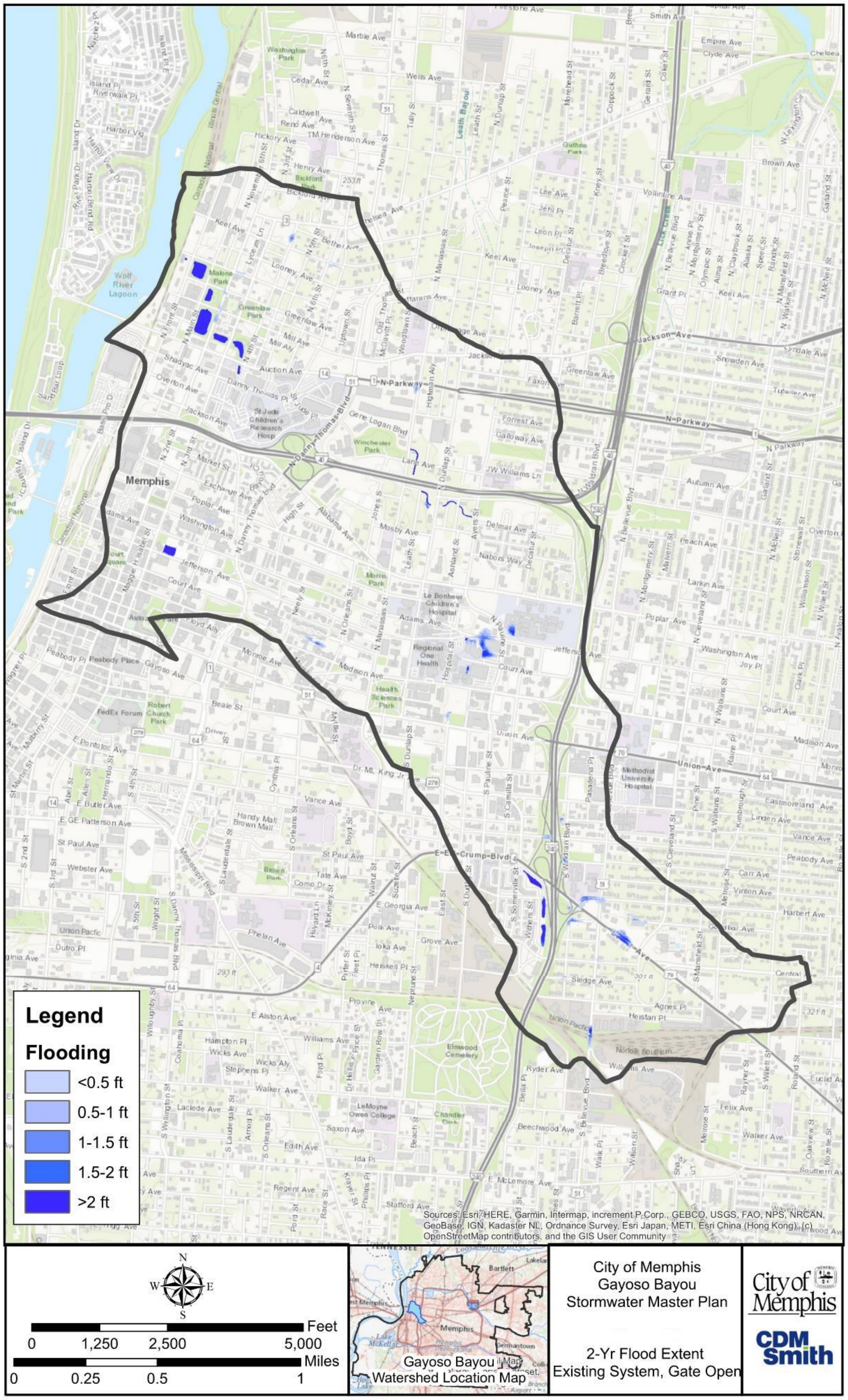

Figure 3-2
2-yr Flood Extent

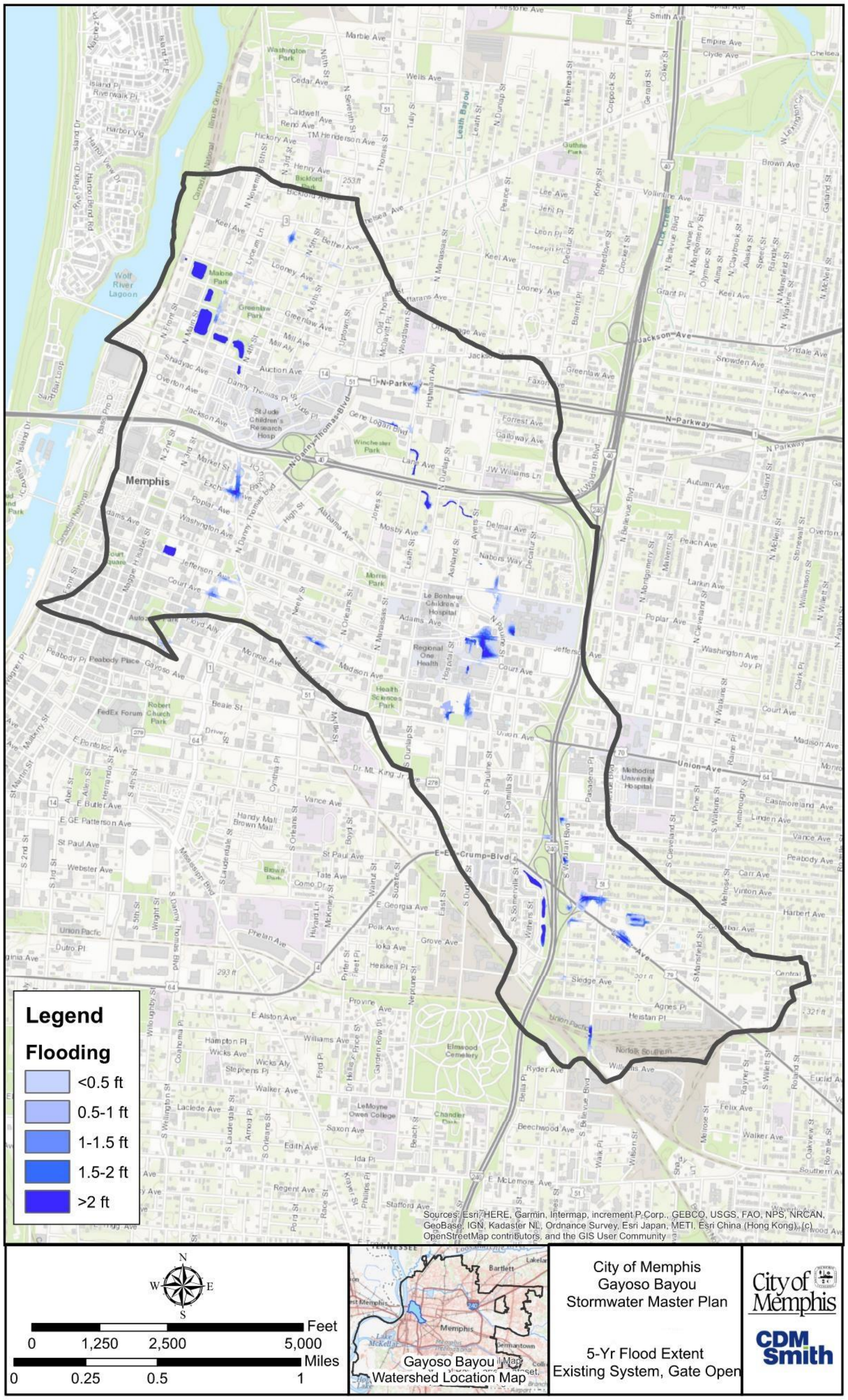

Figure 3-3
5-yr Flood Extent

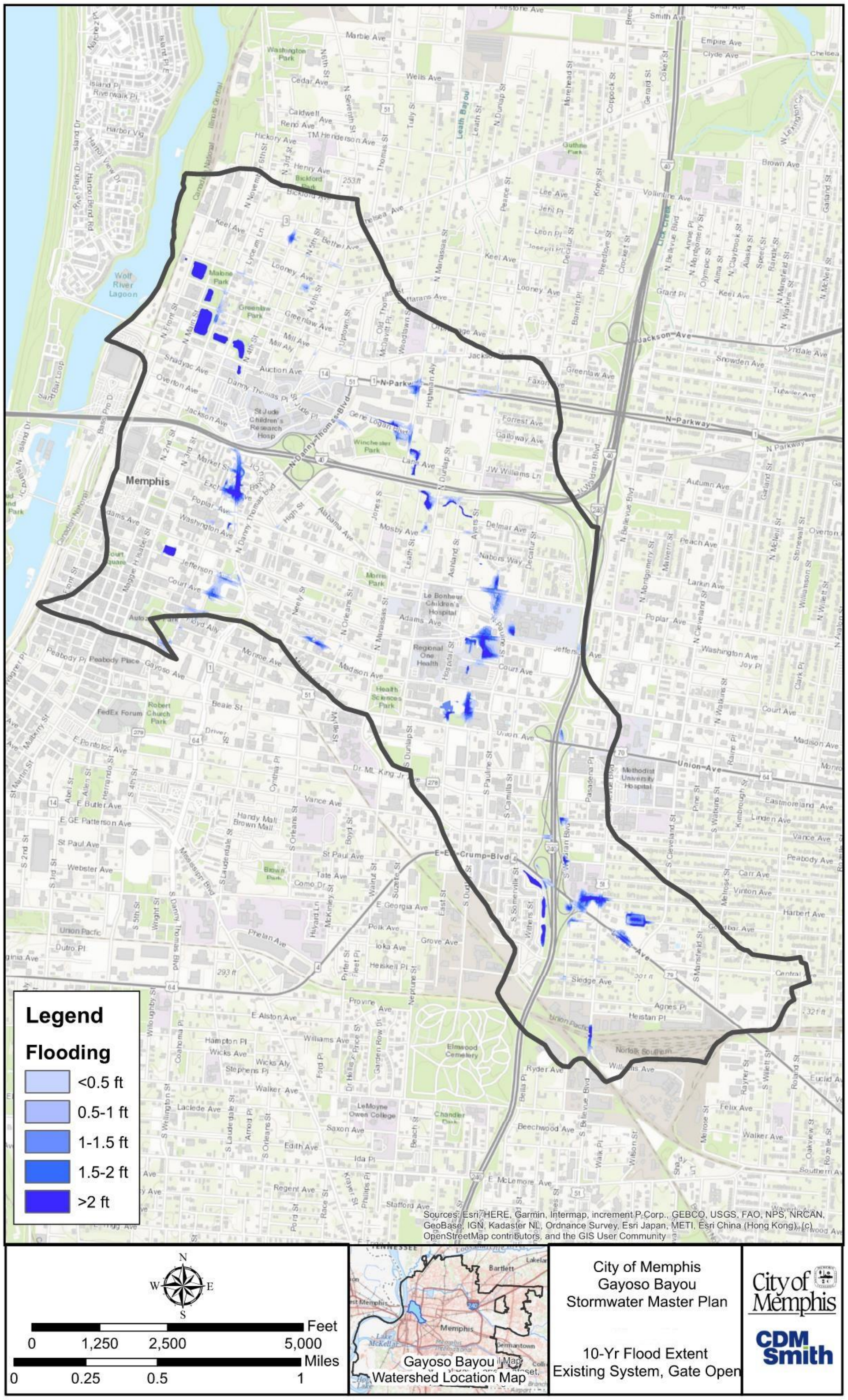

Figure 3-4
10-yr Flood Extent

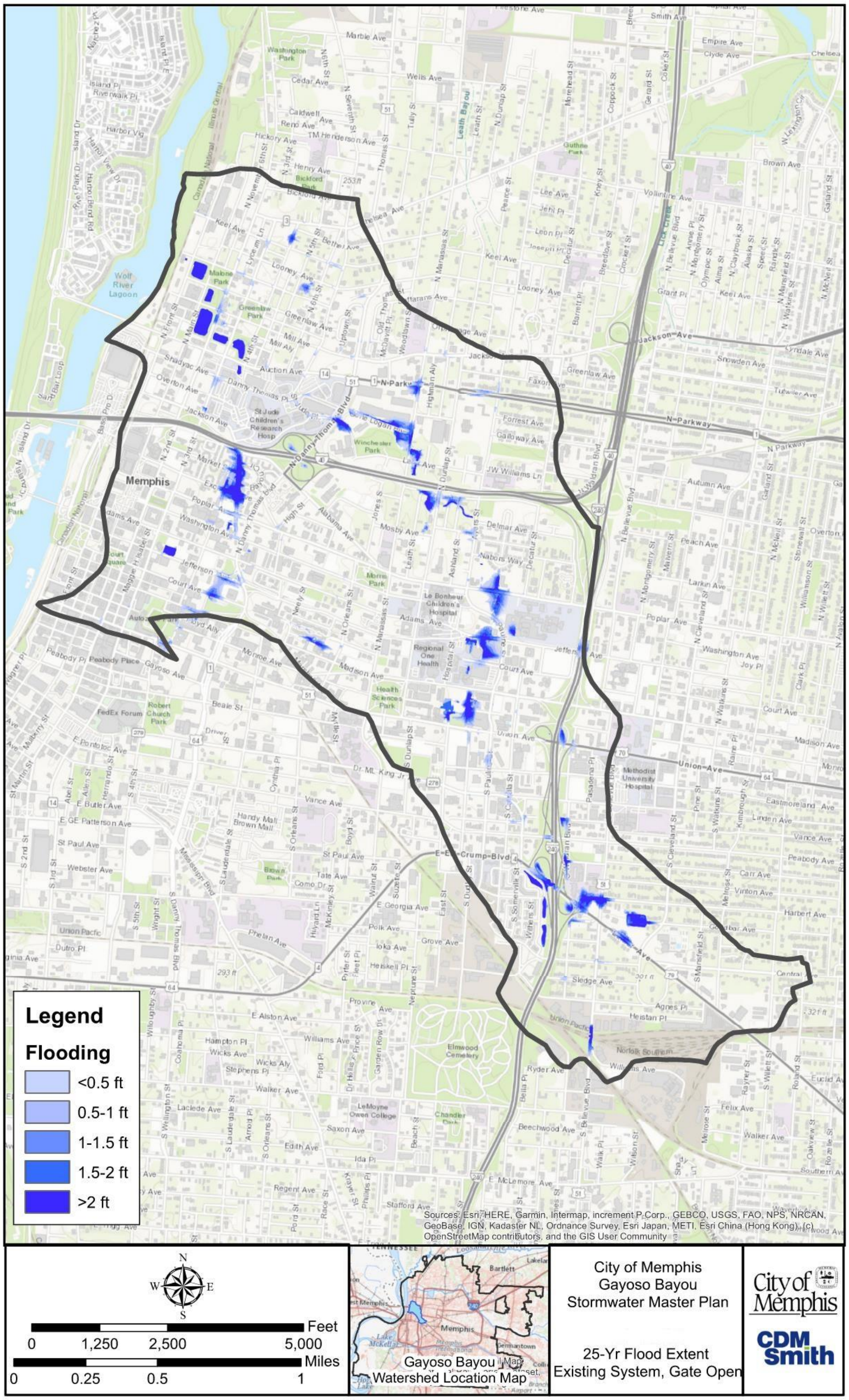

Figure 3-5
25-yr Flood Extent

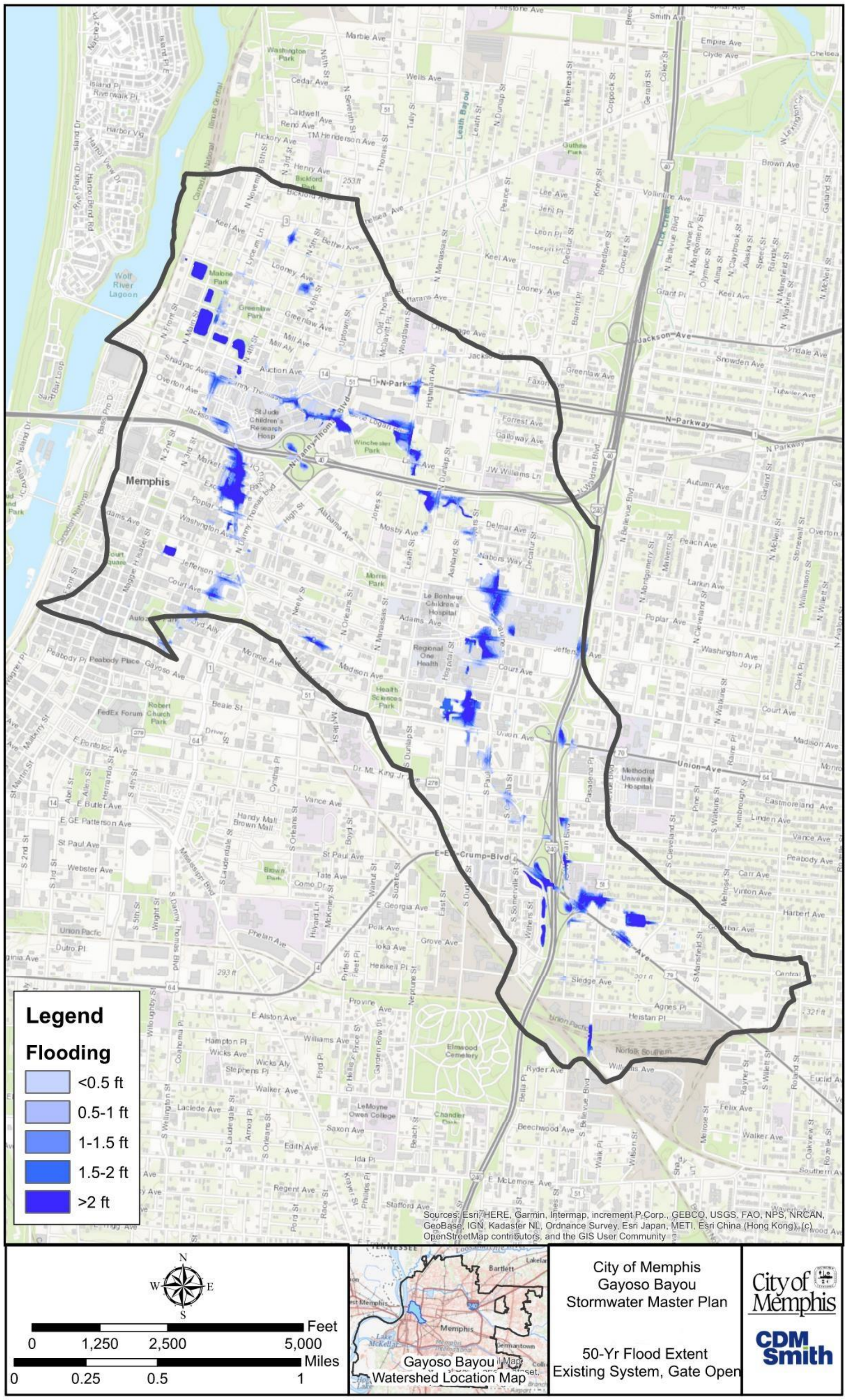

Figure 3-6
50-yr Flood Extent

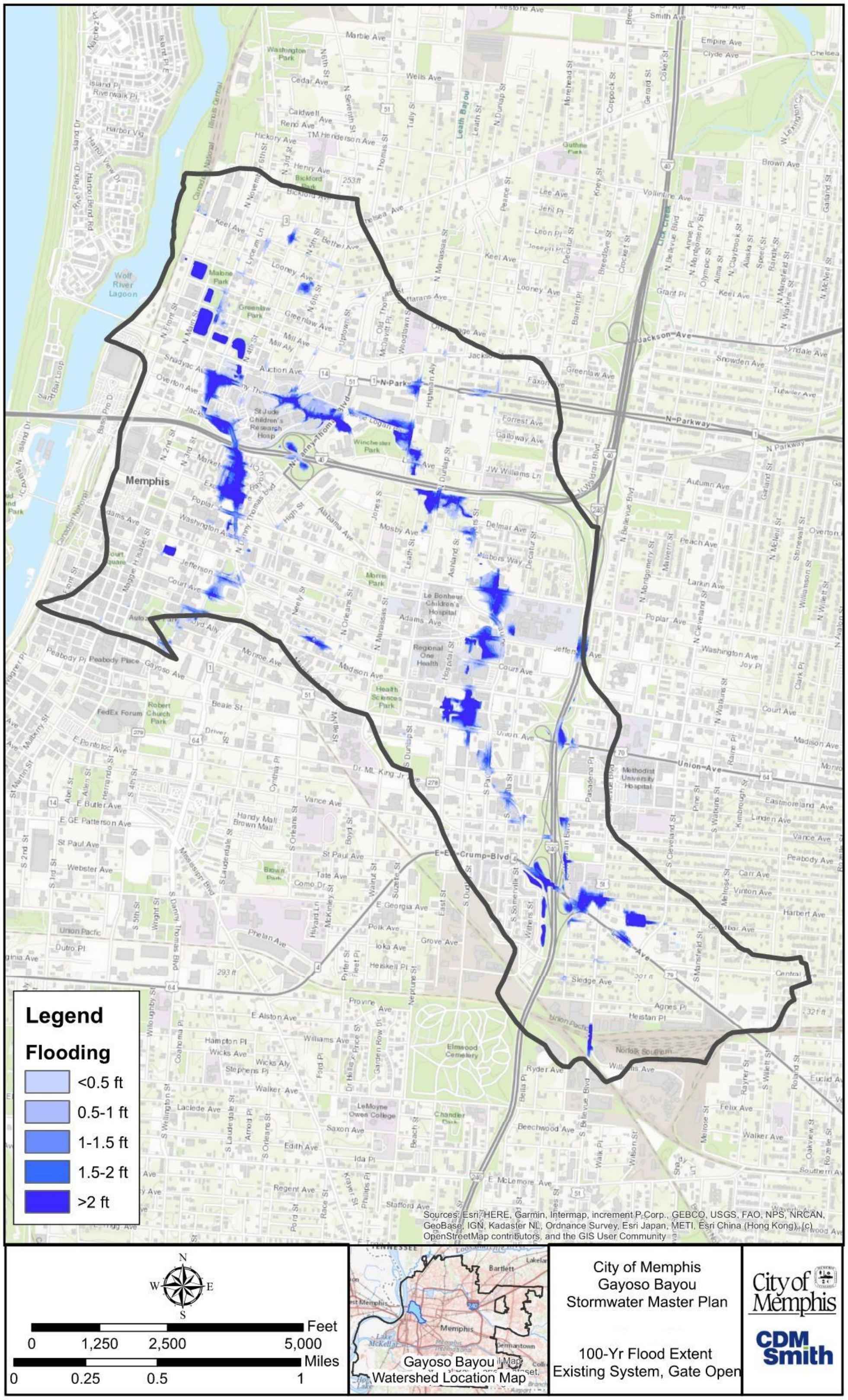

Figure 3-7
100-yr Flood Extent

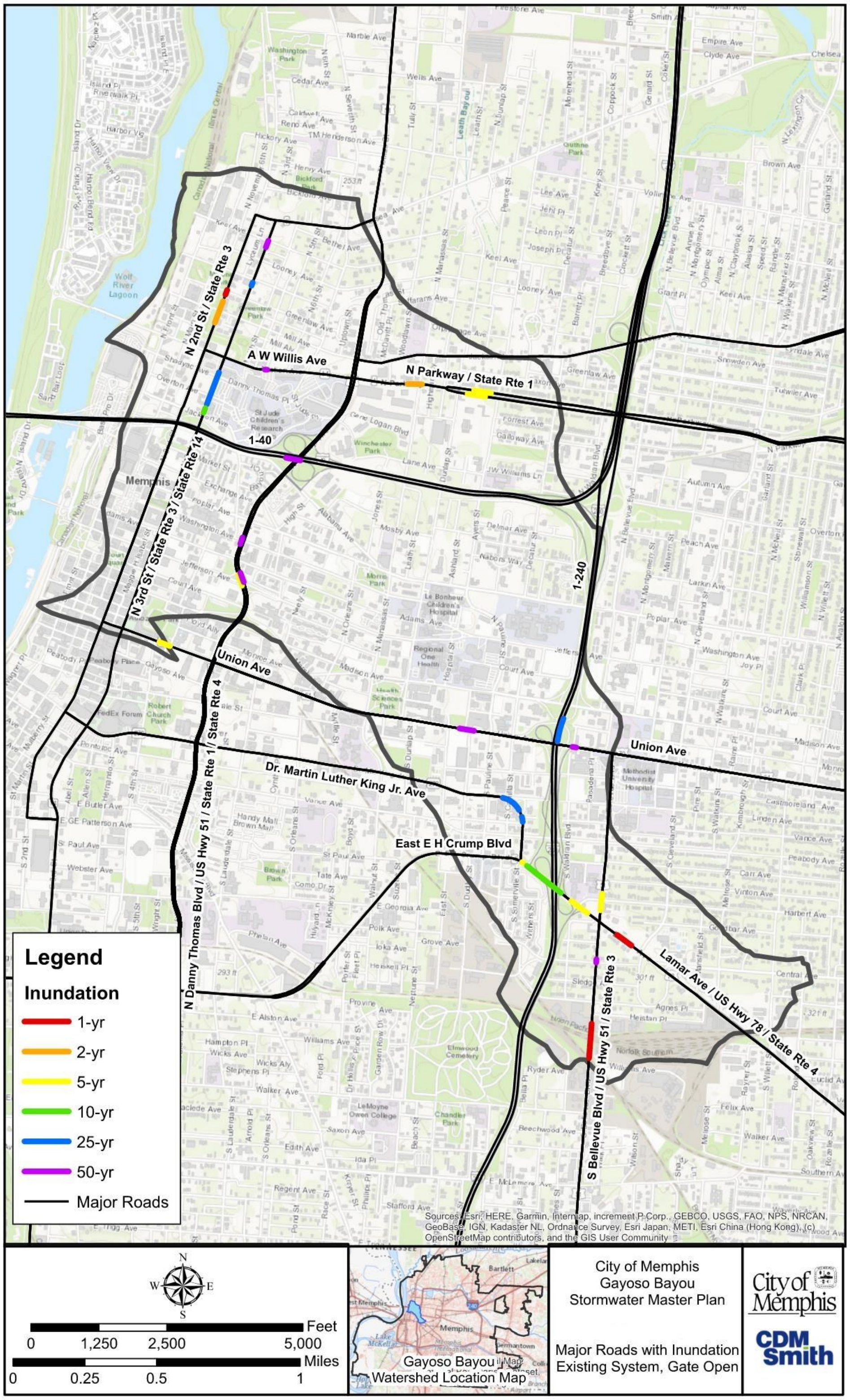

Figure 3-8
Major Roads with Inundation

Section 4

Proposed Results

4.1 Proposed Scenario Summary

In response to historical flooding and the need for infrastructure improvements, the City of Memphis initiated a city-wide Storm Water Master Planning (SWMP) program to identify improvement projects to address roadway and structural flooding. This document provides a SWMP for the Gayoso watershed located in central Memphis. All alternatives were assessed using the 10-year 24-hour SCS Type-II storm. The following subsections describe the improvement projects identified by CDM Smith through field reconnaissance and modeling. Detailed descriptions of the development of each project can be found in Volume II, Section 3 of this report. Each of the four scenarios listed in this section contain multiple correlated projects that have co-benefits that are only fully achieved with the construction of all projects. Section 4.2 below provides a recommended plan and sequencing for execution of the projects based on summary of potential project benefits. Generally, the quoted costs of storage are lower than conveyance as they do not include property acquisition or site remediation costs.

One of the drawbacks of only modeling the primary system is the chance that very local repetitive flooding issues may not rise to the surface. Hydraulic modeling naturally assumes that all flows enter the system and are handled by the PSMS. In practice, inlets, swales, and other secondary features may not function as intended. Flood tickets provided by the City show these issues throughout the watershed. To address these issues, green infrastructure priority areas were stated for areas surrounding current alternatives. An added benefit to utilizing green infrastructure in these areas is that the prescribed storage areas would have a higher likelihood of having available capacity to handle storm flow when storm events occur. Possible green infrastructure implementations could take the form of rain gardens, rain barrels, cisterns, collared inlets in parks, pervious pavement, or bioretention areas. Individual methods should be tailored to the footprint and physical parameters of the location.

A summary of the proposed scenarios is itemized below. **Figure 4-1**, located at the end of this section, includes an overview map. The improvements are only intended to address flooding issues. However, during detailed design, consideration should be given to potential water quality enhancements that could be implemented for synergies with the City's water quality improvement program. Conveyance alternatives were prioritized to take place within City right-of-way to make use of an ordinance that requires utilities to pay for relocation themselves.

Finally, property buyouts were recommended in a limited number of locations, specifically at 279 Exchange Avenue and 218 Lauderdale Street. Another 6 potentially inundated structures are in areas where no improvements have been investigated. These are in areas with less dense development or areas with very isolated predicted flooding. Modeling indicated that these structures were not at risk of flooding in the 10-yr event, but are at risk in higher return period events. Follow up study may show that the structures can be further protected with physical improvements or other options can be considered.

4.1.1 Scenario 1: Pinch District Alternatives

Scenario 1 includes known issues of the central Gayoso Bayou watershed. This includes the critical Gayoso Bayou Pump Station and flood gate and its associated pond system. This area is also home to St. Jude Children's Research Hospital and most of the Pinch District.

4.1.1.1 Scenario 1A: Gate Operations and Pump Station Alternatives

Scenario 1A includes:

1. Implementation of specific and predictable operational guidance for anticipated large storm events when the river is above action stage;
2. Additional study for feasibility, permitting, and costing of an 1,800 cfs pump station near the existing pump station.

No costs were developed for Scenario 1A.

4.1.1.2 Scenario 1B: Pinch District Conveyance Improvements

Scenario 1B includes:

1. 750 LF of replacement 60" pipe/culvert on 3rd Street between Overton and Shadyac;
2. 400 LF of replacement 48" pipe on 2nd Street south of Saffarans, 250 LF of 54" pipe along Greenlaw to the Gayoso Bayou ponds;
3. 200 LF of replacement 30" pipe on 4th Street north of Keel, 750 LF of 30" pipe on Keel Ave between 6th and 4th Street, 600 LF of 36" pipe on 4th Street between Keel and Saffarans.

Under existing conditions for Scenario 1, one major road and three minor roadways are predicted to flood. However, with the proposed improvements, flooding is predicted to be eliminated at one major road crossing and to be improved at two minor road crossings for the 10-year gate-open design storm event. Based on collected finished floor elevations in the area, two structures are predicted to be protected from inundation within the improvement area, while another 65 structures are predicted to have their flood peak HGLs reduced in the vicinity of the improvements.

Conceptual Project Costs: $2,325,000

4.1.1.3 Scenario 1C: Pinch District Storage Alternatives

Scenario 1C includes:

1. A detention basin near 4th Street and Saffarans Ave totaling 3.3 ac-ft, Potential Sites A-E.

As in Scenario 1B, under existing conditions, one major road and three minor roadways are predicted to flood. Conveyance alternatives from 1B provide extensive relief to this flooding; however, with the proposed improvements, flooding is predicted to be eliminated at one minor road crossing for the 10-year gate-open design storm event. Based on collected finished floor elevations in the area, 65 structures are predicted to have their flood peak HGLs reduced in the vicinity of the improvements.

Conceptual Project Costs: $2,195,000

4.1.1.4 Scenario 1C: Pinch District Green Infrastructure Alternatives

Scenario 1D includes:

1. Proposed green infrastructure implementation in the polygon generally east of N Main St, south of Keel Ave, west of 6th St, and north of Greenlaw Ave.

Costs not developed for this scenario.

4.1.2 Scenario 2: Lamar and Bellevue Area Alternatives

Scenario 2 is in the southeastern part of the Gayoso Bayou watershed. The scenario includes pipes/culverts along Bellevue Blvd, Agnes Place, Waldran Blvd, and Lamar Avenue, and is generally East of I-240.

4.1.2.1 Scenario 2A: Lamar and Bellevue Conveyance Alternatives

Scenario 2A includes:

1. 2,800 LF of 48" pipe along S Bellevue Blvd, Agnes Place, and Waldran Blvd to replace existing lines;
2. 850 LF of new 36" pipe along S Bellevue Blvd;
3. 800 LF of relief 5x7' box culvert along Bellevue Blvd and Harbert Ave.

The improvement area for Scenario 2 contains drainage crossings of three major roads and three minor roads. Under existing conditions these crossings are predicted to flood. However, with the proposed improvements, flooding is predicted to be eliminated at one major and two minor road crossings for the 10-year design storm event.

Conceptual Project Costs: $4,780,000

4.1.2.2 Scenario 2B: Lamar and Bellevue Storage Alternatives

Scenario 2B includes:

1. A detention basin at Waldran Blvd and Minna Place totaling 6.25 ac-ft, Potential Sites A-G;
2. A detention basin near Central Ave and Lamar Ave totaling 9 ac-ft, Potential Sites H-J.

The improvement area for Scenario 2 contains drainage crossings of three major roads and three minor roads. Under existing conditions these crossings are predicted to flood. However, with the proposed improvements, flooding is predicted to be eliminated at one minor road crossing, and with the conveyance improvements in Scenario 2A, to be improved at two major road crossings for the 10-year design storm event. Utilizing surveyed finished floor elevations of structures, 4 structures are predicted to be protected from inundation within the improvement areas.

Conceptual Project Costs: $5,100,000

4.1.2.3 Scenario 2C: Lamar and Bellevue Green Infrastructure Alternatives

Scenario 2C includes:

1. Proposed green infrastructure implementation in the polygon generally east of Waldran Blvd, south of Central Ave, west of Willett St, and north of Agnes Place.

Costs not developed for this scenario.

4.1.3 Scenario 3: Dunlap Street Corridor Alternatives

Scenario 3 is in the east-central part of the Gayoso Bayou watershed and is bisected by I-40 and generally follows Dunlap Street, Manassas Avenue, and Pauline Street. The scenario includes pipes and culverts in several locations. Three storage units are recommended for a total storage volume of 26.5 acre-feet.

4.1.3.1 Scenario 3A: Dunlap Street Corridor Conveyance Alternatives

Scenario 3A includes:

1. 950 LF of new 30" pipe along Ayers St from Poplar to Mosby;
2. 1,150 LF of relief 7x8' box culvert following the existing Pauline St culvert between Poplar and Mosby;
3. 1,150 LF of new and relief 4x5' box culvert between N Parkway and Gene Logan Blvd;

The improvement area for Scenario 3 contains drainage crossings of two major roads and five minor roads. Under existing conditions these crossings are predicted to flood. However, with the proposed improvements, flooding is predicted to be eliminated at one major road crossing and two minor road crossings, and to be improved at one other major road crossing for the 10-year design storm event.

Conceptual Project Costs: $5,060,000

4.1.3.2 Scenario 3B: Dunlap Street Corridor Storage Alternatives

Scenario 3B includes:

1. A detention basin near Dunlap St and N Parkway totaling 1 ac-ft, Potential Sites F-AO;
2. A detention basin at Mosby Ave and Ashland St totaling 8.5 ac-ft, Potential Sites AP, AQ;
3. A detention basin near Poplar and Pauline St totaling 8.5 ac-ft, Potential Sites AR-AS;
4. A detention basin south of Dunlap St and I-40 totaling 8.5 ac-ft, site not proposed.

The improvement area for Scenario 3 contains drainage crossings of two major roads and five minor roads. Under existing conditions these crossings are predicted to flood. However, flooding is predicted to be improved at two major road crossings and eliminated at three minor road crossings. Utilizing surveyed finished floor elevations of structures, 4 structures are predicted to be protected from inundation within the improvement areas.

Conceptual Project Costs: $3.080,000

4.1.3.3 Scenario 3C: Dunlap Street Corridor Green Infrastructure Alternatives

Scenario 3C includes:

1. Proposed green infrastructure implementation in the polygon generally east of Manassas St, south of N Parkway, west of Decatur St, and north of Poplar Ave.

Costs not developed for this scenario.

4.1.4 Scenario 4: Tanyard Bayou / Medical District Alternatives

Scenario 4 is in the west-central part of the Gayoso Bayou watershed, generally northwest of Medical Sciences Park. The scenario includes pipe improvements along Avant Lane near the Edison Apartments and along Jefferson Ave between B.B. King and Danny Thomas. Storage totaling 3 acre-feet is included near Orleans St and Madison Ave.

4.1.4.1 Scenario 4A: Tanyard Bayou / Medical District Alternatives

Scenario 4A includes:

1. 300 LF of replacement 42" pipe and 400 LF of 60" pipe through the Edison Apartments;

The improvement area for Scenario 4 contains drainage crossings of one major road and one minor road. Under existing conditions these crossings are predicted to flood, as are three downstream structures. However, with the proposed improvements, flooding is predicted to be eliminated at both major and minor road crossings for the 10-year design storm event. Utilizing surveyed finished floor elevations of structures, no structures are predicted to be protected from inundation within the improvement areas, while another 3 structures are predicted to be protected in other areas of the watershed. Highly concentrated flood tickets from this area suggest major repetitive flooding events, and though Finished Floor Elevations are above modeled peaks, conditions in the secondary system and locally deteriorated drainage features may exacerbate conditions.

Conceptual Project Costs: $597,000

4.1.4.2 Scenario 4B: Tanyard Bayou / Medical District Alternatives

Scenario 4B includes:

1. A detention basin near Orleans St and Madison Ave totaling 3 ac-ft, Potential Sites A-F.

The improvement area for Scenario 4 contains drainage crossings of one major road and one minor road. Under existing conditions these crossings are predicted to flood, as are three downstream structures. Utilizing surveyed finished floor elevations of structures, no structures are predicted to be protected from inundation within the improvement areas, while another 3 structures are predicted to be protected in other areas of the watershed. Highly concentrated flood tickets from this area suggest major repetitive flooding events, and though Finished Floor Elevations are above modeled peaks, conditions in the secondary system and locally deteriorated drainage features may exacerbate conditions. Scenario 4B decreases local flood levels by roughly 16 inches.

Conceptual Project Costs: $1,985,000

4.1.4.3 Scenario 4C: Tanyard Bayou / Medical District Infrastructure Alternatives

Scenario 4C includes:

1. Proposed green infrastructure implementation within the polygon generally east of Neely St, north of Marshall Ave, west of Dunlap St, and south of Adams Ave.

Costs not developed for this scenario.

4.1.5 Scenario 5: Home Buyouts and Green Infrastructure

Scenario 5 consists of the home buyouts and green infrastructure overlays discussed in Section 4.1. Buyouts are limited in scope and are not costed, thus they do not appear in Section 4.2's rankings. More details can be found in Volume II of the Drainage Master Plan.

4.1.6 Scenario 6: Areas with Potentially Surcharged Pipes

Scenario 6 concerns areas with potentially surcharged pipes. As this study progressed, isolated areas of the closed conduit drainage system were identified with the potential for severely surcharged pipes. Pipes in this condition run the risk of blowing out their manholes and creating hazards, particularly when they are in a roadway or sidewalk. Many of these areas were ameliorated by the improvements listed in previous sections, but two lengths of pipe remained with potential surcharge issues.

1. Jefferson Avenue between B.B. King and Danny Thomas – 1,300 LF of replacement 5'x5' box culvert,
2. 700 LF of relief 6x10' box culvert along Adams Ave between Poplar and Jefferson.

No major or minor roads have flooding in the immediate vicinity and no flooding is observed above finished floor elevations. These two alternatives serve to boost overall system capacity and prevent damage to possibly undersized pipes in large storm events.

Conceptual Project Costs: $4,000,000

Section 4.2 – Prioritization of Alternatives

The segment costs listed are only valid if completed within the whole scenario. If completed singularly, costs may increase and the estimated reduction in stage may not be achieved. Generally, the most advantageous phasing of drainage alternatives consists of implementing storage upstream to downstream, then constructing conveyance downstream back upstream, in order to prevent the potential increase in stages that comes with opening up flow restrictions upstream. Some storage features may require conveyance improvements to fulfill their intended functions, however.

Based on a basic analysis of number of houses or businesses protected versus cost, and with considerations given to the importance of major and minor road crossings kept passable, the following is the recommended sequence of scenario improvements:

1. Scenario 2B: Storage in the Lamar and Bellevue Area

Scenario 2B consists of 9 ac-ft of storage in the vicinity of Lamar and Central Avenue and 6.25 ac-ft of storage near Minna Drive. This Scenario benefits large areas of the Gayoso basin as it is the most upstream storage location and would thus reduce flows throughout the eastern system.

- Engineer's Estimate of Conceptual Construction Costs: $ 5,100,000
- Total benefits acquired by Scenario 2B: 4 structures, 2,000 LF of major road

2. Scenario 1B: Pinch District Conveyance Improvements

Scenario 1B is in the Pinch District. The area directly west of St. Jude along 3rd Street is relieved by the installation of a 60" pipe. This area's criticality to St. Jude Hospital and lack of downstream flooding concerns rank it highly among the alternatives. The additional conveyance improvements to northeast also protect an additional 2 structures and improve road passability throughout the neighborhood.

- Engineer's Estimate of Conceptual Construction Costs: $ 2,325,000
- Total benefits acquired by Scenario 1B: 2 structures, 1,250 LF of major road, 500 LF of minor road

3. Scenario 3B: Storage in the Dunlap Street Corridor

Scenario 3B consists of four storage locations in the central basin. The first is 1 ac-ft near N Dunlap St and North Parkway. The second is 8.5 ac-ft and is located south of I-40 between Dunlap Street and Ayers Street. The third is 8.5 ac-ft and is located near Mosby Avenue and Ayers Street. The fourth is 8.5 ac-ft and is located near Poplar and Pauline Street. The centralized location of these storages improves flooding levels for a significant portion of the basin.

- Engineer's Estimate of Conceptual Construction Costs: $ 3,080,000
- Total benefits acquired by Scenario 3B: 4 structures

4. Scenario 3A: Dunlap Street Corridor Conveyance Improvements

Scenario 3A is in the central region of the Gayoso Bayou watershed. It includes three distinct conveyance improvements that will add significant drainage capacity in the area and improve the functionality of the recommended storage units. The first is located on N Manassas Street between North Parkway and Gene Logan. The next is a relief box culvert parallel to the existing box culvert near Poplar Avenue and N Pauline Street. Finally, the third conveyance improvement is a 30" pipe to redirect drainage north along Ayers Street.

- Engineer's Estimate of Conceptual Construction Costs: $ 5,060,000
- Total benefits acquired by Scenario 3A: 400 LF of major road, 700 LF of minor road

5. **Scenario 4B: Storage in Tanyard Bayou**

Scenario 4B consists of 3 ac-ft of storage in the vicinity of Orleans and Madison Avenue. This Scenario benefits most of the western portions of Gayoso basin as it is the most upstream storage location.

- Engineer's Estimate of Conceptual Construction Costs: $1,985,000
- Total benefits acquired by Scenario 4B: 3 structures

6. **Scenario 1C: Storage in the Pinch District**

Scenario 1C consists of 3.33 ac-ft of storage in the vicinity of 4th and Saffarans. This Scenario is most effective when employed along with the Pinch District conveyance improvements.

- Engineer's Estimate of Conceptual Construction Costs: $2,195,000
- Total benefits acquired by Scenario 1C: 300 LF of minor road

7. **Scenario 2A: Waldran Road Conveyance Improvements**

Scenario 2A is in the south region of the Gayoso Bayou watershed. The scenario begins at the railroad underpass and Bellevue Blvd and continues north along Agnes Place and Waldran Road until it meets the Gayoso Bayou interceptor. Additionally, new local pipes in the neighborhood which drain to a relief box culvert along Bellevue Boulevard will add significant drainage capacity in the area and improve the functionality of the recommended storage units.

- Engineer's Estimate of Conceptual Construction Costs: $ 4,780,000
- Total benefits acquired by Scenario 2A: 450 LF of major road, 850 LF of minor road

8. **Scenario 4A: Tanyard Bayou Conveyance Improvements**

Scenario 4A consists of a stretch of improved pipe beginning in the courtyard of the Edison apartments between Avant Lane and Jefferson Avenue and extending west along Jefferson.

- Engineer's Estimate of Conceptual Construction Costs: $ 597,000
- Total benefits acquired by Scenario 4A: 170 LF of major road, 350 LF of minor road

9. **Scenario 6: Conveyance in Areas with Surcharged Pipe**

Scenario 6 consists of two lengths of pipe on separate stretches of Jefferson Avenue. This scenario adds further capacity to the PSMS and prevents local surcharging on major roads.

- Engineer's Estimate of Conceptual Construction Costs: $ 4,000,000
- Total benefits acquired by Scenario 6: Abatement of surcharge along 2,000 lf of pipe.

Summary of Benefits

Taken in total, 13 structures, 5,300 linear feet of major roads, and 6,300 linear feet of minor roads will be relieved of flooding concerns by the projects listed above. **Figures 4-2 to 4-5** focus on the locations of benefits by each scenario's area.

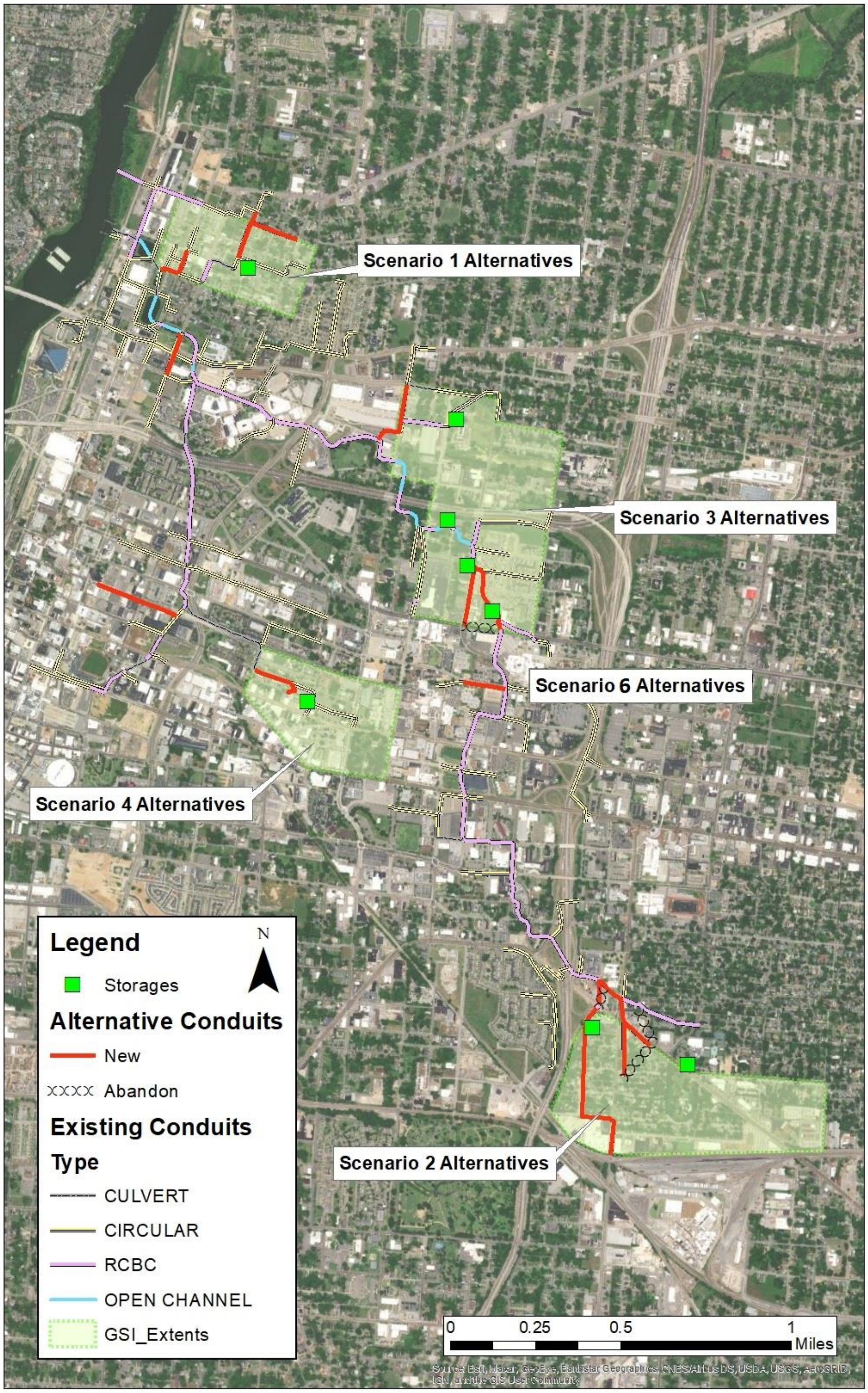

Figure 4-1
Alternatives Overview

Figure 4-2
Scenario 1 – Areas Improved by Alternatives

Figure 4-3
Scenario 2 – Areas Improved by Alternatives

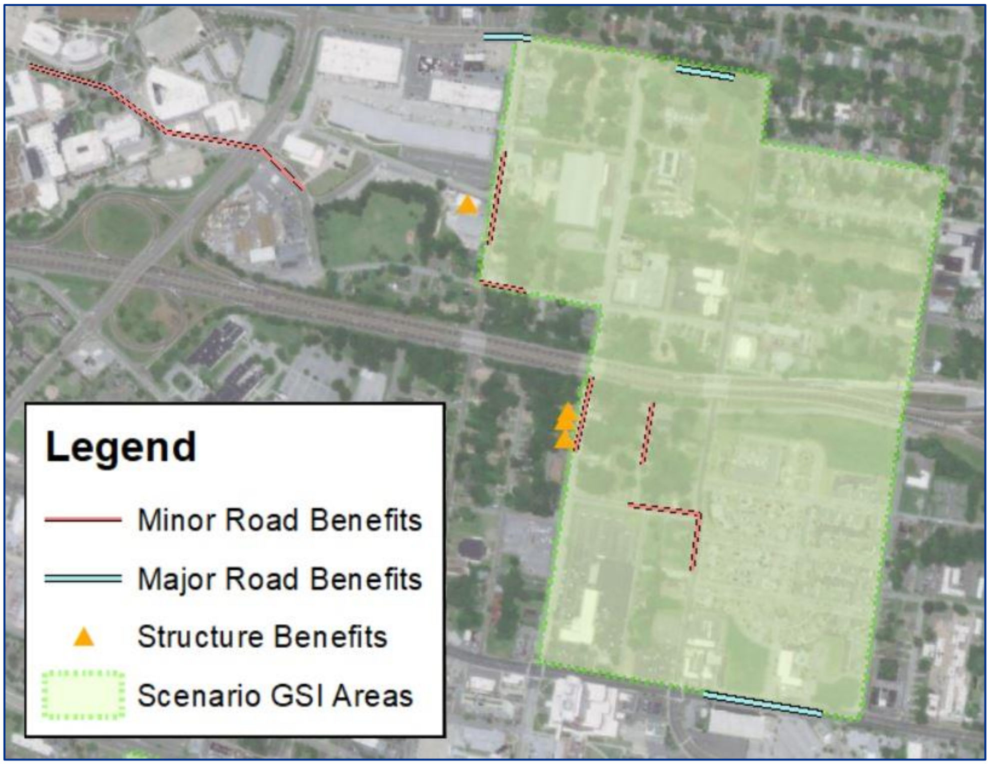

Figure 4-4
Scenario 3 – Areas Improved by Alternatives

Figure 4-5
Scenario 4 – Areas Improved by Alternatives






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