CITY OF GREENVILLE

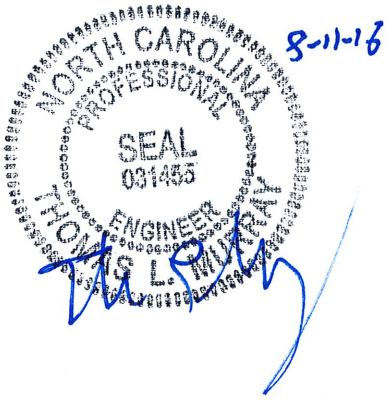
HARDEE CREEK
WATERSHED MASTER PLAN

WKD # 20140067.00.RA

August 2016

Prepared for

City of Greenville
1500 Beatty Street
Greenville, NC 27834



Prepared by
W. K. Dickson & Co., Inc.
Raleigh, NC
919/782/0495
NC License No. F-0374

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Appendices

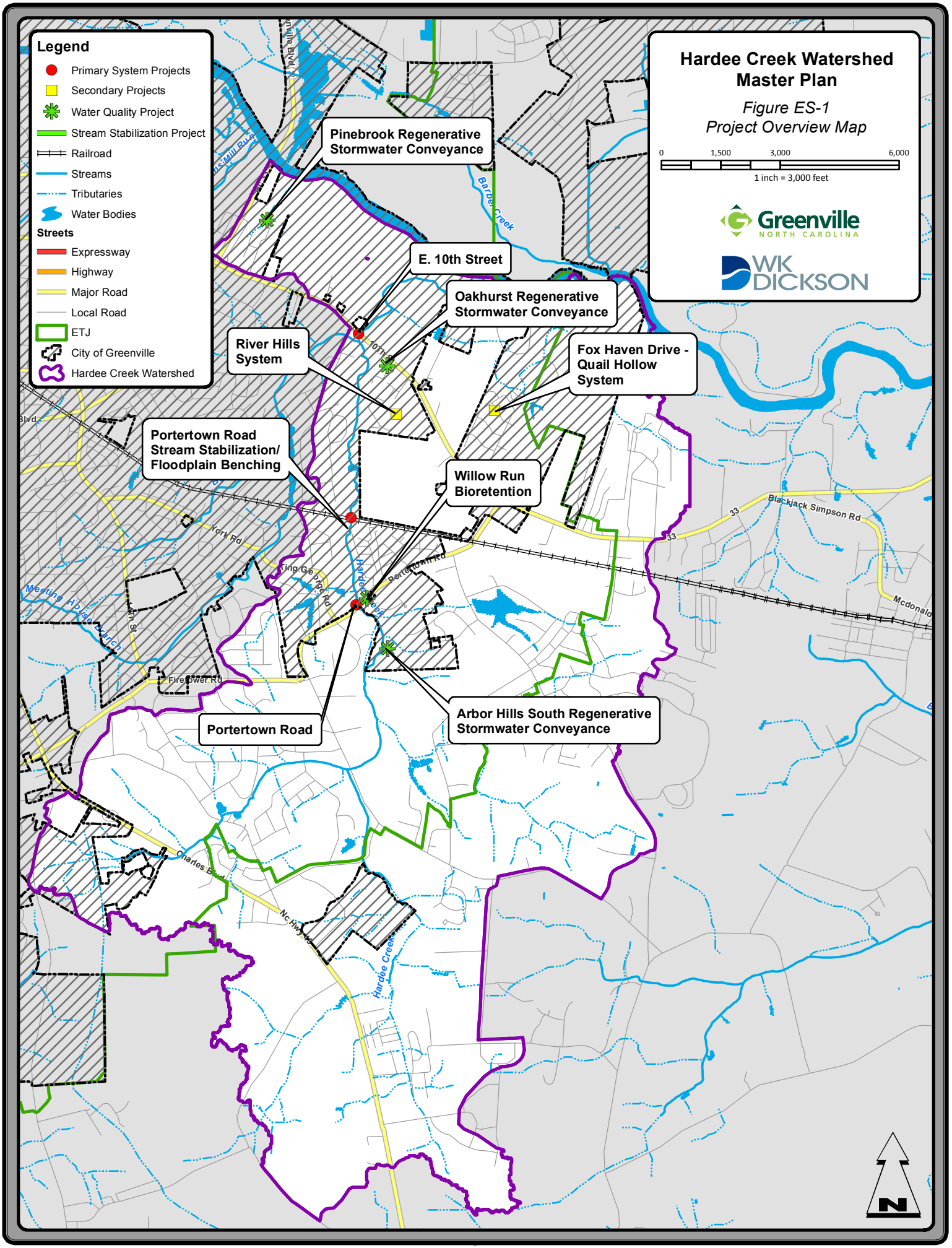
EXECUTIVE SUMMARY

The City of Greenville has retained WK Dickson to complete a Master Plan for the Hardee Creek watershed. The goals of this master plan include: (1) evaluate the existing flooding, water quality and erosion problems, (2) recommend and prioritize capital improvements to control existing flooding by reducing the frequency and severity of flooding for property owners, and (3) identify stream stabilization projects to reduce the risk of property loss along streams and reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, WK Dickson completed a stormwater drainage infrastructure inventory for drainage structures and features within the Hardee Creek watershed. Over 560 drainage structures and approximately 8 miles of drainage pipes was located and incorporated into a GIS database as part of this effort.

The project included a broad range of stakeholders to collect as much data, information, and tacit knowledge of the watershed as feasible. The general public was solicited through questionnaires mailed to all property owners in the watershed and through an open house public meeting where residents and business owners were encouraged to provide feedback on stormwater issues in the watershed. Information collected from the questionnaires and public meeting can be found in Section 2.1 and Appendix D. City staff served as a critical stakeholder by providing valuable information regarding historical flooding and erosion problems in the watershed as well as providing feedback on potential capital improvements and their prioritization.

The project watershed is approximately eight (8) square miles and is located in the eastern portion of Greenville just south of the Tar River. Approximately 30% of the watershed is contained within City limits, and the watershed is 65% developed as predominantly residential land use. WK Dickson conducted an Existing Conditions Analysis in order to evaluate the existing hydrologic and hydraulic characteristics of the Hardee Creek watershed. Noted in this report as the Primary System, Hardee Creek and an unnamed tributary to Hardee Creek (referred to as HCUT1), were hydraulically studied in detail based on historical flooding of residential areas and roadways. Furthermore, high storm flows have eroded channel banks over time causing impacts to private yards, fences, and other property enhancements. In addition to the Primary Systems, select conveyance systems (referred to as secondary systems) in the Hardee Creek watershed were analyzed to determine if they meet the desired City design requirements outlined in Section 1.2. These secondary systems were identified based on feedback from City residents and staff.

As a result of the Existing Conditions Analysis, multiple capital improvement and maintenance projects were identified to reduce the severity and frequency of flooding, stabilize stream banks, and improve water quality through stormwater treatment practices. The proposed capital projects are as follows with the locations of each project shown on Figure ES-1.


Legend
Primary System Projects
Secondary Projects
Water Quality Project
Stream Stabilization Project
Railroad
Streams
Tributaries
Water Bodies
Streets
Expressway
Highway
Major Road
Local Road
ETJ
City of Greenville
Hardee Creek Watershed
Hardee Creek Watershed Master Plan
Figure ES-1
Project Overview Map
0
1,500
3,000
6,000
1 inch = 3,000 feet
Greenville
NORTH CAROLINA
WK DICKSON
Pinebrook Regenerative Stormwater Conveyance
E. 10th Street
Oakhurst Regenerative Stormwater Conveyance
River Hills System
Fox Haven Drive - Quail Hollow System
Portertown Road Stream Stabilization/ Floodplain Benching
Willow Run Bioretention
Portertown Road
Arbor Hills South Regenerative Stormwater Conveyance
Barbee Creek
Hardee Creek
York Rd
Blackjack Simpson Rd
Fire Tower Rd
Charles Blvd
Nc Hwy 11
Mcdonald
N

Flood Control Projects

Hardee Creek Primary System

Portertown Road – The existing bridge at this crossing is 2-years old and is currently providing a 10-year level of service. The recommended alternative is to reduce the tailwater by grading floodplain benches downstream of Portertown Road in the left overbank for approximately 2,000 linear feet. The proposed floodplain benching will improve the performance of the existing bridge at Portertown Road and bring it up to the desired 25-year level of service. Water surface reductions in the 25-year storm will be up to 1.3 feet along the project corridor and upstream of Portertown Road. Seven properties will be removed from potential lowest adjacent grade (LAG) flooding in the 25-year storm along Brook Creek Lane and four properties will be removed from potential LAG flooding during the 100-year storm.

Railroad Crossing – The existing trestle bridge at this crossing is in good condition and is currently exceeding a 100-year level of service. Therefore, no capital improvements are proposed at this location.

East 10th Street (NC33) – The twin 12' x 6' RCBCs located downstream of the Hardee Creek and Meetinghouse Branch tie-in are currently providing a 10-year level of service. Since East 10th Street is a major thoroughfare, the desired level of service is the 50-year storm. In order to provide a 50-year level of service at this crossing, the recommended alternative includes installation of two additional 72" floodplain culverts. It should be noted that due to the high traffic volume at this crossing, it is assumed that the floodplain culverts will be installed using tunneling techniques such as jack and bore. The existing twin RCBCs are in good condition and will remain in place. The proposed improvements are expected to lower WSELs by up to 3.07 feet upstream of the crossing for the 50-year event.

Hardee Creek UT 1 Primary System

Holly Hills Road – The existing private bridge at this crossing is currently exceeding a 100-year level of service. No capital improvements are proposed at this private location.

Cardinal Drive – The twin 24" CMPs at this crossing are currently providing a 10-year level of service and are in poor condition. In order to meet a 25-year level of service, the twin 24" CMPs would need to be replaced with twin 24" RCPs. However, this will not be included as part of the City's recommended capital improvement plan since Cardinal Drive is private.

King George Road – The existing 2.5' x 3.5' corrugated metal arch pipe at this crossing is perched and in poor condition. Although it is meeting the desired 25-year level of service, it is

recommended that the CMP be replaced with a 30" RCP. Improvements for this project are currently in the design phase.

Secondary Systems

Fox Haven Drive – Quail Hollow Road System – Roadway flooding has been reported at the intersection of Fox Haven Drive and Quail Hollow Road. This flooding occurs primarily due to the lack of drainage inlets to accept flow into the conveyance system. To reduce flooding at this intersection, the proposed improvements include installing inlets along with 18" RCP to capture and convey flow back to stream.

River Hills System – The majority of the system is operating below a 10-year level of service. Therefore, the proposed improvements include upsizing the existing pipe system and adding an 18" RCP lateral system along Syme Circle. The proposed pipe improvements range in size from 42" RCP to 48" RCP.

Flood Control Prioritization

To appropriately allocate City resources, the flood control projects listed above were prioritized based on the following categories as described in Appendix L:

- Public health and safety
- Severity of street flooding
- Cost effectiveness
- Effect of improvements
- Water quality – BMP
- Open channel – erosion control
- Implementation constraints
- Grant funding
- Constructability

Scores were assigned to each project for the factors listed above to determine the priority list. In some instances, project prioritization will be impacted by the required sequencing of projects to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. Table ES-1 shows the proposed prioritizations and conceptual cost estimates for the Flood Control Improvements. The City should re-visit the prioritization lists annually to determine if priorities should shift. The prioritization scoring for each project and a description of the aforementioned categories is included in Appendix L. The total cost for all of the recommended primary and secondary system capital improvements in the Hardee Creek watershed is approximately $5,630,000.

In addition to the proposed capital projects, a total of $110,000 of maintenance costs are anticipated in the watershed to correct known structural issues with existing infrastructure as listed in Table 10-4. The maintenance costs are estimated assuming City staff would complete the maintenance. If private contractors are required to complete the work, a more detailed cost estimate is recommended for budgeting purposes. The maintenance costs listed above are based on only those deficiencies that could be visually observed during the inventory field work. With the exception of outfalls, the condition of stormwater pipes is difficult to assess in the absence of visual evidence of sink holes or other surface disturbance. A comprehensive condition assessment would be required to accurately determine all of the maintenance needs in the watershed. The maintenance costs listed above also do not include the routine maintenance required to keep the conveyance system operational as designed.

Table ES-1: Flood Control Project Prioritization – Primary Systems

Prioritization	Project	Cost
1	Portertown Road Floodplain Benching	$3,780,000
2	East 10th Street Floodplain Culverts	$890,000
	Total	$4,670,000

Table ES-2: Flood Control Project Prioritization – Secondary Systems

Prioritization	Project	Cost
1	Fox Haven Drive – Quail Hollow Road	$410,000
2	River Hills	$550,000
	Total	$960,000

Stream Stabilization and Water Quality Projects

During the Existing Conditions Analysis, the majority of the streams were quantitatively assessed for stability. Based on the assessments completed, there were no recommended stream stabilization projects within the Hardee Creek watershed.

Water quality BMP retrofit projects were identified to provide treatment for areas not currently treated. Potential project locations were initially identified using available GIS data by focusing on locations with contributing drainage areas that are highly impervious and preferably on publically-owned land. Impervious areas typically generate the highest concentration of pollutants, so treating the runoff from these areas would provide more pollutant material than treating water that carried fewer pollutants. Publically-owned land is ideal for BMP retrofits to reduce or eliminate potential land acquisition costs. See Section 5.2 for additional evaluation criteria for BMP retrofit sites. Potential locations that were identified using GIS were then presented to the City. Following concurrence with the City, the final list of BMPs were field inspected to determine any project constraints present that may not be discernible from GIS data, such as utility conflicts, limited access to the site, or private property conflicts.

The water quality projects were prioritized using categories similar to those used to prioritize the flood control projects described above (See Appendix L). Cost effectiveness for the water quality projects was calculated based on the cost of nutrient pounds removed per acre per year. Table ES-2 shows the prioritization of the water quality projects along with estimates of their preliminary cost.

Table ES-3: Water Quality Project Prioritization

Prioritization	Project	Cost
1	Pinebrook RSC	$320,000
2	Oakhurst RSC	$150,000
3	Willow Run Bioretention	$250,000
4	Arbor Hills RSC	$160,000
	Total	$880,000

25-Year Detention

The City of Greenville's 25-year detention requirement for new development and redevelopment requires analysis for areas within the watershed and ETJ that require detention based on "well documented water quantity problems." The watershed was analyzed for historical cases of structural flooding and roadway overtopping, however there are limited reports of significant flooding in the watershed. Future development scenarios were evaluated based on existing land use and proposed land use from City and County zoning. Results of the future development analysis showed that the impact from future development on the existing conveyance system would not be significant as future flows for the 25-year storm were approximately 8% higher than existing flows. The anticipated capital savings from requiring 25-year detention are estimated to be less than $1 Million. Based on the analysis and evaluating feedback from the City staff, model results, public feedback, and anticipated future development, there are no recommendations for requiring 25-year detention for future development in the watershed. It is recommended that the City closely evaluate rezoning applications both within City limits and in the ETJ to determine if the rezoning could potentially cause an increase in the risk of downstream flooding.

INTRODUCTION

1.1 PROJECT DESCRIPTION

The City of Greenville had retained WK Dickson to complete a Watershed Master Plan for the Hardee Creek watershed. As shown in Figure 1-1, the Hardee Creek watershed is located in the eastern portion of Greenville and generally drains south to north discharging to the Tar River. As noted in the Executive Summary, the goals of the Master Plan include: (1) evaluate the existing flooding, water quality and erosion problems, (2) recommend and prioritize capital improvements to control existing flooding by reducing the frequency and severity of flooding for property owners, and (3) identify stream stabilization projects to reduce the risk of property loss along streams and reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, WK Dickson completed a stormwater drainage infrastructure inventory for drainage structures and features within the Hardee Creek watershed.

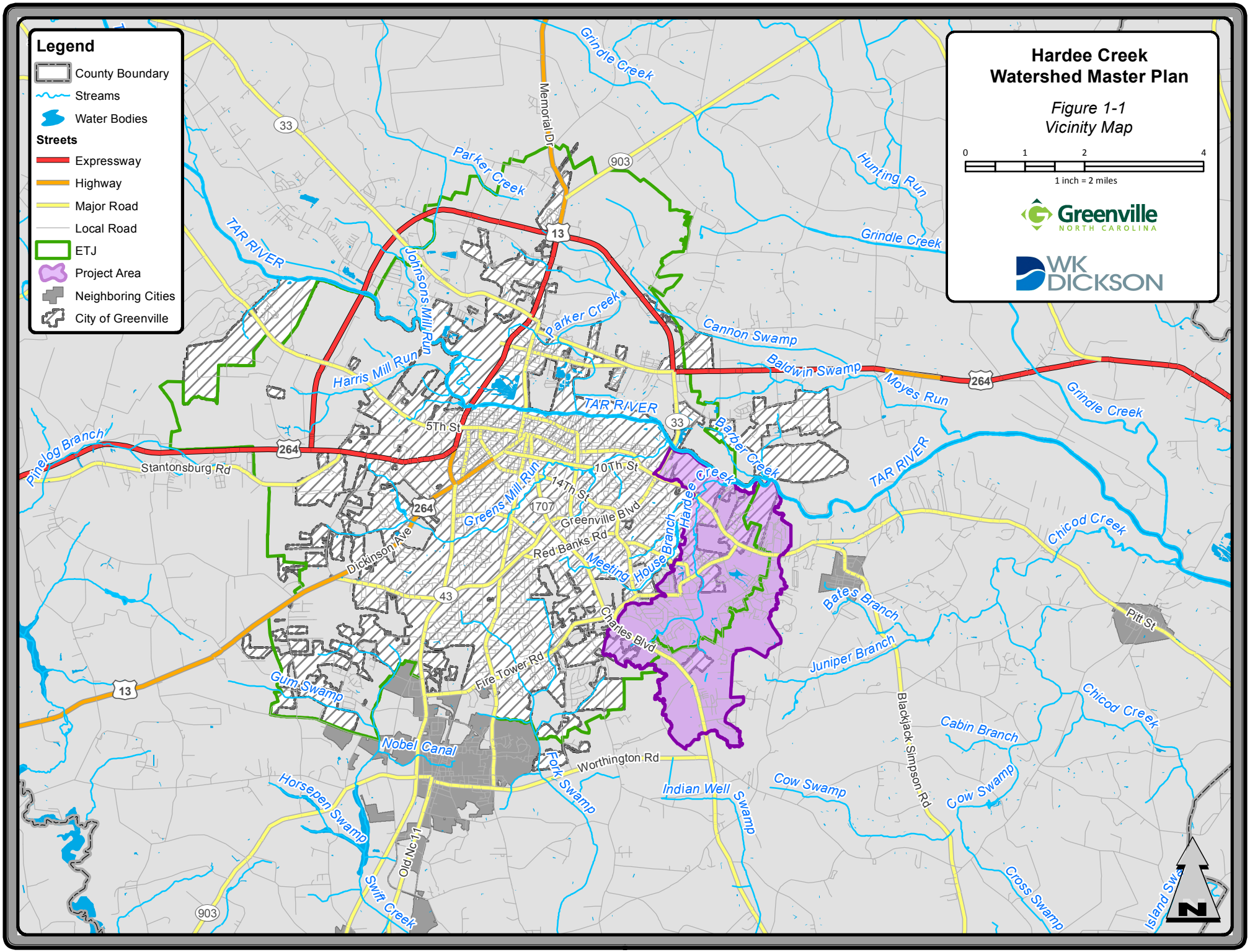
The Master Plan includes an evaluation of the segment of Hardee Creek from approximately 1,900 feet upstream of Portertown Road at the upstream end to its outfall at the Tar River as well as an unnamed tributary to Hardee Creek (referred to as HCUT1) from it confluence with Hardee Creek at the downstream end to approximately 170 feet upstream of the Holly Hills Road crossing. Additionally, two (2) conveyance systems that drain to the main creeks were evaluated. For the purposes of this report, Hardee Creek and HCUT1 will be noted as primary systems and the conveyance systems will be noted as secondary systems. A project area map showing the Hardee Creek watershed and the conveyance systems evaluated as part of this Master Plan is included as Figure 1-2. Two (2) sub-basins were delineated within the Hardee Creek project limits, but drain directly to the Tar River and therefore were not included in detailed hydrologic modeling. Inventory was completed in these areas as they are within the City limits, although no flooding concerns were identified by either City staff or residents. These basins can be seen in Figure C-1 Primary System Watersheds in Appendix C.

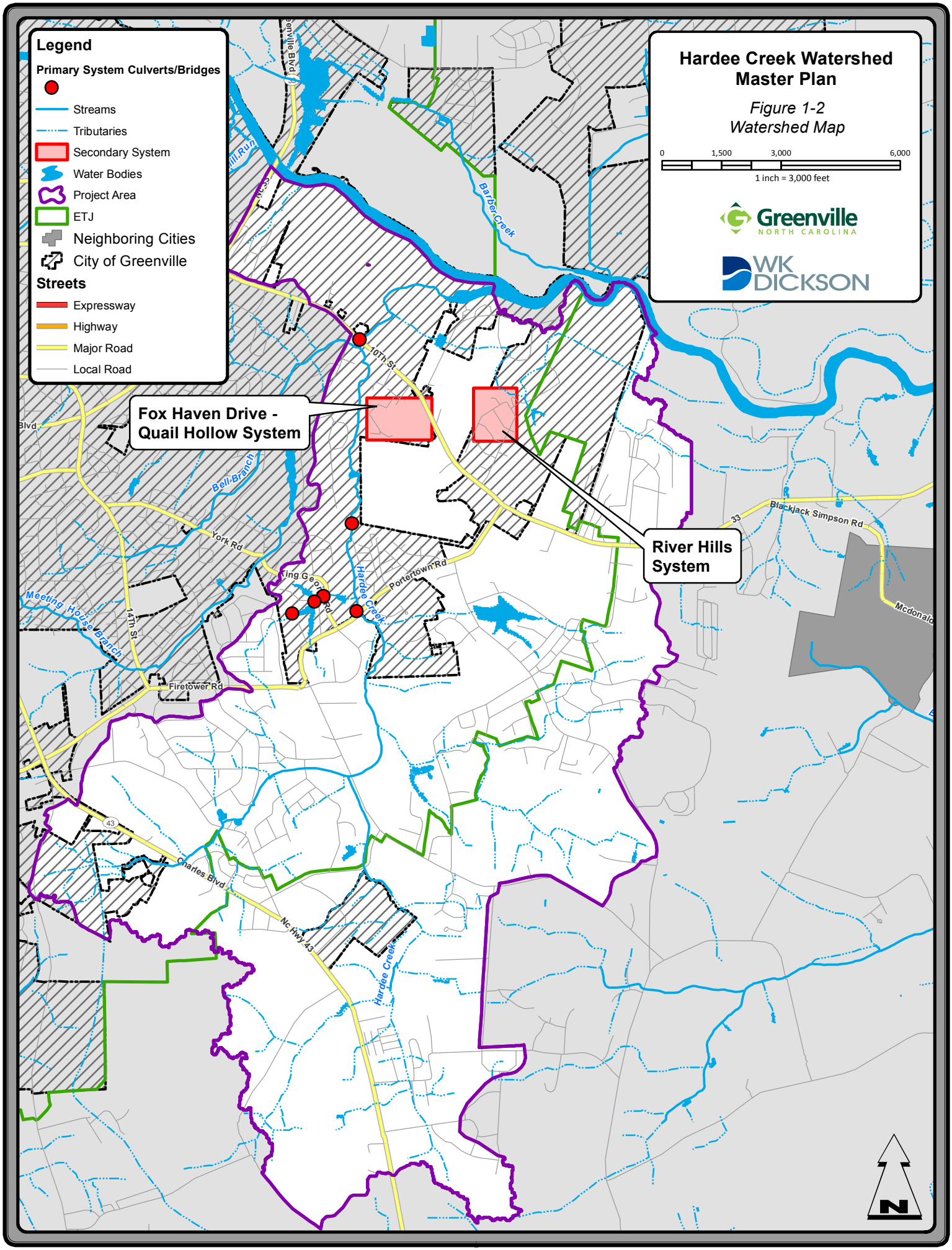
Detailed hydraulic analysis included the following:

- Primary System – Hardee Creek
  - Portertown Road Bridge
  - Railroad Crossing Bridge
  - East 10th Street Culvert

- Primary System – HCUT1
  - Holly Hills Road Bridge
  - Cardinal Drive Culvert
  - King George Road Culvert

- Secondary Systems
    - Fox Haven Drive – Quail Hollow Road System
    - River Hills System


Legend
County Boundary
Streams
Water Bodies
Streets
Expressway
Highway
Major Road
Local Road
ETJ
Project Area
Neighboring Cities
City of Greenville
Hardee Creek
Watershed Master Plan
Figure 1-1
Vicinity Map
0
1
2
4
1 inch = 2 miles
Greenville
NORTH CAROLINA
WK DICKSON
Grindle Creek
Memorial Dr
Parker Creek
Hunting Run
TAR RIVER
Johnsons Mill Run
Harris Mill Run
Cannon Swamp
Baldwin Swamp
Moyes Run
Pinelog Branch
Stantonsburg Rd
5Th St
10Th St
14Th St
Greens Mill Run
Greenville Blvd
Red Banks Rd
Dickinson Ave
Meeting House Branch
Hardee Creek
Barber Creek
Chicod Creek
Bates Branch
Juniper Branch
Pitt St
Charles Blvd
Fire Tower Rd
Gum Swamp
Nobel Canal
Worthington Rd
Fork Swamp
Horsepen Swamp
Old Nc 11
Swift Creek
Indian Well Swamp
Cow Swamp
Blackjack Simpson Rd
Cabin Branch
Cross Swamp
33
903
13
264
43
1707
N


Legend
Primary System Culverts/Bridges
Streams
Tributaries
Secondary System
Water Bodies
Project Area
ETJ
Neighboring Cities
City of Greenville
Streets
Expressway
Highway
Major Road
Local Road
Hardee Creek Watershed Master Plan
Figure 1-2
Watershed Map
0
1,500
3,000
6,000
1 inch = 3,000 feet
Greenville
NORTH CAROLINA
WK DICKSON
Fox Haven Drive - Quail Hollow System
River Hills System
Barber Creek
Bell Branch
Meeting House Branch
Hardee Creek
York Rd
Portertown Rd
Blackjack Simpson Rd
Firetower Rd
14Th St
10Th St
Charles Blvd
Nc Hwy 43
N

1.2 DESIGN STANDARDS AND CRITERIA

The following design storms were used to evaluate the performance of the primary and secondary systems in this Master Plan:

- 10-year storm event – piped collection systems;
- 25-year storm event – minor thoroughfare roadway bridges and culverts;
- 50-year storm event – major thoroughfare roadway bridges and culverts;
- 100-year storm event – structural flooding of homes; and
- 100-year storm event – overtopping of railroad.

Table 1-1 shows the applicable storm for the project areas evaluated as part of this Master Plan. The corresponding rainfall depths for the design storms are included in Appendix A.

Table 1-1: Project Area Design Standards and Criteria

Drainage Type	Design Storm (years)	Project Area
Piped Collection Systems	10	• Fox Haven Drive – Quail Hollow Closed System • River Hills System
Minor Thoroughfare Roadway Crossings	25	• Portertown Road Bridge (Hardee Creek) • Holly Hills Road Bridge (HCUT1) • Cardinal Drive Culvert (HCUT1) • King George Culvert (HCUT1)
Major Thoroughfare Roadway Crossings	50	• East 10th Street (NC 33) Culvert (Hardee Creek)
Railroad Crossing	100	• Hardee Creek – Bridge

EXISTING WATERSHED CONDITIONS

2.1 CITIZEN INPUT

The Master Plan included a citizen input component to solicit feedback and information regarding stormwater impacts and future stormwater management in the City. In August of 2014, the City began distribution of questionnaires related to stormwater management property owners in the Hardee Creek watershed. Fifteen (15) questionnaires were completed and returned to the City for consideration from Hardee Creek watershed property owners. The questionnaire results were georeferenced according to the address of the questionnaire respondent (See Figures 2-1 and 2-2). Three (3) of the respondents indicated some level of property flooding, with one (1) property owners experiencing living space flooding at least once per year. Eight (8) respondents identified locations where street flooding occurs while another three (3) residents reported yard flooding. A total of six (6) residents reported erosion threatening streets, yards, garages, or fences. One (1) report of street flooding, three (3) reports of crawl space flooding, and one (1) report of building flooding came from outside the City limits. See Figure 2-2 for locations of reported erosion. A sample questionnaire and the tabulated results are provided in Appendix D.

On November 4, 2014, the City provided another avenue for obtaining citizen input by holding a public meeting. An open house format allowed property owners to attend at their convenience and speak to City staff or representatives from WK Dickson. Four (4) residents from the watershed provided feedback at the meeting, however three (3) of these attendees live and have concerns outside the City limits. Minutes from this meeting are included in Appendix D.

The results and comments from the citizen's input contributed significantly to the identification and prioritization of problem areas, and validation of model results.

2.2 WATERSHED CHARACTERISTICS

The Hardee Creek watershed is approximately 5,150 acres (8 square miles) between its downstream boundary in the vicinity of East 10th Street and its upstream boundary west of Charles Boulevard. Approximately 30% of this total watershed area is within the City limits, including the two basins that drain directly to the Tar River. The sub-basins that drain to the Tar River comprise of 985 acres (1.5 square miles), of which 66% is within the City limits. Land use in the watershed is approximately 65 percent built out as shown on the Existing Conditions Land Use Map included in Appendix C. The existing land use in the watershed is mostly residential and agricultural with a small percentage of commercial, office, and institutional (See Table 2-1).

Table 2-1a: Hardee Creek Watershed Existing Land Use*

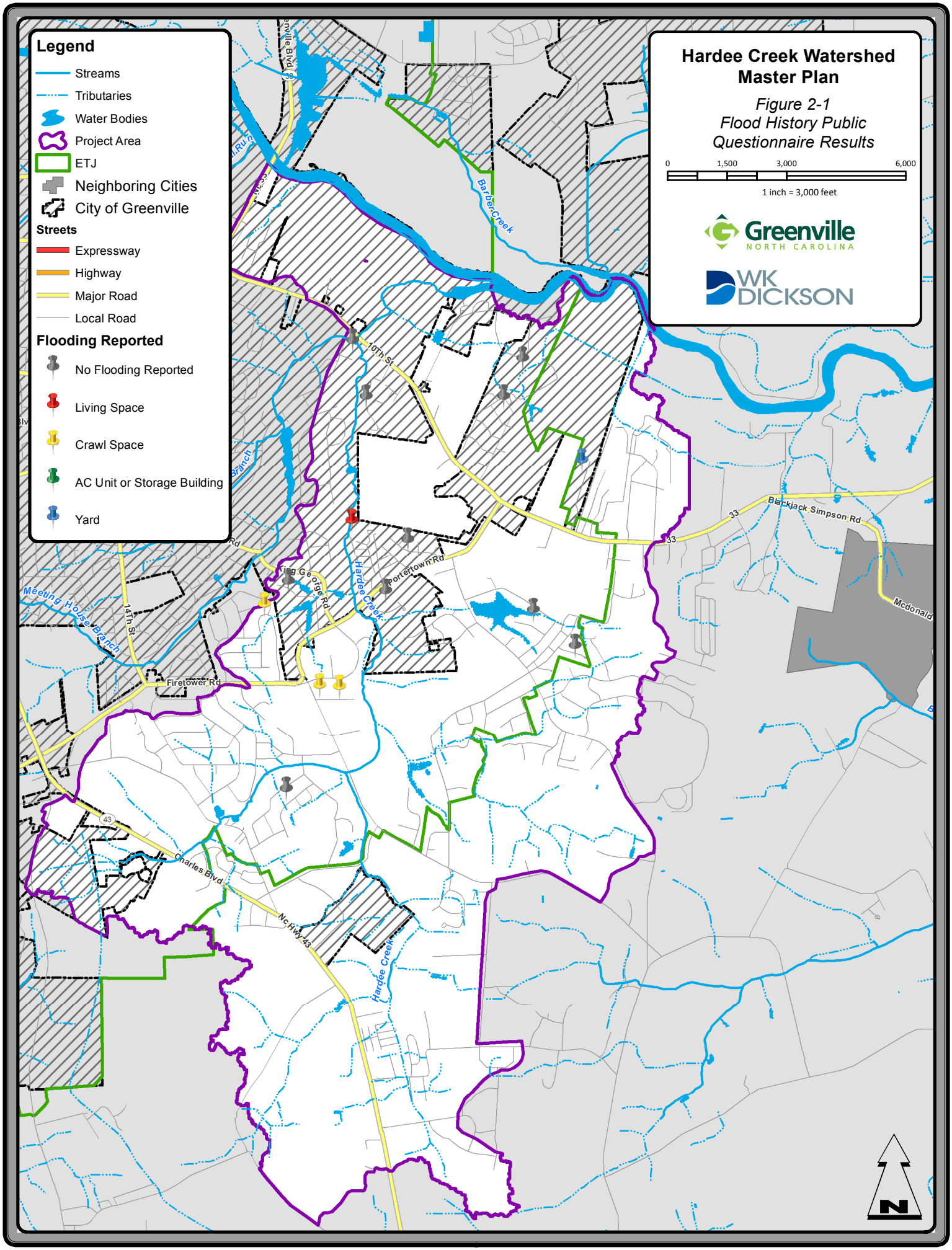
Land Use Category	Area (acres)
Commercial	94
Mixed Use/Office/Institutional	9
Medical Core	2
Office/Institutional/Multi-Family	1
High Density Residential	97
Medium Density Residential	296
Low Density Residential	1,255
Very Low Density Residential	433
Conservation/Open Space	1,289
Right-of-Way	370
Agricultural/Cropland	305
Open Water	14

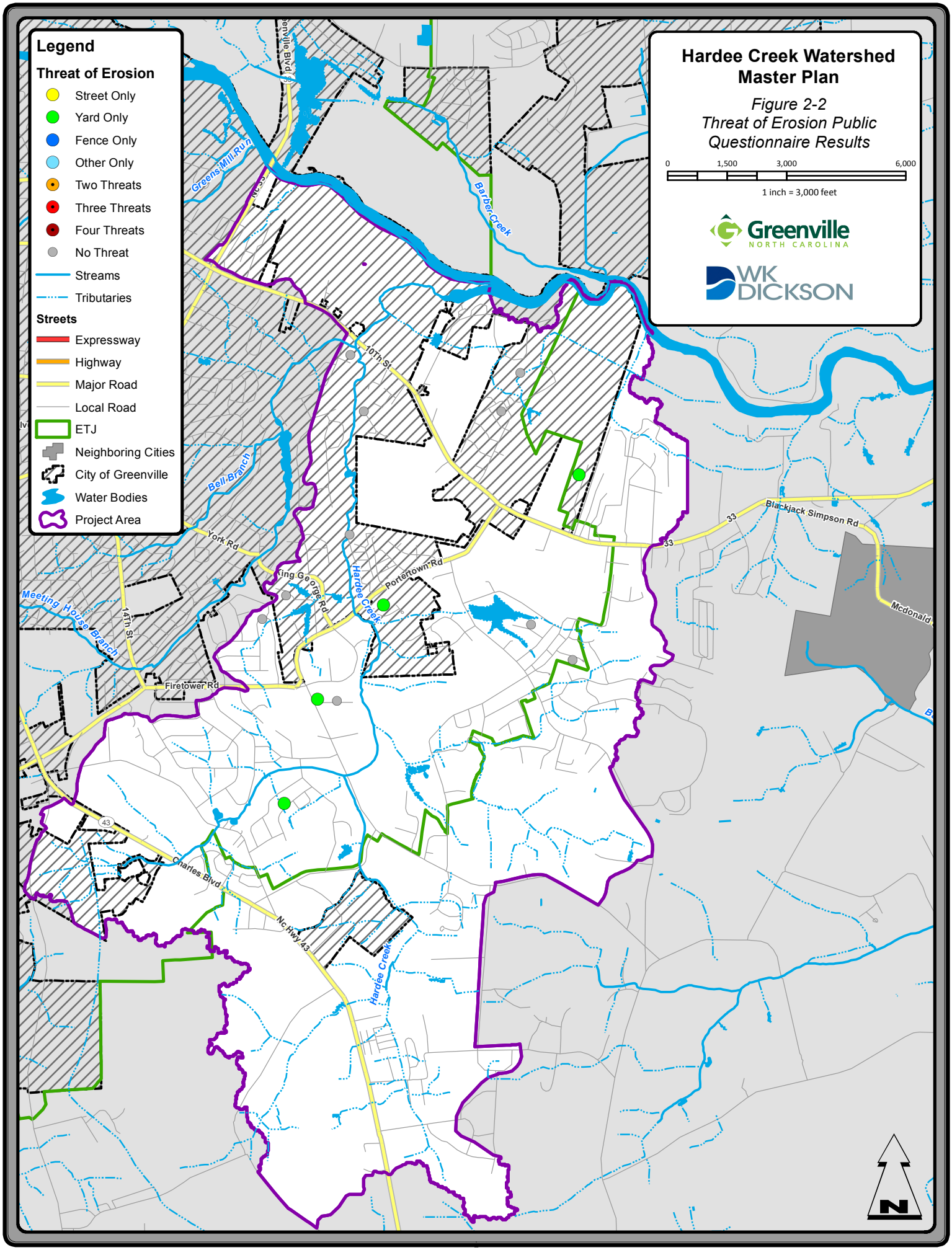
*Does not include downstream basins with unnamed tributaries that drain to the Tar River

Table 2-1b: Hardee Creek Watershed Future Land Use*

Land Use Category	Area (acres)
Commercial	177
Mixed Use/Office/Institutional	10
Medical Core	2
Office/Institutional/Multi-Family	8
High Density Residential	149
Medium Density Residential	293
Low Density Residential	1,569
Very Low Density Residential	1,063
Conservation/Open Space	507
Right-of-Way	373
Open Water	14

*Does not include downstream basins with unnamed tributaries that drain to the Tar River


Legend
Streams
Tributaries
Water Bodies
Project Area
ETJ
Neighboring Cities
City of Greenville
Streets
Expressway
Highway
Major Road
Local Road
Flooding Reported
No Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Hardee Creek Watershed Master Plan
Figure 2-1
Flood History Public Questionnaire Results
0
1,500
3,000
6,000
1 inch = 3,000 feet
Greenville
NORTH CAROLINA
WK DICKSON
Barber Creek
10th St
Blackjack Simpson Rd
33
Portertown Rd
King George Rd
Hardee Creek
Meeting House Branch
14Th St
Firetower Rd
Charles Blvd
NC Hwy 43
43
Mcdonald
N


Legend
Threat of Erosion
Street Only
Yard Only
Fence Only
Other Only
Two Threats
Three Threats
Four Threats
No Threat
Streams
Tributaries
Streets
Expressway
Highway
Major Road
Local Road
ETJ
Neighboring Cities
City of Greenville
Water Bodies
Project Area
Hardee Creek Watershed Master Plan
Figure 2-2
Threat of Erosion Public Questionnaire Results
0
1,500
3,000
6,000
1 inch = 3,000 feet
Greenville
NORTH CAROLINA
WK DICKSON
Greens Mill Run
Barber Creek
10th St
Bell Branch
York Rd
King George Rd
Portertown Rd
Hardee Creek
Meeting House Branch
14th St
Firetower Rd
Blackjack Simpson Rd
33
Mcdonald
Charles Blvd
NC Hwy 43
43
N

The soils within the watershed are predominately NRCS hydrologic groups A and C as shown on the Soils Map included in Appendix C. More detailed information about the land use and soils in the Hardee Creek watershed is provided in Appendix A.

2.3 EXISTING CONDITIONS SURVEY AND FIELD DATA COLLECTION

For the Hardee Creek Watershed Master Plan, stormwater utility infrastructure throughout the watershed in City limits was collected by WK Dickson and River & Associates personnel to compile a Geographic Information System (GIS) stormwater inventory database for the City. This was accomplished by using survey grade Global Positioning Systems (GPS) as the primary means of data capture to locate the x, y, and z coordinates of each visible stormwater system structure. Conventional surveying techniques were used to obtain attributes including but not limited to size, material, slope, and length. The data was collected using horizontal datum NAD 1983 and vertical datum NAVD 1988. A total of 560 closed system structures and 43,876 linear feet of pipe were collected as part of the inventory. Tables 2-2 and 2-3 summarize the inventory collected in the Hardee Creek watershed.

Table 2-2: Inventory Summary – Closed System Structures

Structure Type	Number Surveyed
Yard Inlet	56
Drop Inlet	10
Junction Box	21
Pipe End	163
Pond Structure	4
Chimney Top	15
Catch Basin	287
Underground Pipe Junction	4

Table 2-3: Inventory Summary – Pipes

Size	Length (Linear Feet)
8″ Diameter	103
10″ Diameter	137
12″ Diameter	974
15″ Diameter	13,520
18″ Diameter	10,285
24″ Diameter	7,070
30″ Diameter	4,239
36″ Diameter	4,941
42″ Diameter	680
48″ Diameter	478
54″ Diameter	129
60″ Diameter	727
72″ Diameter	72
'Other' Diameter	494

*Does not include 'mismatched' pipe ends or diameters from underground pipe junctions

Data was obtained for those open channels required to complete connectivity for modeling purposed. Attributes such as shape, lining type, bed type, flow, bottom width, top width, and bank heights were collected for 52 open channel sections totaling over nine (9) miles in length. For those sections of open channel where more detailed information was required for model input, cross sections were surveyed. Data including elevations for the top of the back, bottom of bank, and channel centerline was obtained at 14 cross sections throughout the Hardee Creek watershed to supplement the existing FEMA cross section data. Four (4) bridges were also included in the inventory. Refer to the City of Greenville's Storm Water System Inventory Standard Operating Procedures for additional information about the processes and details of the inventory database.

EXISTING WATERSHED ANALYSIS

3.1 PRIMARY SYSTEM HYDROLOGIC AND HYDRAULIC ANALYSES

3.1.1 HYDROLOGY

The purpose of the hydrologic analysis is to estimate the magnitude of selected frequency floods for the Hardee Creek Watershed. The United States Army Corps of Engineers (USACE) HEC-HMS was selected to model the primary systems. HEC-HMS simulates the surface runoff response to precipitation for an interconnected system of surfaces, channels, and ponds. Input data for the HEC-HMS model was developed using topographic, land use, and soils maps in GIS to delineate and calculate the basin areas and Natural Resources Conservation Service (NRCS) hydrologic parameters. Detailed descriptions of the model parameters can be found in Appendices A and B.

The HEC-HMS model offers a variety of methods for simulating the rainfall-runoff response, hydrograph development, channel and pond routing. The selection of methods for the analyses is based on the study objectives, data availability, and watershed characteristics. The precipitation data for the 24-hour duration, Type III storm was used to represent the synthetic rainfall event. The Type III storm was selected based on the location of the City of Greenville. The geographic boundaries for the different NRCS rainfall distributions are shown on Figure B-2 of NRCS document Urban Hydrology for Small Watersheds, dated June 1986 and commonly referred to as TR-55 (See Appendix A). As shown in TR-55 for the coastal regions of North Carolina including Greenville, a Type III storm is more characteristic. The NRCS curve number approach was selected to calculate runoff volumes from the precipitation data, and the sub-basin unit hydrographs for these flood volumes were developed using the NRCS lag times.

Peak flows for the primary systems were developed for the 2-, 10- , 25- , 50- and 100-year storm events. The existing conditions flows were developed assuming attenuation occurs at the following locations:

- East 10th Street (Hardee Creek)
- King George Road (HCUT1)

Storage routing was modeled just upstream of the culverts listed above because of the large storage volume available behind the pipe's entrance. The culverts that have not been included provide little to no accessible storage volume in the area upstream of its respective crossing. The results of the hydrologic model used as input for HEC-RAS are summarized in Table 3-1. A hard copy of the HEC-HMS output is included as Appendix H. The CD found in Appendix J contains this digital information.

Table 3-1: Existing Conditions Flows from HEC-HMS for Hardee Creek Watershed

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
HARDEE CREEK							
US End	Upstream Limit of Hardee Creek	14866	426	1,019	1,480	1,909	2,397
Portertown Road	Portertown Road	12786	443	1,070	1,558	2,014	2,532
HCUT1_HC_ Confl	Confluence of HCUT and Hardee Creek	11882	491	1,260	1,861	2,427	3,071
Railroad	Railroad	10345	501	1,285	1,925	2,517	3,188
E. 10th	East 10th Street (NC 33)	5340	777	1,811	2,516	3,124	3,794
HARDEE CREEK UT1							
ADD_HCUT_2-1	Holly Hills Road	1712	9	22	31	40	50
Cardinal Culvert	Cardinal Drive	1033	8	25	36	46	61
King George Road Culvert	King George Road	763	9	28	43	65	88

3.1.2 HYDRAULICS

The purpose of the hydraulic analysis is to determine an existing level of flooding for the storm drainage network and to develop proposed solutions to mitigate flooding. The USACE HEC-RAS was selected to model the primary systems to remain consistent with the existing FEMA modeling. HEC-RAS calculates water surface profiles for steady, gradually varied flow in channels and floodplains. The standard backwater analysis for sub-critical flow was modeled for the Hardee Creek Watershed. The model calculates the effect of obstructions, such as culverts, and building structures in the channel and floodplain on the water surface profile. The hydraulic computations are based on the solution of a one-dimensional energy equation with energy loss due to friction evaluated by Manning's equation. Input data for HEC-RAS include the following:

- Cross-section geometry of the channel and floodplain;
- Roughness coefficients to describe characteristics of the channel and floodplain;
- Size, shape, and characteristics of culverts and roadways along the stream reach; and
- Energy loss coefficients for flow in the channel and at roadway crossings.

Channel cross sections utilized in the HEC-RAS model were based on the existing FEMA cross sections and WK Dickson surveyed cross sections. The channel cross sections were merged with State LiDAR data to develop cross sections spanning the entire floodplain area.

There were two (2) HEC-RAS separated models developed to analyze the stream reaches located in the Hardee Creek watershed. The starting water surface elevations for the HEC-RAS models were calculated using the slope-area method. They are as follows:

- 0.0007 feet/feet for Hardee Creek Main Branch
- 0.003 feet/feet for HCUT1

Hydraulic Performance

Six (6) roadway crossings were analyzed for flooding potential for the primary system. Three (3) were located along Hardee Creek while the remaining three (3) were located along HCUT1. Descriptions of the existing primary system crossings analyzed are summarized in Table 3-2. Pictures 3-1 through 3-6 of this report provide a visual image of the primary system crossings.

Table 3-2: Existing Condition of Primary System Crossings

Location	Size/Material	Condition
Portertown Road (Hardee Creek)	Bridge	Good – Relatively New
Railroad Crossing (Hardee Creek)	Trestle Bridge	Fair
East 10th Street (Hardee Creek)	Twin 12′ x 6′ RCBC	Good
Holly Hills Road (HCUT1)	Bridge	Fair
Cardinal Drive (HCUT1)	Twin 24″ CMP	Poor – Rusted Bottom
King George Road (HCUT1)	2.5′ x 3.5′ CMP Arch	Fair

Picture 3-1: Portertown Road Bridge – Downstream Face

Picture 3-2: Railroad Crossing Bridge – Downstream Face

Picture 3-3: East 10th Street Culvert – Downstream Face

Picture 3-4: Holly Hills Road Bridge – Downstream Face

Picture 3-5: Cardinal Drive Culvert – Downstream Face

Picture 3-6: King George Road Culvert – Downstream Face

The 2-, 10-, 25-, 50- and 100-year existing conditions flood elevations for the primary system crossings, along with their corresponding minimum elevation at the top of the road are listed in Table 3-3. Along Hardee Creek, only one out of the three crossings is meeting the desired level of service. The railroad is privately maintained but easily passes the 100-year level of service. Portertown Road and E 10th St are both NCDOT maintained crossings with a 25-year and 50-year desired level of service, respectively. Currently both crossings provide a 10-year level of service. Of the Hardee Creek Tributary crossings, Cardinal Drive does not meet the desired 25-year level of service. Both Cardinal Drive and Holly Hills Road are private streets. King George Road is maintained by the City, and although it meets the desired 25-year level of service, the inventory noted corrosion concerns that warrant maintenance or replacement.

Table 3-3: Hydraulic Performance for Existing Conditions Roadway Flooding

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Portertown Road (Main Branch)	25.58	25-yr	23.73	25.21	**26.83**	**28.01**	**28.91**
Railroad (Main Branch)	41.51	100-yr	18.72	20.80	22.20	23.38	24.20
East 10th Street (Main Branch)	17.87	50-yr	10.05	16.08	**18.27**	**19.76**	**20.27**
Holly Hills Road (HCUT1)	50.94	25-yr	43.84	44.04	44.15	44.24	44.33
Cardinal Drive (HCUT1)	35.73	25-yr	34.41	35.69	**36.27**	**36.44**	**36.54**
King George Road (HCUT1)	35.01	25-yr	31.33	32.94	34.24	**35.13**	**35.27**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.

In addition to evaluating the roadway crossings, an evaluation was performed to determine the residences along the primary system streams that are at risk of flooding during the 25- and 100-year storm event. The existing 25- and 100- year floodplains for these streams are shown in Figures 3-1 through 3-2. The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.

Table 3-4 lists the lowest adjacent grade elevations along with the existing 25- and 100-year water surface elevation for those properties at risk of flooding. The lowest adjacent grade (LAG) elevations shown in the table are not surveyed and are estimated based on the State of North Carolina's LiDAR data. LAG flooding shown in Table 3-4 may not result in actual LAG or finished floor flooding, but it is indicative of structures being at risk of flooding.

Table 3-4: Existing Conditions At-Risk Properties/Structures – Hardee Creek

Address	LAG (feet NAVD)	Calculated Water Surface Elevations (feet NAVD)	
		25-year flood	100-year flood
101 Dundee Lane	19.24	18.36	**20.38**
3590 East 10th Street	14.10	**18.42**	**20.47**
4104A/B Brook Creek Lane	22.63	22.60	**24.65**
4108A/B Brook Creek Lane	22.64	**22.99**	**25.12**
4112A/B Brook Creek Lane	22.64	**23.08**	**25.22**
4116A Brook Creek Lane	22.10	**23.19**	**25.31**
4116B Brook Creek Lane	22.64	**23.14**	**25.26**
4120A Brook Creek Lane	21.70	**23.23**	**25.34**
4120B Brook Creek Lane	21.90	**23.27**	**25.38**
4124A Brook Creek Lane	23.40	**23.38**	**25.48**
4124B Brook Creek Lane	22.40	**23.34**	**25.44**
4132A/B Brook Creek Lane	25.10	23.63	**25.72**
4136A Brook Creek Lane	25.20	23.70	**25.78**
4136B Brook Creek Lane	25.71	23.70	**25.79**
4210B Williamsbrook Lane	25.10	23.64	**25.72**
4230A Williamsbrook Lane	25.00	23.71	**25.80**
4230B Williamsbrook Lane	25.20	23.85	**25.92**
4240A Williamsbrook Lane	20.53	**25.29**	**27.40**
4240B Williamsbrook Lane	21.05	**25.43**	**27.57**
4250A Williamsbrook Lane	21.05	**25.58**	**27.73**
4250B Williamsbrook Lane	26.00	**25.74**	**27.91**
4260B Williamsbrook Lane	27.90	25.70	**27.94**
3610 Willow Run Drive	28.78	27.80	**29.76**
3612 Willow Run Drive	28.52	27.80	**29.78**

*Bold text indicates LAG flooding.

As shown in Table 3-4, thirteen (13) properties along Hardee Creek were identified for being at risk of flooding in the 25-year storm event and an additional eleven (11) properties were identified for the 100-year event. At the East 10th Street crossing, two (2) properties (Willow Run Drive) are affected by the 100-year event. One of these properties also floods during the 25-year event. Properties along Williamsbrook Lane and Brook Creek Lane are likely floodprone due to limited storage in the floodplain. One resident at 4108A Brook Creek Lane submitted a questionnaire indicating that they are experiencing yard and living space flooding.

There are no properties along HCUT1 that were identified for being at risk of flooding in the 25- or 100- year storm events.

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard
- Primary System Crossings
- 100-Year FEMA Floodplain
- 500-Year FEMA Floodplain
- Flooded Properties - 25-Year Storm
- Flooded Properties - 100-Year Storm
- 25-Year Existing Floodplain
- 100-Year Existing Floodplain
- Outside City Limits
- ETJ
- Hardee Creek Watershed

EX Twin 12' X 6' RCBC

SILVER MAPLE LN
COPPER BEECH WY
DUNDEE LN
OXFORD RD
Meetinghouse Branch
PORT TERMINAL RD
HAWTHORNE RD
FOX HAVEN DR
Hardee Creek
QUAIL HOLLOW RD
E 10TH ST
PAM S LN
OAKDOWNE WY
MANN FARM RD
JARED CI
RIVER CHASE DR
SYME CI
SLOAN DR
TANGLEWOOD DR
RIVER HILL DR
BRAMBLEWOOD DR
BRUTON CI
LORI DR
KENT RD
REGENTS CI
STEWARD LN
WINCHESTER DR
HAMPTON CI
CHURCHILL DR
WINDSOR RD
LOCH-VIE W DR

5Th St
10Th St
14Th St
York Rd
Charles Blvd
Firetower Rd
Worthington Rd
33
264
43

Hardee Creek Watershed Master Plan

Figure 3-1
Hardee Creek - North
Existing Conditions Floodplain

8,000 4,000 0 8,000 Feet

1 inch = 500 feet

Greenville NORTH CAROLINA

WK DICKSON

The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.

N

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard
- Primary System Crossings
- 100-Year FEMA Floodplain
- 500-Year FEMA Floodplain
- Flooded Properties - 25-Year Storm
- Flooded Properties - 100-Year Storm
- 25-Year Existing Floodplain
- 100-Year Existing Floodplain
- Outside City Limits
- ETJ
- HardeeCreekWatershed

Railroad Crossing

EX 2.5' X 3.5' CMP Arch

EX Twin 24" CMP

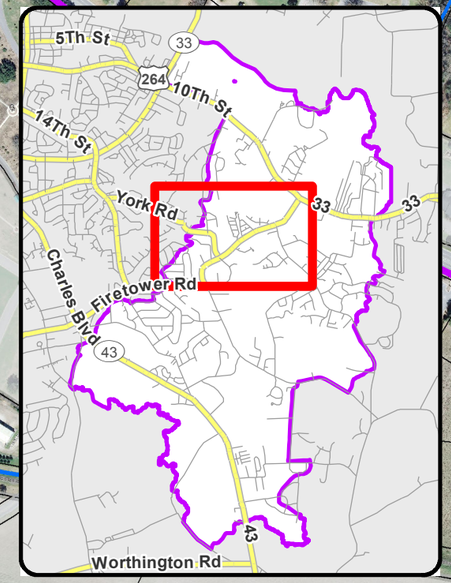
Girder/Wood Bridge

Portertown Bridge

Study Limit

LOCHVIEW DR
CHURCHILL DR
SCOTTISH CT
HASTINGS CT
WINDSOR R
IRIS CT
ROSE RD
PINE BROOK CT
BROOK CREEK LN
ROCKET RD
KALEY CT
ELKIN RIDGE DR
ASHLEY WY
RHEMA ST
CORAL ST
BOYD PARK DR
SASSAFRAS CT
CATTAIL LN
WILLOW RUN DR
LEON DR
SALEM CI
RUSTIC CI
ARBOR DR
EASTERN PINES RD
BRYANT CI
PINERIDGE DR
VALLEY RD
FAULT CI
PLATEAU DR
KNOLL CI
GREY FOX TR
OLD OAK WK
LANCELOT DR
GUINEVERE
AVALON LN
HOLLY HILLS RD
ROBIN RD
DOGWOOD CT
WISTERIA LN
CARDINAL DR
E FIRE TOWER RD

Meetinghouse Branch
Hardee Creek Tributary 1
Hardee Creek



Hardee Creek Watershed Master Plan

Figure 3-2
Hardee Creek - South
Existing Conditions Floodplain

8,000 4,000 0 8,000 Feet

1 inch = 500 feet

Greenville NORTH CAROLINA

WK DICKSON

The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.

3.2 SECONDARY SYSTEM HYDROLOGIC AND HYDRAULIC ANALYSES

While Hardee Creek and HCUT1 are the primary source of flooding within the watershed, undersized systems can also lead to structural and roadway flooding. Based on the questionnaire responses, public meeting, and feedback from City staff, two (2) secondary systems were identified for further evaluation. The secondary systems evaluated are as follows:

- Fox Haven Drive – Quail Hollow Closed System
- River Hills System

3.2.1 HYDROLOGY

The Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) was used to model the two (2) secondary drainages systems located in the Hardee Creek watershed. A detailed description about the hydrologic modeling methodology is included in Appendix A.

3.2.2 HYDRAULICS

Fox Haven Drive – Quail Hollow Closed System

The Fox Haven Drive – Quail Hollow Closed System collects drainage from approximately 40 acres in the Oakhurst subdivision and the surrounding commercial parcels. It discharges directly to Hardee Creek. The conveyance system is comprised of CMP ranging in size from 15 to 42 inches in diameter in good condition based on data collected during the inventory. There is one report of flooding in this area. It is a report of street flooding at the intersection of Fox Haven Drive and Quail Hollow Road. According to the resident, this intersection floods often after rain events.

Figure 3-3 shows that the level of service being provided by the existing closed system. The model results show that the existing system is operating at or above the required 10-year level of service. The primary flooding issue for this area appears to be the lack of infrastructure along Fox Haven Drive. While the road does have curb and gutter and sufficient slope in most areas, there are no inlets or drainage pipes other than at the sag point and culvert crossing along Fox Haven Drive.

River Hills System

The River Hills System collects drainage from 84 acres in the River Hills subdivision and the adjacent parcels. It discharges to a trapezoidal channel north of the subdivision. The conveyance system is comprised of RCP and CMP ranging in size from 24 to 42 inches in diameter in good condition based on data collected during the inventory. There is one report of general street flooding in this area. Figure 3-4 shows that the level of service being provided by the existing closed system. The model results show that the majority of the existing system is operating between a 2- and 10-year level of service. The desired level of service for this system is the 10-year storm.

EX 15" CMP

EX 15" CMP

EX 42" CMP

Drainage Area to Outfall ~40 acres

Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 4.5 ft
Bank Height: 1.5 ft

The channel is able to pass the 10-year peak flow without ovetopping its banks.

EX 18" CMP

FOX HAVEN DR

QUAIL HOLLOW RD

5Th St
Elm St
14Th St
10Th St
264
York Rd
Portertown Rd
33
Charles Blvd
43
Worthington Rd

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard Flooding

- Flared End Section
- Headwall
- Pipe End
- Catch Basin
- Difficult Access Structure
- Drop Inlet
- Junction Box
- Pond Structure
- Pond Dam
- Slab Top Inlet
- Underground Pipe Junction
- Yard Inlet
- Channels

Modeled Pipe Level of Service

- < 2-year
- 2-year
- 10-year
- 25-year
- 50-year
- 100-year
- Non-Modeled Pipes
- BMP
- Watershed Boundary

Hardee Creek Watershed Master Plan

Figure 3-3
Fox Haven Drive
Quail Hollow Closed System Existing Condtions

0 50 100 200

1 inch = 100 feet

Greenville NORTH CAROLINA

WK DICKSON

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard Flooding

- Flared End Section
- Headwall
- Pipe End
- Catch Basin
- Difficult Access Structure
- Drop Inlet
- Junction Box
- Pond Structure
- Pond Dam
- Slab Top Inlet
- Underground Pipe Junction
- Yard Inlet
- Channels

Modeled Pipe Level of Service

- < 2-year
- 2-year
- 10-year
- 25-year
- 50-year
- 100-year
- Non-Modeled Pipes

Drainage Area to Outfall ~84 acres

EX 42" RCP

EX 42" RCP

EX 36" CMP

EX 42" RCP

EX 42" RCP

Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 18 ft
Bank Height: 6 ft

The channel is able to pass the 2-year peak flow without ovetopping its banks.

EX 36" RCP

EX 36" RCP

EX 36" RCP

Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 12 ft
Bank Height: 4 ft

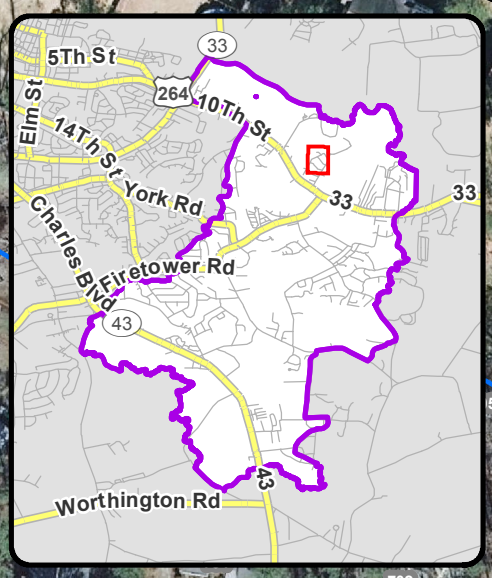
The channel is able to pass the 2-year peak flow without ovetopping its banks.

Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 12 ft
Bank Height: 4 ft

The channel is able to pass the 10-year peak flow without ovetopping its banks.

EX 24" RCP

EX 24" RCP



Hardee Creek Watershed Master Plan

Figure 3-4
River Hill Closed System
Existing Conditions

0 50 100 200

1 inch = 100 feet

Greenville NORTH CAROLINA

WK DICKSON

3.3 STREAM STABILITY FIELD ASSESSMENTS

There are 19.1 miles of streams located in the Hardee Creek Watershed. Within the watershed, all 5.4 miles of Hardee Creek is classified for secondary recreation and aquatic wildlife survival and propagation (Class C) by NCDWR. Hardee Creek is also classified as nutrient sensitive waters (NSW) by NCDWR, indicating it is subject to excessive growth of microscopic or macroscopic vegetation, or it may contribute to downstream nutrient loading (NCDWR 2011). None of the streams in the watershed are listed on the NC Water Quality Assessment and Impaired Waters List (also known as the Integrated 305(b) and 303(d) Report).

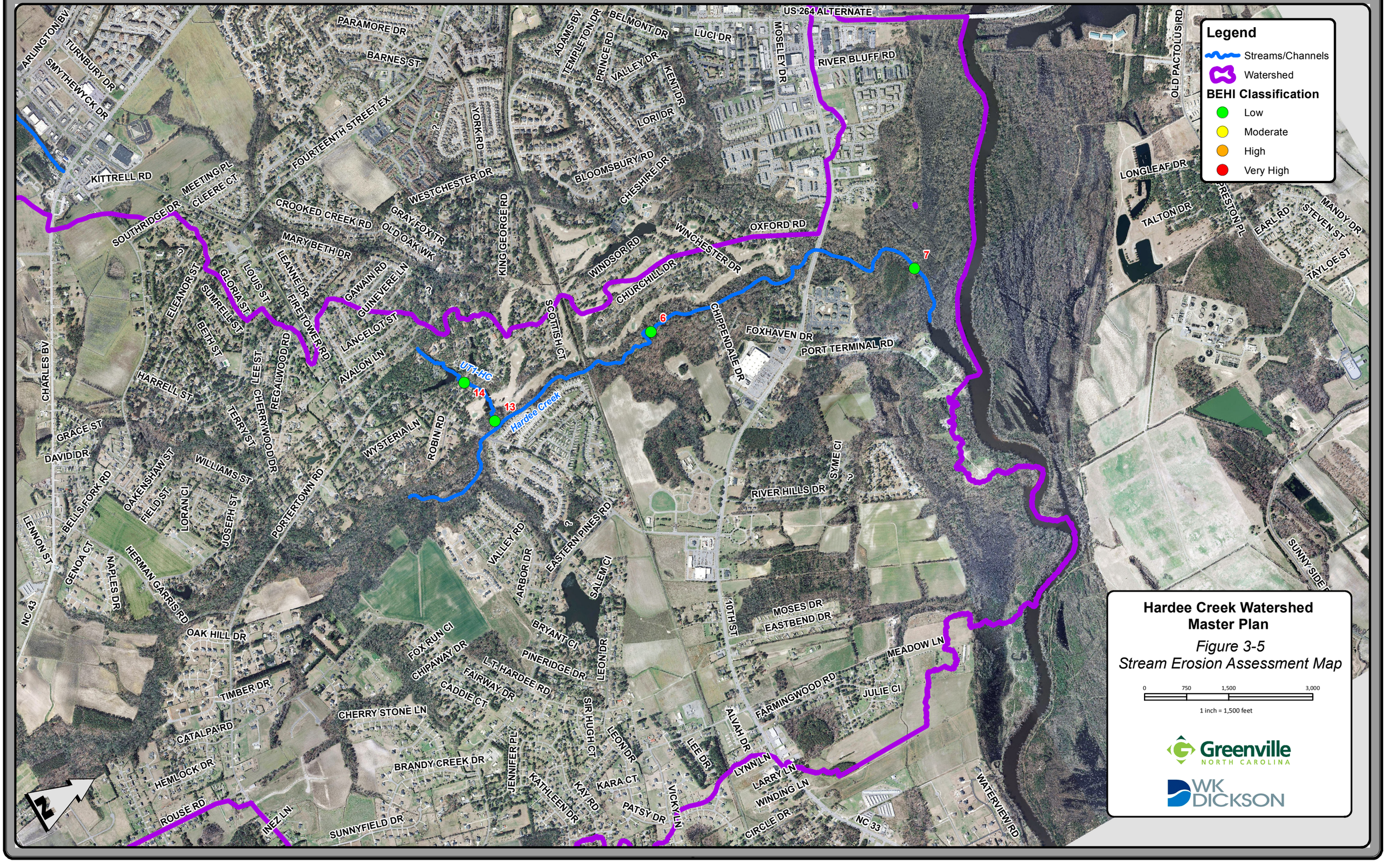
Field assessments measuring bank stability were conducted on all of the major stream channels within the Hardee Creek Watershed. The Bank Erosion Hazard Index (BEHI) developed by Rosgen was used to evaluate the streams in the watershed. BEHI is an assessment tool that is used to quantify the erosion potential of a stream bank. Characteristics assessed as part of the BEHI rating include bank height ratio (stream bank height/maximum bankfull depth), ratio of rooting depth to bank height, root density, bank angle, and percent surface protection, and bank material composition. Each of these variables that affect the potential rate of stream bank erosion is assigned points based on specific evaluation criteria. BEHI scores range from five to fifty, with a score of fifty indicating the highest potential for erosion. A BEHI score of 5 to 19.5 indicates a very low or low potential for erosion; a score between 20 and 29.5 indicates a moderate potential for erosion; scores from 30 to 45 represent a high to very high potential for erosion; and scores between 46 and 50 indicate extreme erosion potential. The completed BEHI scores are provided in Appendix K.

In addition to BEHI ratings, a modified version of the channel stability assessment method (CSA) provided in "Assessing Stream Channel Stability at Bridges in Physiographic Regions" by Johnson (2006) was used to assess channel stability channels in the watershed. The CSA method was designed to evaluate stability indicators in the field. These parameters include: watershed characteristics, flow habit, channel pattern, entrenchment/channel confinement, bed material, bar development, presence of obstructions/debris jams, bank soil texture and coherence, average bank angle, bank vegetation/protection, bank cutting, and mass wasting/bank failure. The twelve indicators were scored in the field, and a rating of excellent, good, fair, or poor was assigned to each project reach based on the total score. The completed CSA scores and a field datasheet are provided in Appendix K.

There are two main drainage features, Hardee Creek and an unnamed tributary (UT1-HC), in the Hardee Creek Watershed (See Figure 3-5). Four BEHI assessments were performed along the Hardee Creek drainage. The two BEHI assessments performed on Hardee Creek both scored in the Low Range. Hardee Creek is a sandbed channel with low bank height/bankfull height ratios, low bank angles, and very low root density scores (i.e. high percentage of root density protecting banks). Two BEHI assessments were performed on UT1-HC, both of which scored in the Low range. UT1-HC is a sandbed channel with low bank height/bankfull height ratios and low bank

angles. Hardee Creek and UT1-HC both scored very low for surface protection (i.e. majority of the banks were vegetated).

The CSA results for the Hardee Creek watershed ranged from Good to Excellent. Overall, Hardee Creek and UT1-HC appear to be physically stable, as there is little to no active erosion. These characteristics are reflected in the good to excellent scores for flow habit, channel pattern, and watershed characteristics. UT1-HC scored lower in the bed material and bank soil texture parameters, but these scores were in the expected range for a sandbed channel.


Legend
Streams/Channels
Watershed
BEHI Classification
Low
Moderate
High
Very High
Hardee Creek Watershed Master Plan
Figure 3-5
Stream Erosion Assessment Map
0
750
1,500
3,000
1 inch = 1,500 feet
Greenville
NORTH CAROLINA
WK DICKSON
N
UT1-HC
Hardee Creek
14
13
6
7
US 264 ALTERNATE
RIVER BLUFF RD
OXFORD RD
WINCHESTER DR
CHURCHILL DR
WINDSOR RD
CHIPPENDALE DR
FOXHAVEN DR
PORT TERMINAL RD
SCOTTISH CT
KING GEORGE RD
WESTCHESTER DR
BLOOMSBURY RD
CHESHIRE DR
YORK RD
PARAMORE DR
BARNES ST
BELMONT DR
LUCI DR
MOSELEY DR
VALLEY DR
KENT DR
LORI DR
ADAMS BV
TEMPLETON DR
PRINCE RD
FOURTEENTH STREET EX
KITTRELL RD
MEETING PL
CLEERE CT
SOUTHRIDGE DR
CROOKED CREEK RD
GRAY FOX TR
OLD OAK WK
MARY BETH DR
LEANNE DR
FIRE TOWER RD
GAWAIN RD
GUINEVERE LN
LANCELOT ST
AVALON LN
ELEANOR ST
SUMRELL ST
GLORIA ST
LOUIS ST
BETH ST
LEE ST
CHERRYWOOD DR
REGALWOOD RD
TERRY ST
HARRELL ST
CHARLES BV
ARLINGTON BV
TURNBURY DR
SMYTHEWYCK DR
LONGLEAF DR
TALTON DR
OLD PACTOLUS RD
PRESTON PL
EARL RD
STEVEN ST
MANDY DR
TAYLOE ST
RIVER HILLS DR
SYME CI
MOSES DR
EASTBEND DR
MEADOW LN
FARMINGWOOD RD
JULIE CI
10TH ST
ALVAH DR
LYNN LN
LARRY LN
WINDING LN
CIRCLE DR
NC 33
WATERVIEW RD
SUNNY SIDE
EASTERN PINES RD
VALLEY RD
ARBOR DR
SALEM CI
LEON DR
SIR HUGH CT
LEE DR
KARA CT
KAY RD
KATHLEEN DR
JENNIFER PL
PATSY DR
VICKY LN
BRYANT CI
PINERIDGE DR
L.T HARDEE RD
FAIRWAY DR
CADDIE CT
FOX RUN CI
CHIPAWAY DR
OAK HILL DR
TIMBER DR
CHERRY STONE LN
CATALPA RD
HEMLOCK DR
BRANDY CREEK DR
ROUSE RD
INEZ LN
SUNNYFIELD DR
WYSTERIA LN
ROBIN RD
PORTERTOWN RD
WILLIAMS ST
OAKENSHAW ST
FIELD ST
LORAN CI
JOSEPH ST
GRACE ST
DAVID DR
BELLS FORK RD
LENNON ST
GENOA CT
NAPLES DR
HERMAN GARRIS RD
NC 43

FLOOD MITIGATION ALTERNATIVES

4.1 PRIMARY SYSTEMS

Developing flood control alternative in an urban environment is a complex process based in limitations imposed by the constraints within the environment such as floodplain encroachments, increased peak flows due to impervious areas, public and private utilities, and private property. Improvements in this portion of the study were identified through an iterative process of infrastructure improvements, increasing floodplain storage, and evaluating detention options. Alternatives were finalized based on discussions with City staff. The top alternatives that achieve the goals of the project while minimizing impacts to residents and traffic are presented.

4.1.1 HARDEE CREEK

Portertown Road – As determined by the existing conditions analysis, the existing bridge at this crossing does not meet the desired 25-year level of service without overtopping. Currently, it provides between a 10- and 25- year level of service. As noted in Section 3.1.2, the bridge at Portertown Road has recently been upgraded by NCDOT, therefore alternatives were evaluated that would not require replacement of the relatively new bridge that is in good condition. The recommended alternative is to reduce the tailwater elevation during the 25-year design storm by grading floodplain benches downstream of Portertown Road in the left overbank for approximately 2,000 linear feet and in the right overbank for approximately 380 linear feet.

Figure 4-1 shows the locations of the proposed floodplain benching. The benching will range in width between 40 and 170 feet. The proposed floodplain benching will improve the performance of the existing bridge at Portertown Road and bring it up to the desired 25-year level of service for existing and future land use conditions. The resulting upstream water surface elevation will be reduced by between 0.17 to 1.29 feet in the 25-year storm event depending on the location.

Picture 4-1: Portertown Road - Upstream Face

There are seven (7) properties located in the existing conditions 25-year floodplain immediately downstream of Portertown Road (along Williamsbrook Lane) that are at risk for LAG flooding. All seven (7) properties will be removed from the 25-year floodplain if the floodplain benching alternative is implemented. An additional four (4) properties are affected by the 100-year storm and at risk for LAG flooding. Two (2) of these properties are located upstream of Portertown Road in the Willow Run subdivision. If the

proposed floodplain benching is installed, three (3) out of the four (4) properties will be removed from the 100-year floodplain.

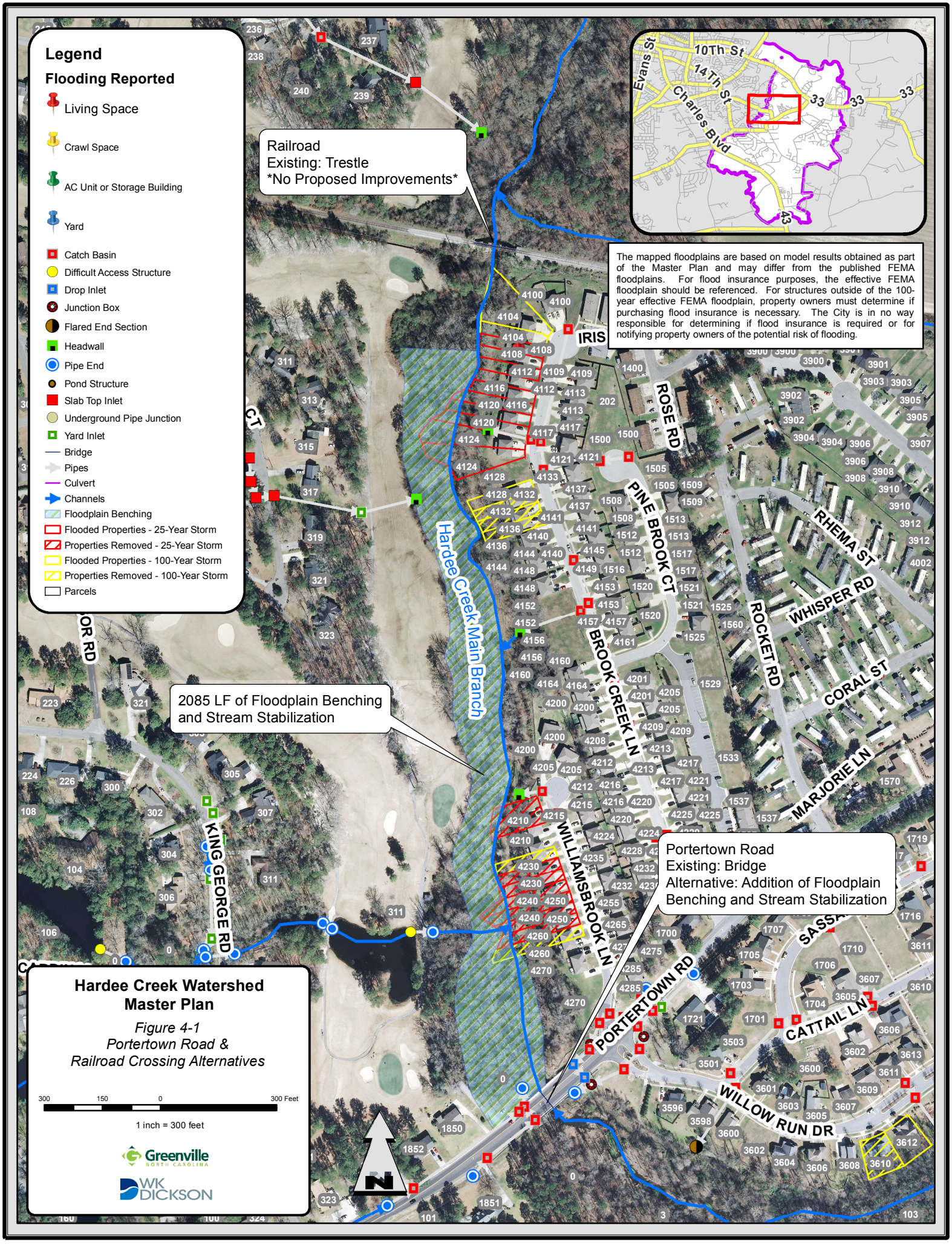
During a field inspection, there were several potential site restrictions and utility conflicts that were identified. Overhead power lines are located along Portertown Road, which may need to be temporarily relocated based on where the contractor accesses the site. Impacts to the sanitary sewer lines along the right bank were minimized to the extent possible, although manhole adjustments or other minor sanitary sewer improvements may need to be completed based on the elevations of the sanitary sewer system and the final design of the floodplain benching. Impacts to traffic flow during construction are anticipated to be minor with the exception of construction equipment accessing the site from Portertown Road. In order to gain access and to install the proposed floodplain benching, tree removal would be significant and would reduce the buffer between the Brook Valley golf course and the residential homes along Brook Creek Lane. The installation of construction staging areas and entrances will require additional tree removal, temporary construction easements, and a NCDOT encroachment agreement. It should be noted that the majority of the proposed improvements are located on private property (Brook Valley Country Club) therefore an easement would be required to complete this project and maintain the bench in the future. The total estimated cost for this project is $3,780,000.

Railroad Crossing – The existing trestle bridge at the railroad crossing along Hardee Creek meets the desired 100-year level of service. The bridge appears to be in good condition therefore, no improvements are proposed at this location (See Figure 4-1).

Picture 4-2: Railroad Trestle - Upstream Face

There are ten (10) properties upstream of the railroad that are at risk for LAG flooding during the 25-year storm event, and three (3) additional properties affected by the 100-year storm event.

Three (3) properties on Brook Creek Lane were removed from the 100-year floodplain as a result of floodplain benching upstream. Properties in the 25-year floodplain were unaffected by proposed improvements upstream.

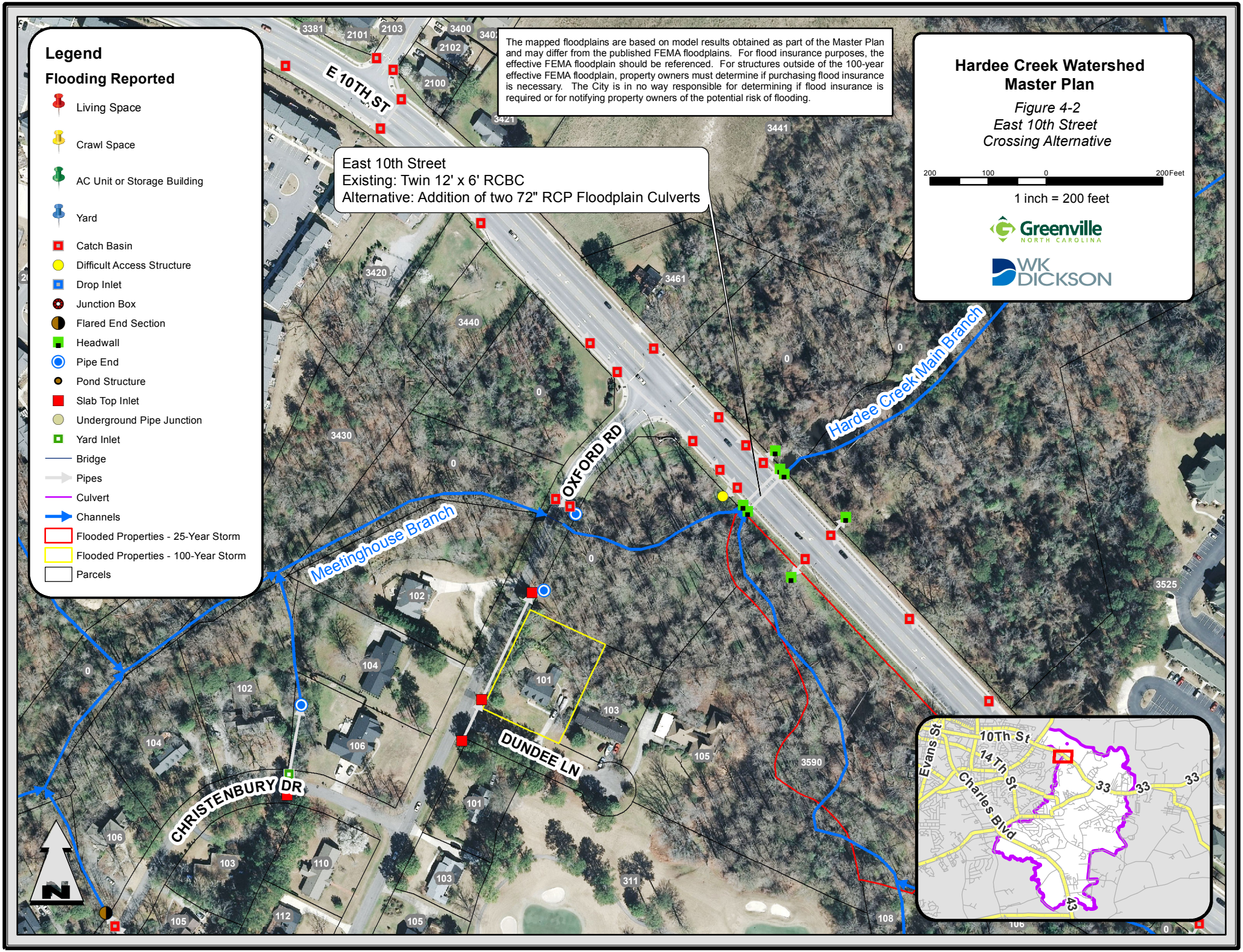

Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Culvert
Channels
Floodplain Benching
Flooded Properties - 25-Year Storm
Properties Removed - 25-Year Storm
Flooded Properties - 100-Year Storm
Properties Removed - 100-Year Storm
Parcels
Railroad
Existing: Trestle
No Proposed Improvements
The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.
2085 LF of Floodplain Benching and Stream Stabilization
Portertown Road
Existing: Bridge
Alternative: Addition of Floodplain Benching and Stream Stabilization
Hardee Creek Main Branch
IRIS
ROSE RD
PINE BROOK CT
BROOK CREEK LN
WILLIAMSBROOK LN
ROCKET RD
RHEMA ST
WHISPER RD
CORAL ST
MARJORIE LN
SASSA
PORTERTOWN RD
CATTAIL LN
WILLOW RUN DR
KING GEORGE RD
Evans St
10Th St
14Th St
Charles Blvd
Hardee Creek Watershed Master Plan
Figure 4-1
Portertown Road &
Railroad Crossing Alternatives
300 150 0 300 Feet
1 inch = 300 feet
Greenville
NORTH CAROLINA
WK DICKSON

East 10th Street (NC 33) – Based on the results obtained from the existing conditions analysis, the existing twin 12′ x 6′ RCBCs are currently providing a 10-year level of service. In order to provide the required 50-year level of service at this crossing, the recommended alternative includes installation of two additional 72″ floodplain culverts. The existing twin RCBCs are in good condition and will remain in place (See Figure 4-2). In addition to the improved level of service at East 10th Street, upsizing this culvert crossing provides upstream water surface reductions for the 25-year storm ranging between 0.27 to 3.07 feet.

One (1) property is affected by the 25- year storm event and at risk of experiencing LAG flooding just upstream of the East 10th Street bridge, and one (1) additional property is affected by the 100- year storm event. Although the proposed improvements may decrease the upstream water surface elevations by up to 3.07 feet, these properties will remain in their respective floodplains.

Picture 4-3: E 10th Street - Upstream Face

East 10th Street is a major thoroughfare roadway maintained by NCDOT. Due to the high traffic volume, it is anticipated that tunneling techniques would be required to install the culverts. In order to gain access for installing the proposed culverts, trees must be removed. The installation of construction staging areas will likely require additional tree removal, temporary construction easements, and a NCDOT encroachment agreement. Coordination with NCDOT may require additional time for permitting and design. A 20″ ductile iron sanitary sewer pipe is located approximately 20 feet upstream of the existing culvert. The contractor may need to provide additional protections when siting the upstream bore pit to avoid impacts to the existing sanitary sewer line. The total estimated cost for this project is $890,000.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Culvert
Channels
Flooded Properties - 25-Year Storm
Flooded Properties - 100-Year Storm
Parcels
The mapped floodplains are based on model results obtained as part of the Master Plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The City is in no way responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.
East 10th Street
Existing: Twin 12' x 6' RCBC
Alternative: Addition of two 72" RCP Floodplain Culverts
Hardee Creek Watershed Master Plan
Figure 4-2
East 10th Street
Crossing Alternative
200 100 0 200 Feet
1 inch = 200 feet
Greenville NORTH CAROLINA
WK DICKSON
E 10TH ST
OXFORD RD
Hardee Creek Main Branch
Meetinghouse Branch
DUNDEE LN
CHRISTENBURY DR
N
Evans St
10Th St
14Th St
Charles Blvd

A summary of the hydraulic performance for the improvements proposed are included in Table 4-1. The water surface elevations shown assume all proposed primary system improvements for Hardee Creek are constructed. The level of improvement will be reduced if all projects are not implemented.

Table 4-1: Hydraulic Performance for Hardee Creek

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Portertown Road (Existing Bridge with Proposed Floodplain Benching)	25.58	25-yr	22.32	23.52	25.54	**26.55**	**27.58**
Railroad (Existing Bridge)	41.51	100-yr	18.96	20.98	22.22	23.23	24.46
East 10th Street (Existing Twin 12′ x 6′ RCBCs with Proposed Twin 72″ RCPs)	17.87	50-yr	9.06	12.66	15.20	16.85	**19.44**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.

4.1.2 HARDEE CREEK UT1

Holly Hills Road – The existing private bridge at this crossing is currently exceeding a 100-year level of service. No capital improvements are proposed at this private location (See Figure 4-3).

Cardinal Drive – Based on the results obtained from the existing conditions analysis, the existing twin 24″ CMPs are currently providing a 10-year level of service. In order to provide a 25-year level of service, the existing CMPs would need to be replaced with twin 24″ RCPs. This culvert replacement project will not be included as part of the City's recommended capital improvement plan since Cardinal Drive is privately maintained (See Figure 4-3).

King George Road – As determined by the existing conditions analysis, the existing 2.5′ x 3.5′ corrugated metal arch pipe at King George Road is currently providing the required 25-year level of service. As shown in Picture 4-1, the existing CMP is perched and in poor condition therefore, it is recommended that this culvert be replaced with a 30″ RCP.

Picture 4-1: King George Road Culvert – Upstream Face

Upgrading this culvert crossing will allow it to continue to provide the 25-year level of service while significantly reducing the potential of failure which would cause significant impacts to traffic in the area. During a field inspection, there were several potential site restrictions and utility conflicts that were identified including sanitary sewer lines that may require temporary

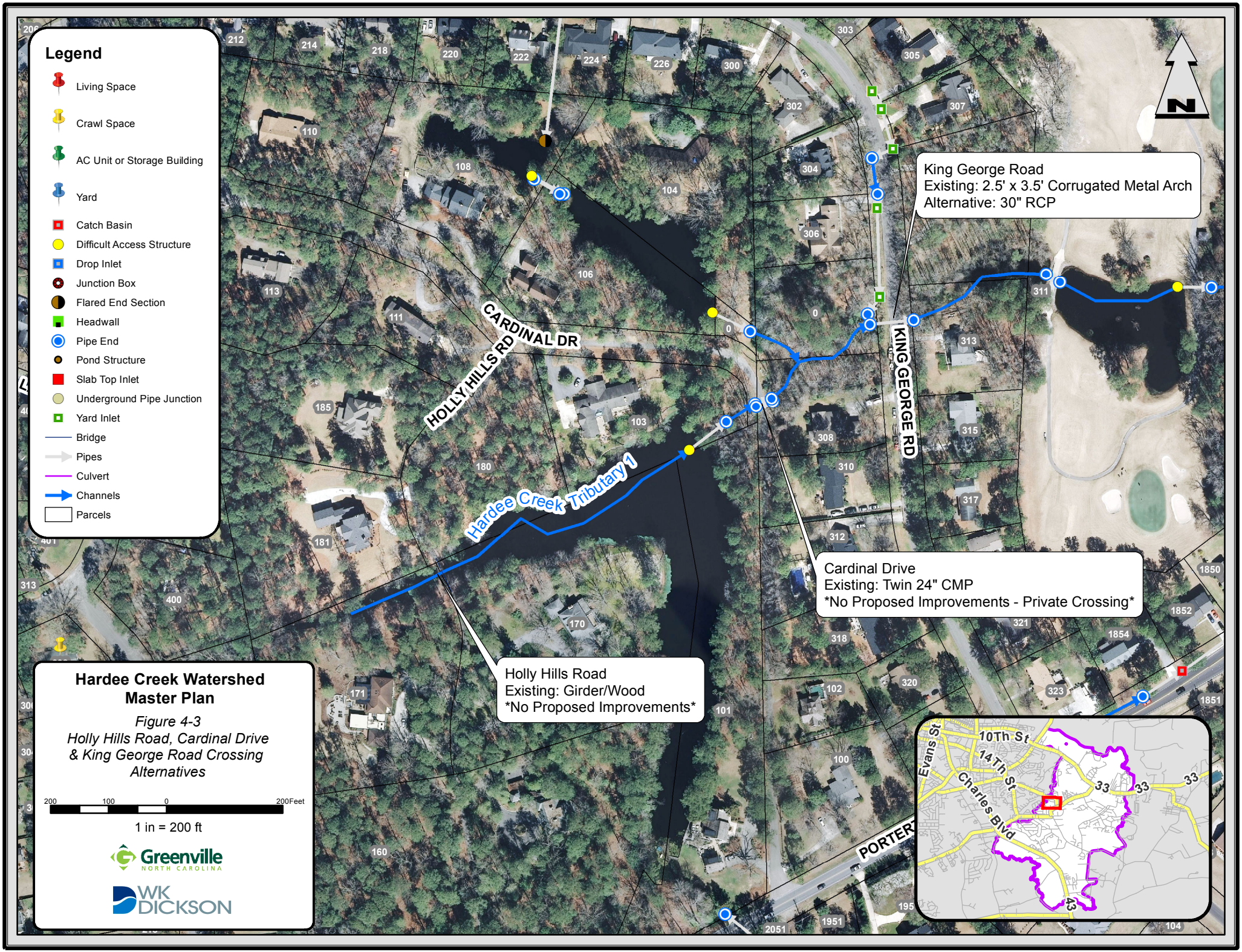
protection or relocation during construction. King George Road is a two-lane residential roadway and it is anticipated that a road closure or a flagged two-way one–lane operation will be required. The King George Road replacement will be classified as a maintenance project since capacity of the culvert is not a concern and no flooding has been reported. The estimated cost for the maintenance project at King George Road is $13,500.

A summary of the hydraulic performance for the improvements proposed along HCUT1 are included in Table 4-2.

Table 4-2: Hydraulic Performance for Hardee Creek UT1

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
King George Road (Proposed 30″ RCP)	35.01	25-yr	31.44	32.94	34.71	**35.17**	**35.29**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.


Legend
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Culvert
Channels
Parcels
King George Road
Existing: 2.5' x 3.5' Corrugated Metal Arch
Alternative: 30" RCP
Cardinal Drive
Existing: Twin 24" CMP
No Proposed Improvements - Private Crossing
Holly Hills Road
Existing: Girder/Wood
No Proposed Improvements
CARDINAL DR
HOLLY HILLS RD
KING GEORGE RD
Hardee Creek Tributary 1
PORTER
Hardee Creek Watershed Master Plan
Figure 4-3
Holly Hills Road, Cardinal Drive & King George Road Crossing Alternatives
200 100 0 200Feet
1 in = 200 ft
Greenville NORTH CAROLINA
WK DICKSON
N
Evans St
10Th St
14Th St
Charles Blvd

4.1.3 HYDROLOGY

The future land use was accounted for during the development of the proposed improvements. The hydrologic parameters including curve numbers were adjusted for the future conditions and alternatives models.

Peak flows for the primary systems were developed for the 2-, 10-, 25-, 50-, and 100-year storm events. The future conditions flows were developed taking into account attenuation for the proposed culvert sizes. Attenuation was assumed upstream of East 10th Street (Hardee Creek) and King George Road (HCUT1). The peak flows used for sizing the proposed culverts for the alternatives are summarized in Table 4-3. In comparison to the existing conditions flows, the future conditions flows increase by 10% in the 25-year storm along Hardee Creek. There are no changes in the flows along HCUT1 for the future conditions. A hard copy of the HEC-HMS output is included as Appendix H. The CD found in Appendix J contains a digital copy of the HEC-HMS model for the Hardee Creek watershed.

Table 4-3: Future Conditions Flows from HEC-HMS for Hardee Creek Watershed

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
HARDEE CREEK							
US End	Upstream Limit of Hardee Creek	14866	493	1,121	1,597	2,034	2,527
Portertown Road	Portertown Road	12786	513	1,176	1,682	2,145	2,668
HCUT1_HC_ Confl	Confluence of HCUT and Hardee Creek	11882	564	1,382	2,004	2,581	3,236
Railroad	Railroad	10345	574	1,407	2,070	2,674	3,357
E. 10th	East 10th Street (NC 33)	5340	925	2,005	2,516	3,331	4,005
HARDEE CREEK UT1							
ADD_HCUT_2-1	Holly Hills Road	1712	9	22	31	40	50
Cardinal Culvert	Cardinal Drive	1033	8	25	36	46	61
King George Road Culvert	King George Road	763	9	28	43	65	88

4.1.4 HYDRAULICS

The hydraulic analysis for the proposed conditions was similar to the analysis completed for the existing conditions. The model was updated to reflect the proposed culvert improvements, as well as the floodplain benching locations.

4.2 SECONDARY SYSTEMS

Developing flood control alternatives for the secondary systems typically included increase in pipe capacity and/or rerouting flows where more space was available for improvements. In general, the proposed improvements for the secondary system are less complex from a permitting perspective since they typically do not require FEMA or 401/404 permits. However, the proposed improvements for secondary systems are oftentimes constrained by private property as space is typically limited between houses or other structures. Utility conflicts are another constraint that is typical for secondary system improvements. Secondary system improvements also considered feedback from City staff and residents as well as maintenance needs based on findings from the inventory and/or feedback from City staff.

The projects described are the recommended alternatives for each of the secondary systems.

Fox Haven Drive – Quail Hollow Closed System

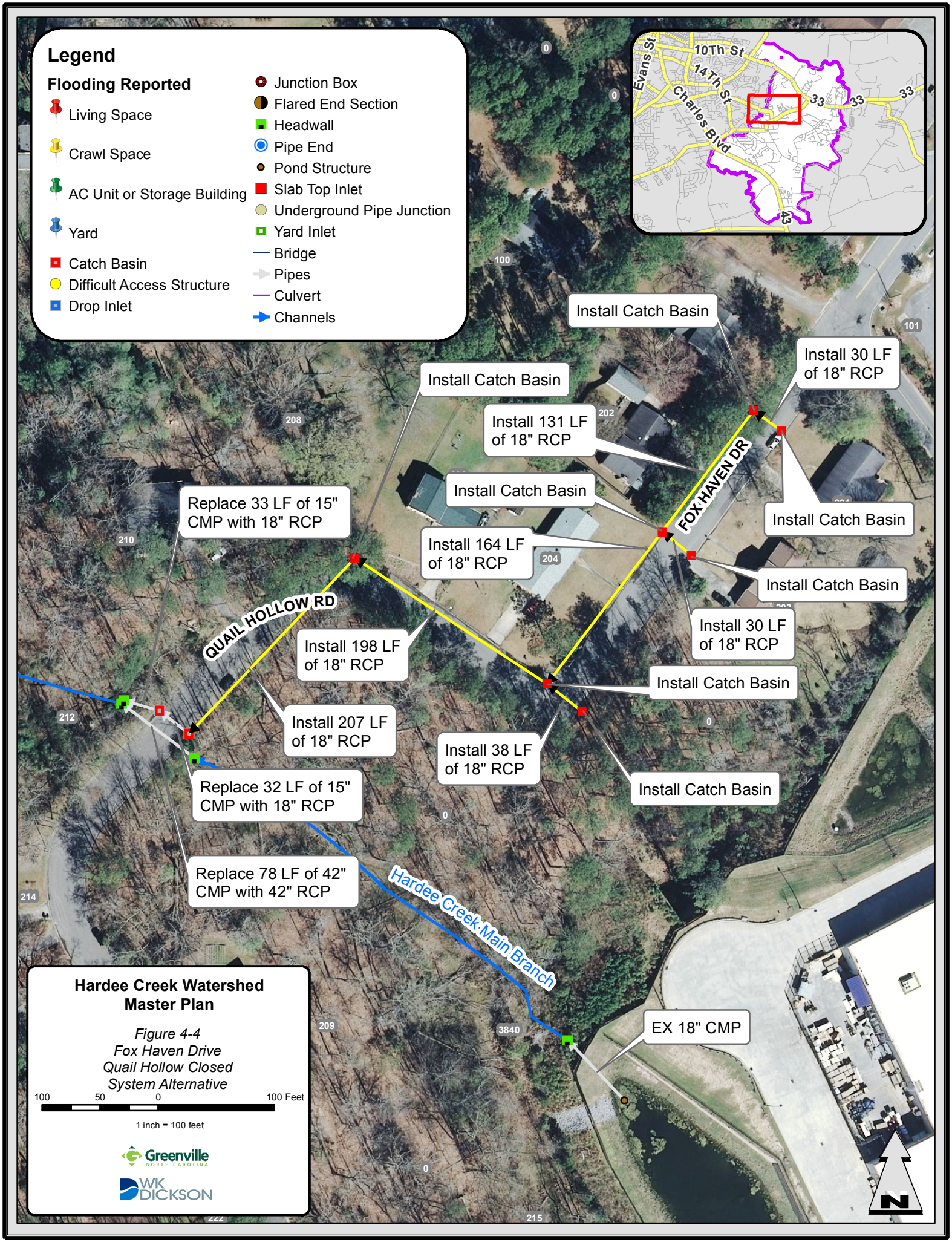
WK Dickson recommends the following improvements for the Fox Haven Drive – Quail Hollow Closed System as shown in Figure 4-4:

- Install 393 linear feet of 18" RCP along Fox Haven Drive;
- Install 405 linear feet of 18" RCP along Quail Hollow Road;
- Replace 65 linear feet of 15" CMP with 18" RCP along Quail Hollow Road;
- Replace 78 linear feet of 42" CMP with 42" RCP along Quail Hollow Road; and
- Install 9 inlets.

It should be noted that the downstream segments of pipe discharging to the channel section are in poor condition. The bottom of the existing 15" and 42" CMPs are rusted at the bottom. Replacement of these pipes is recommended as part of the proposed system improvements.

The proposed improvements will provide a 10-year level of service for the Fox Haven Drive – Quail Hollow Closed System. The total estimated cost for the recommended alternative is $410,000. The majority of the project will be located in the right-of-way; there will be minimal impacts to private properties. Sections of the curb and gutter along Fox Haven Drive and Quail Hollow Road will need to be removed and replaced to complete the proposed improvements. Underground electric, water, and sanitary sewer lines were also identified as potential site restrictions and utility conflicts.

There is one report of flooding in this area. It is a report of street flooding at the intersection of Fox Haven Drive and Quail Hollow Road. According to the resident, this intersection floods often after rain events. The addition of the 18" RCP and inlets to capture and convey the water back to the stream will reduce the frequency and severity of the street flooding at this intersection.


Legend
Flooding Reported
Living Space
Crawl Space
AC Unit or Storage Building
Yard
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Culvert
Channels
Evans St
10Th St
14Th St
Charles Blvd
33
43
Install Catch Basin
Install 30 LF of 18" RCP
Install Catch Basin
Install 131 LF of 18" RCP
FOX HAVEN DR
Install Catch Basin
Replace 33 LF of 15" CMP with 18" RCP
Install Catch Basin
Install 164 LF of 18" RCP
Install Catch Basin
QUAIL HOLLOW RD
Install 30 LF of 18" RCP
Install 198 LF of 18" RCP
Install Catch Basin
Install 207 LF of 18" RCP
Install 38 LF of 18" RCP
Install Catch Basin
Replace 32 LF of 15" CMP with 18" RCP
Replace 78 LF of 42" CMP with 42" RCP
Hardee Creek Main Branch
EX 18" CMP
Hardee Creek Watershed Master Plan
Figure 4-4
Fox Haven Drive
Quail Hollow Closed
System Alternative
100 50 0 100 Feet
1 inch = 100 feet
Greenville
NORTH CAROLINA
WK DICKSON
N

River Hills System

WK Dickson recommends the following improvements for the River Hills System as shown in Figure 4-5:

- Replace 170 linear feet of 24" RCP with 30" RCP between Tanglewood Drive and Sloan Drive;
- Replace 111 linear feet of 36" RCP with 42" RCP between Tanglewood Drive and Sloan Drive;
- Replace 114 linear feet of 36" RCP with 42" RCP along River Hill Drive;
- Install 79 linear feet of 18" RCP at intersection of River Hill Drive and Syme Circle;
- Install 109 linear feet of 18" RCP along River Hill Drive;
- Install 166 linear feet of 18" RCP along Syme Circle;
- Replace 257 linear feet of 42" RCP with 48" RCP adjacent to Syme Circle;
- Replace 42 linear feet of 36" CMP with 48" RCP along Syme Circle; and
- Install 10 inlets

The proposed improvements will provide a 10-year level of service for the River Hills System. The total estimated cost for the recommended alternative is $550,000. While a significant portion of the project will be constructed within the public ROW, there will be approximately 550 linear feet of pipe installed or replaced on private property. The driveways, landscaping, and/or fencing at the following properties will be impacted:

- 503 River Hill Drive;
- 800 River Hill Drive;
- 802 River Hill Drive;
- 803 River Hill Drive;
- 805 River Hill Drive;
- 806 River Hill Drive;
- 808 River Hill Drive; and
- 111 Syme Circle.

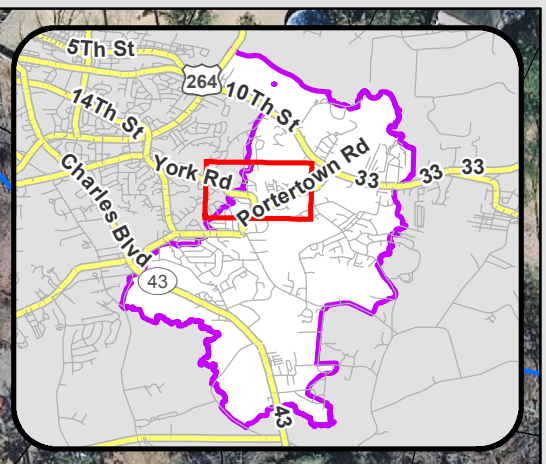
Sections of the curb and gutter along River Hill Drive and Syme Circle will need to be removed and replaced to complete the proposed improvements. Underground electric, electric boxes, water, and sanitary sewer lines were also identified as potential site restrictions and utility conflicts.

There is one report of flooding in this area. It is a report of street flooding at the intersection of River Hill Drive and Syme Circle. According to the resident, this intersection floods during heavy rain events. The addition of the 18" RCP and inlets to capture and convey the water back to the existing system will reduce the frequency and severity of the street flooding at this intersection.

Legend

Flooding Reported

- Living Space
- Crawl Space
- AC Unit or Storage Building
- Yard
- Catch Basin
- Difficult Access Structure
- Drop Inlet
- Junction Box
- Flared End Section
- Headwall
- Pipe End
- Pond Structure
- Slab Top Inlet
- Underground Pipe Junction
- Yard Inlet
- Bridge
- Pipes
- Culvert
- Channels
- Hardee Creek Watershed
- Parcels



Replace 29 LF of 42" RCP with 48" RCP

Replace 106 LF of 42" RCP with 48" RCP

Replace 95 LF of 42" RCP with 48" RCP

Replace 27 LF of 42" RCP with 48" RCP

Replace 42 LF of 36" CMP with 48" RCP

SYME CI

Install 166 LF of 18" RCP

Install 31 LF of 18" RCP

Install Catch Basin

Install Catch Basin

Proposed 48 LF of 18" RCP

Plug and Abandon 182 LF of 18" RCP

Install Catch Basin

Replace 74 LF of 36" RCP with 42" RCP

Proposed 109 LF of 18" RCP

Replace 40 LF of 36" RCP with 42" RCP

RIVER HILL DR

Replace 111 LF of 36" RCP with 42" RCP

SLOAN DR

TANGLEWOOD DR

Replace 139 LF of 24" RCP with 30" RCP

Replace 31 LF of 24" RCP with 30" RCP

BRAMBLEWOOD DR

RIVER HILL DR

Hardee Creek Watershed Master Plan

Figure 4-5
River Hills Closed System Alternatives

100 50 0 100 Feet

1 inch = 100 feet

Greenville NORTH CAROLINA

WK DICKSON

4.3 25-YEAR DETENTION ANALYSIS

In 2014, the City of Greenville enacted legislation requiring attenuation for new development and re-development for the one-year, five-year, and ten-year, 24-hour storm events. In addition, Section 9-9-10 of Ordinance No. 13-054 states the following:

"New development and redevelopment, as described in section 9-9-3, in areas at special risk with well documented water quantity problems as determined by the City Engineer, shall not result in a net increase in peak flow leaving the site from pre-development conditions for the 25-year, 24-hour storm event."

As part of the Hardee Creek Master Plan, an analysis was completed to determine if there are areas within the watershed and the ETJ that should be considered "well documented water quantity problems" requiring detention for the 25-year, 24-hour storm event. Areas may be defined as well documented water quantity problems if either of the following is true:

- Structural flooding has been historically noted by property owners during storms considered smaller than the design event and this structural flooding has been corroborated by either high water marks, City staff input, or model results.
- Model results indicate structural flooding or roadway overtopping during storms smaller than the design storm and models results are corroborated by City staff input.

Portions of the watershed draining to the "well documented water quantity problems" may be considered for 25-year detention if any of the following are true:

- Future condition flows are 10% or greater than existing flows for a given subwatershed upstream of the water quantity problem.
- Proposed capital projects are not deemed to be feasible or cost effective for providing the required level of service for these water quantity problems based on future land use conditions.
- Cost differential between designing for existing conditions and future conditions is deemed to be significant and/or a significant number of structures would become floodprone during the 25-year design storm based on future conditions flows when compared to existing conditions flows.

It is assumed that for this analysis, systems with a 10-year level of service design would not be considered for the 25-year detention since the 10-year detention requirements would result in little to no increase in peak flows for the design event. Typically, this would include most secondary systems, although secondary systems with significant documented water quantity problems that also includes infrastructure requiring a level of service greater than a 10-year event may be evaluated for the 25-year detention requirement.

As noted in Section 3.1 the crossings at Portertown Road and East 10th Street do not meet the required level of service based on model results. However, based on interviews with City staff and resident feedback these crossings were not considered well documented water quantity

problems as a history of overtopping at these crossings has not been observed. Additionally, the future 25-year flows within the primary streams are a maximum of 8% higher than existing flows throughout Hardee Creek. There are isolated subwatersheds with increases greater than 10% for the future conditions 25-year flows; however, these increases do not result in substantially higher flows within the streams as noted above and do not drain to existing floodprone areas. Subwatersheds HC-7b and HC-9 have the highest increases in 25-year future flows, approximately 25 to 30% higher than existing. Subwatershed HC-7b drains to Hardee Creek north (downstream) of the railroad. As shown in Figure 3-1, the floodprone area north of the railroad has few structures at risk of flooding as the majority of the land use is the golf course. Requiring 25-year detention in Subwatershed HC-7b would not impact flooding of roads or structures. Subwatershed HC-9 is located downstream of 10th Street in undeveloped areas. Any development in this portion of the watershed would have limited impact on flooding due to the timing difference of peak flows from Hardee Creek when compared to the Tar River. Future development plans in these subbasins include conversion of agricultural and open space into commercial, office/institutional, and low density residential land use.

Since the East 10th Street culvert improvements are required to provide a 50-year level of service, it is assumed that 25-year detention upstream of the culvert would not result in substantial cost savings when designing a 50-year level of service. The length of the proposed Portertown Road floodplain benching could potentially be reduced by approximately 900 linear feet if 25-year detention was required in the areas upstream of the proposed project, which would result in an estimated cost savings of $920,000. However, as noted below because the Portertown Road area is not considered an area of repetitive flooding or damages, requiring 25-year detention upstream of the project area is not recommended.

There have been documented quantity issues for the dam associated with Lake Glenwood near the intersection of Leon Drive and Eastern Pines Road. This area is outside of the existing City limits, although it is within the City ETJ and there are areas draining to the Lake within the City's ETJ. Projected increases for future flows for the 25-year storm event for the two subwatersheds draining to Lake Glenwood are 3% and 6%. Since the projected increases are below the 10% threshold it is not likely that the 25-year detention requirement would provide substantial additional protection for the dam. It is recommended that the City carefully consider any re-zoning applications and/or annexation requests in the ETJ draining to Lake Glenwood to determine if a change from the projected zoning would change the projected future flows and thereby possibly necessitate detention for the 25-year storm event.

In summary based on an analysis of the Hardee Creek watershed evaluating feedback from the public, City staff, model results, and anticipated future development, there are no recommendations for requiring 25-year detention for future development in the watershed.

WATER QUALITY RECOMMENDATIONS

Traditional stormwater management has typically been designed to reduce flooding, but at times has neglected water quality by collecting runoff directly from impervious surfaces and discharging directly into a stream causing erosion and deterioration of water quality. Runoff from impervious areas collects high concentrations of pollutants and nutrients that if left untreated can cause negative impacts to water quality in the receiving waters. Negative impacts may include less biodiversity, hazards to the health of fish and wildlife, as well as human health hazards. Many communities in North Carolina now require some form of water quality treatment for new development; however existing developments typically have little or no water quality treatment. The City of Greenville developed a Stormwater Management Program (September, 2004) to outline its water quality requirements.

Stream stabilization projects can be constructed to reduce instream sediment loads and to protect private property from further erosion. Best management practices (BMPs) can be constructed to treat runoff prior to being discharged to the stormwater conveyance system and ultimately the receiving waters of the system. Retrofitting BMPs can be difficult due to limited space and other constraints. Several types of BMPs were evaluated: Bioretention Cells, Stormwater Wetlands, Wet Ponds, Regenerative Stormwater Conveyance (RSC), Rainwater Harvesting, Permeable Pavement, and Water Quality Swales. Projects identified in the watershed are described below.

5.1 STREAM STABILIZATION PROJECTS

Based on the basin-wide stream assessment completed as described in Section 3.3, there are no standalone stream stabilization projects identified for the Hardee Creek Watershed. Spot stabilization may be required as part of the Portertown Road floodplain benching, however no significant stabilization projects were identified as part of the stream assessments or based on City and public feedback.

5.2 BMP PROJECT IDENTIFICATION

BMPs were initially identified using various layers in GIS including the following: aerial photography, parcels, land use, storm water inventory, and topography. Five (5) potential BMP locations were initially identified. These locations were field visited by WK Dickson staff in November 2015 to determine the feasibility of each site for a BMP. An overview map has been provided showing these sites (See Figure 5-1).

The proposed locations for the BMPs were evaluated based on the following criteria:

- Watershed Size/Drainage Area – Larger watershed sizes allow an opportunity for more treatment. A significant contributing drainage area would allow the use of a larger, more regional BMP such as a wet pond or extended detention wetland.

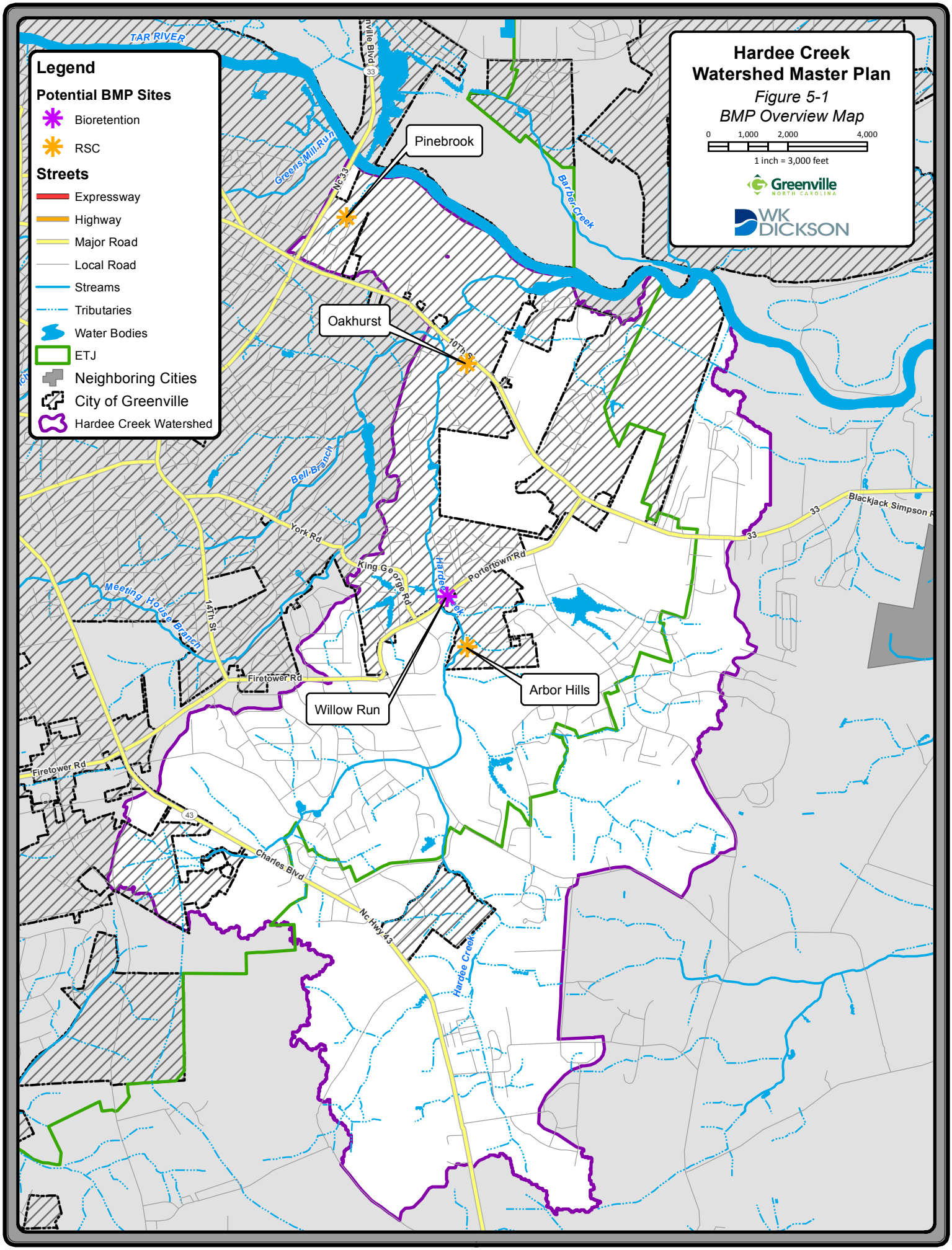
- Percentage of impervious area – Areas with high impervious percentages allow an opportunity for more treatment.
- Proximity to existing conveyance system – Runoff will need to be diverted into the BMP and then discharged back to the conveyance system. Locations in close proximity to the existing conveyance system will reduce the cost associated with constructing new drainage structures.
- Land Availability/Ownership – The proposed BMPs will require undeveloped land. Attempts were made to concentrate on publicly owned land because the high cost of private land can make a project unlikely.
- Topography – Sufficient vertical relief, up to 5 feet, is required to allow certain BMPs (i.e., bioretention and wet ponds) to function per NCDEQ design requirements.
- Hydrologic conditions – BMPs such as wet ponds or extended detention wetlands need the proper hydrologic conditions for plants to survive. The soils or existing water table must allow for the BMP facility to permanently hold stormwater runoff.

Residents who provided feedback via online survey or by attending the public meeting held in November 2014 were also taken into account. The feedback helped determine several locations where erosion, flooding, or water quality were of concern. Several of the sites identified met multiple criteria for a successful project and were therefore recommended in this Master Plan.

5.3 RECOMMENDED BMPS

Based on field visits and the above criteria, four (4) sites were recommended for BMP retrofits in the Hardee Creek Watershed. Factors that eliminated a site from consideration included the following: limited space, tree density, utility conflicts (e.g. high voltage transformers and other electrical distribution equipment), and insufficient topographic relief.

Preliminary conceptual design calculations completed for each of the four (4) BMPs are included in Appendix I. The design calculations were based on methodologies found in the NCDEQ Stormwater BMP Manual. The size of the BMP is based on the contributing watershed area and the amount of impervious area within the watershed. Per NCDEQ requirements, the recommended BMPs were designed to treat runoff from the first one-inch of rainfall. The treatment volume is directly correlated to the amount of impervious area. Watersheds with larger amounts of impervious area convert more of the rainfall into runoff, thereby requiring a larger sized BMP.


Hardee Creek
Watershed Master Plan
Figure 5-1
BMP Overview Map
0 1,000 2,000 4,000
1 inch = 3,000 feet
Greenville
NORTH CAROLINA
WK DICKSON
Legend
Potential BMP Sites
Bioretention
RSC
Streets
Expressway
Highway
Major Road
Local Road
Streams
Tributaries
Water Bodies
ETJ
Neighboring Cities
City of Greenville
Hardee Creek Watershed
TAR RIVER
Greens Mill Run
Pinebrook
NC 33
Barber Creek
Oakhurst
10th St
Bell Branch
York Rd
King George Rd
Portertown Rd
Hardee Creek
Meeting House Branch
14th St
Firetower Rd
Arbor Hills
Willow Run
Charles Blvd
Nc Hwy 43
Hardee Creek
Blackjack Simpson Rd
33
43

Hardee Creek Water Quality Project #1: Willow Run Bioretention

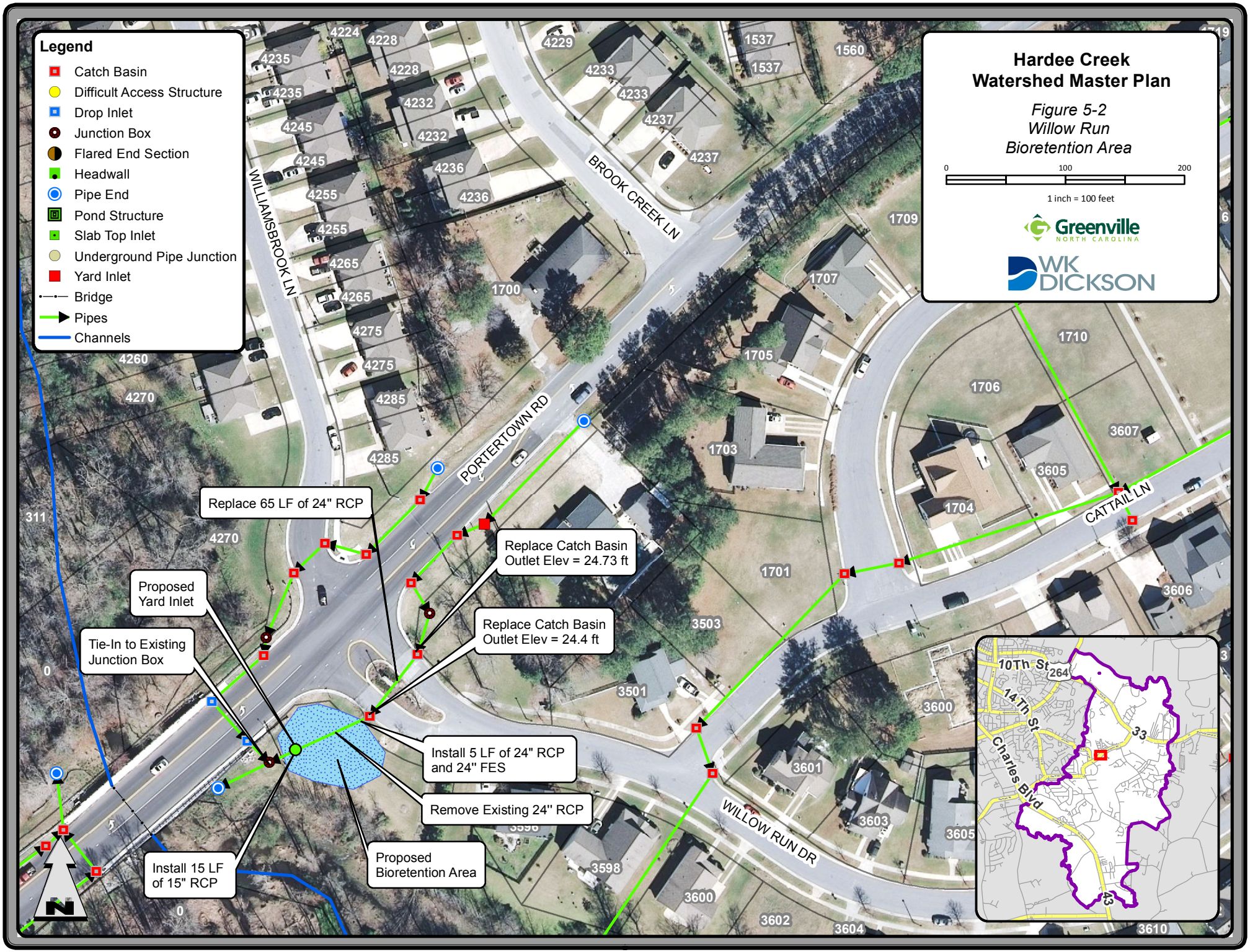
A bioretention area is proposed in the open space located in the lot adjacent to 1721 Portertown Road (See Picture 5-1). This area drains several residential lots and runoff from Portertown Road. The proposed location is also near a nature trail and at the entrance to a community with green infrastructure practices including grass medians and disconnected impervious areas. Impacted utilities may include active gas lines running through the proposed area. A bioretention cell is proposed at this location as significant runoff from untreated impervious areas can be directed to the site and there will be enough elevation difference between the inlet and outlet to allow for the required depth of soil media. The existing storm drainage infrastructure would require some retrofits to provide the bioretention cell with the appropriate depth of treatment.

Picture 5-1. Proposed Location for Willow Run Bioretention Area

The required surface area for the proposed bioretention is approximately 5,000 square feet (0.11 acres). A concept level plan of the proposed improvements is shown in Figure 5-2. The proposed bioretention project consists of the following improvements:

- Install a bioretention pond designed to treat runoff from the adjacent lot and road. The proposed impervious areas draining to the proposed pond is approximately 0.87 acres.
- Remove existing catch basins on Willow Run Drive, and replace at higher elevations.
- Remove and replace 65 LF of 24'' RCP traversing Willow Run Drive.
- Install a yard inlet with a 24" outfall pipe directing flow into an existing conveyance system.

The proposed water quality project is located on common area. In order to construct the bioretention area, an easement agreement would be required with the owner. The estimated construction cost for the bioretention area at Willow Run is $250,000.


Legend
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Channels
Hardee Creek
Watershed Master Plan
Figure 5-2
Willow Run
Bioretention Area
0
100
200
1 inch = 100 feet
Greenville
NORTH CAROLINA
WK DICKSON
WILLIAMSBROOK LN
BROOK CREEK LN
PORTERTOWN RD
CATTAIL LN
WILLOW RUN DR
Replace 65 LF of 24" RCP
Replace Catch Basin
Outlet Elev = 24.73 ft
Proposed
Yard Inlet
Replace Catch Basin
Outlet Elev = 24.4 ft
Tie-In to Existing
Junction Box
Install 5 LF of 24" RCP
and 24" FES
Remove Existing 24" RCP
Proposed
Bioretention Area
Install 15 LF
of 15" RCP
10Th St
14Th St
Charles Blvd
264
33
43

Hardee Creek Water Quality Project #2: Pinebrook Regenerative Stormwater Conveyance

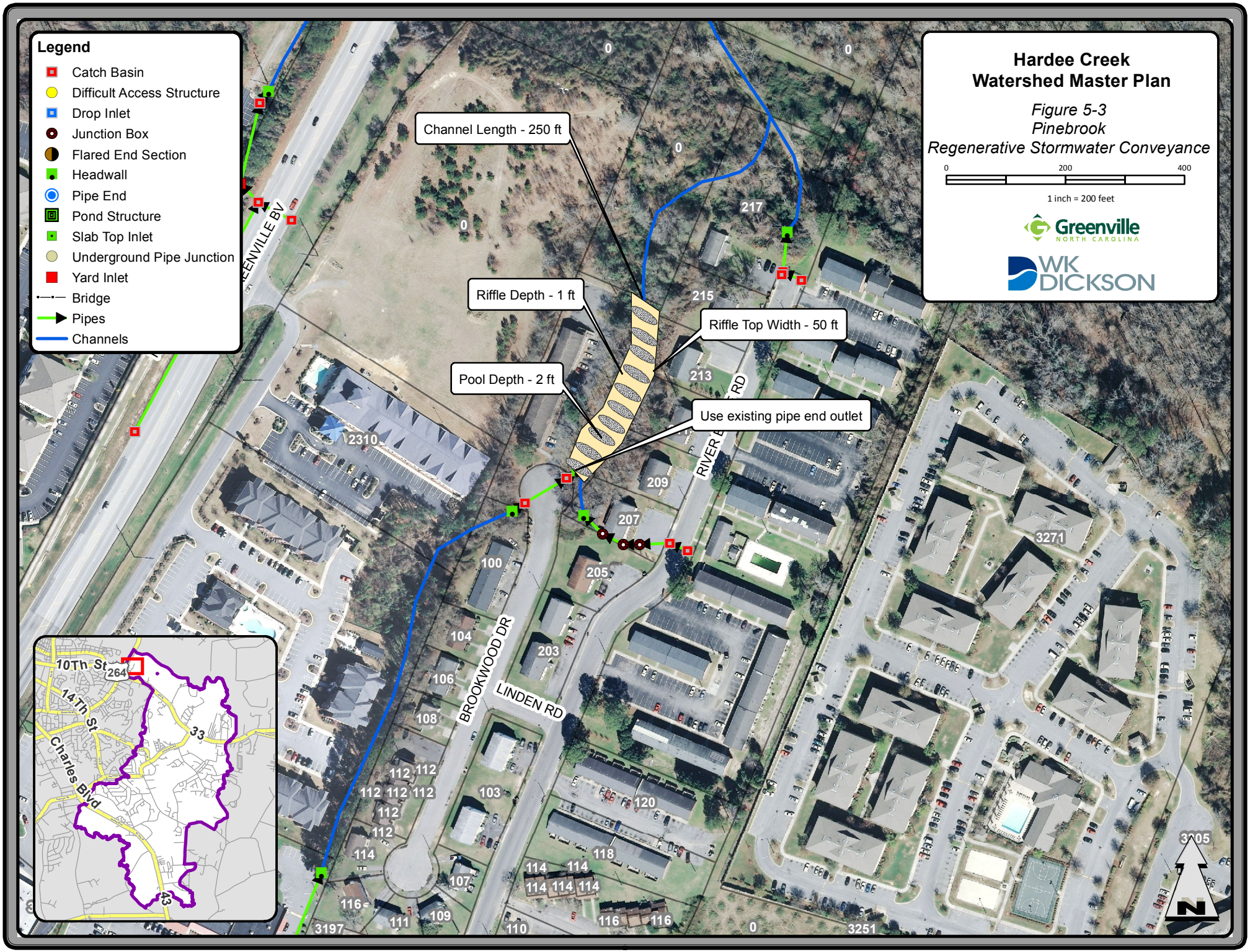
A Regenerative Stormwater Conveyance (RSC) system is proposed in the open channel ditch located at the end of Brookwood Drive (See Picture 5-2). This area drains several residential lots, commercial parking lots, and some runoff from River Bluff Road, Brookwood Drive, and Linden Road. The proposed RSC is located in a steep, incised stream channel that drains a large percentage of impervious drainage area. The RSC would provide treatment for high density residential impervious areas and stabilized the downstream channel thereby reducing sediment loads to the Tar River. Runoff from River Bluff Road and Brookwood Drive could both be directed through the RSC.

Picture 5-2. Proposed Location for Pinebrook RSC

The required surface area of the RSC is 12,500 square feet. A concept level plan of the proposed improvements is shown in Figure 5-3. The proposed RSC project consists of the following improvements:

- Install RSC channel designed to treat runoff from the adjacent lots and road. The proposed impervious areas draining to the enhanced channel is approximately 11.1 acres.
- Excavate step pools and install required boulders, cobbles, and infiltration media. The quantities are specified in Appendix I.

The proposed water quality project is located on private property. In order to construct the RSC, an easement agreement would be required with the owner. The estimated construction cost for the RSC at Pinebrook is $320,000.


Legend
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Channels
Hardee Creek
Watershed Master Plan
Figure 5-3
Pinebrook
Regenerative Stormwater Conveyance
0
200
400
1 inch = 200 feet
Greenville
NORTH CAROLINA
WK DICKSON
Channel Length - 250 ft
Riffle Depth - 1 ft
Riffle Top Width - 50 ft
Pool Depth - 2 ft
Use existing pipe end outlet
BROOKWOOD DR
LINDEN RD
RIVER RD
10Th St
14Th St
Charles Blvd
264
33
43
N

Hardee Creek Water Quality Project #3: Oakhurst Regenerative Stormwater Conveyance

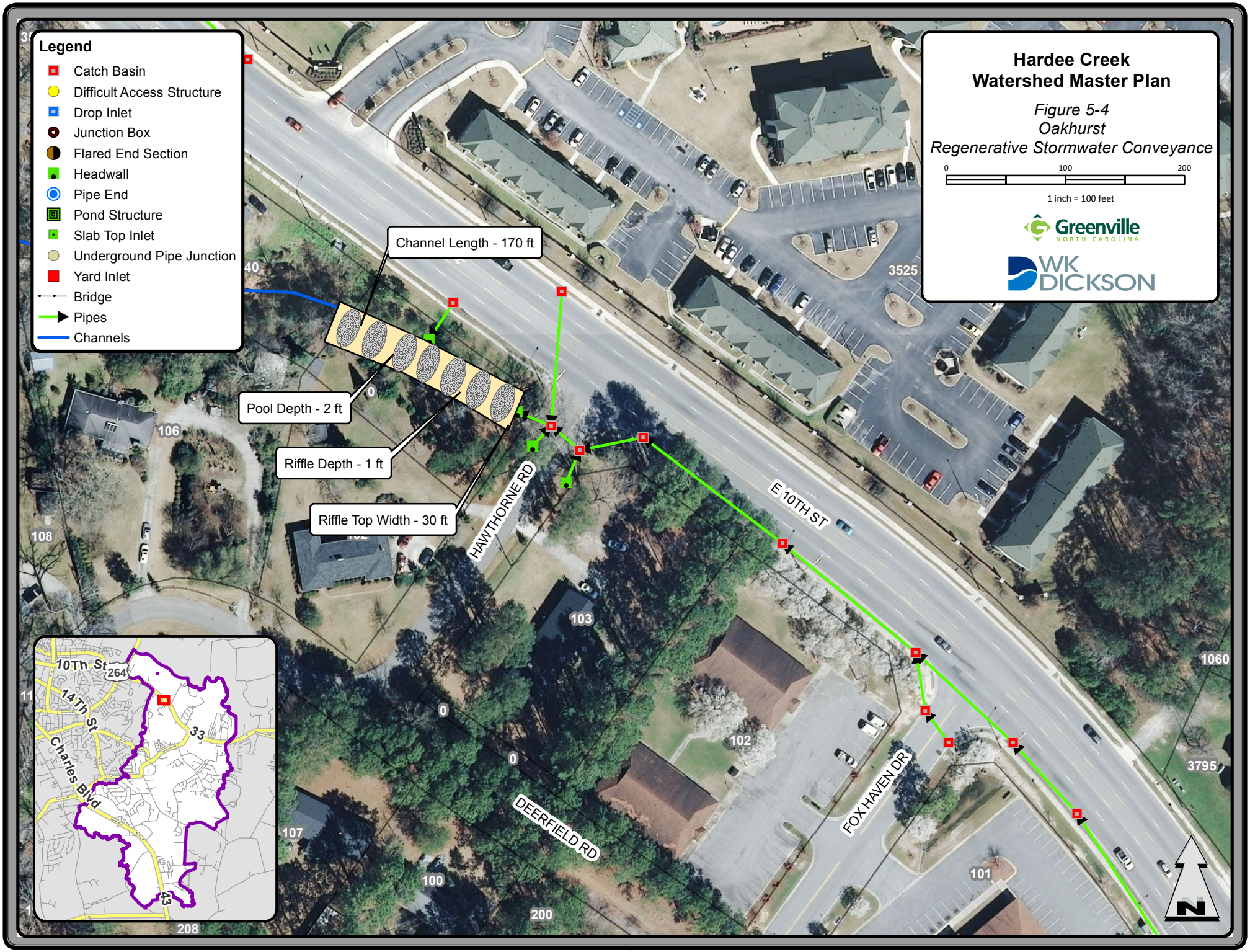
A Regenerative Stormwater Conveyance (RSC) system is proposed in the vacant property adjacent to 102 Hawthorne Road (See Picture 5-3). This area drains several commercial parking lots, and some runoff from East 10th Street. The RSC will be located in an existing channel bed that is currently located on private property, but the listed sales price is $8,000 in the GIS parcel database. It is assumed the parcel is not large enough to develop a residential property. Some limited impacts to utilities are expected, with some buried electrical lines that run parallel to East 10th St. Required infrastructure retrofit for this proposed project are minimal, as the existing 30'' RCP pipe end can be used. The largest impact to this parcel would likely be landscaping and demolition of a covered 'bridge' crossing. Due to the slope of this parcel and some light existing channel erosion, a RSC is recommended.

Picture 5-3. Proposed Location for Oakhurst Bioretention

The required surface area for the proposed RSC is approximately 5,100 square feet (0.11 acres). A concept level plan of the proposed improvements is shown in Figure 5-4. The proposed bioretention project consists of the following improvements:

- Install RSC channel designed to treat runoff from the adjacent lots and road. The proposed impervious areas draining to the enhanced channel is approximately 6.5 acres.
- Excavate step pools and install required boulders, cobbles, and infiltration media. The quantities are specified in Appendix I.

The proposed water quality project is located on private property. In order to construct the bioretention area, an easement agreement would be required with the owner or purchase of the parcel. Since the proposed BMP treats runoff from East 10th Street, the City may want to consider coordinating with NCDOT to determine if they would partner in construction of the BMP as part of their NPDES permit requirements. The estimated construction cost for the bioretention area at Oakhurst is $150,000.


Legend
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Channels
Channel Length - 170 ft
Pool Depth - 2 ft
Riffle Depth - 1 ft
Riffle Top Width - 30 ft
HAWTHORNE RD
E 10TH ST
DEERFIELD RD
FOX HAVEN DR
10Th St
14Th St
Charles Blvd
Hardee Creek
Watershed Master Plan
Figure 5-4
Oakhurst
Regenerative Stormwater Conveyance
0
100
200
1 inch = 100 feet
Greenville
NORTH CAROLINA
WK DICKSON
N

Hardee Creek Water Quality Project #4: Arbor Hills South RSC

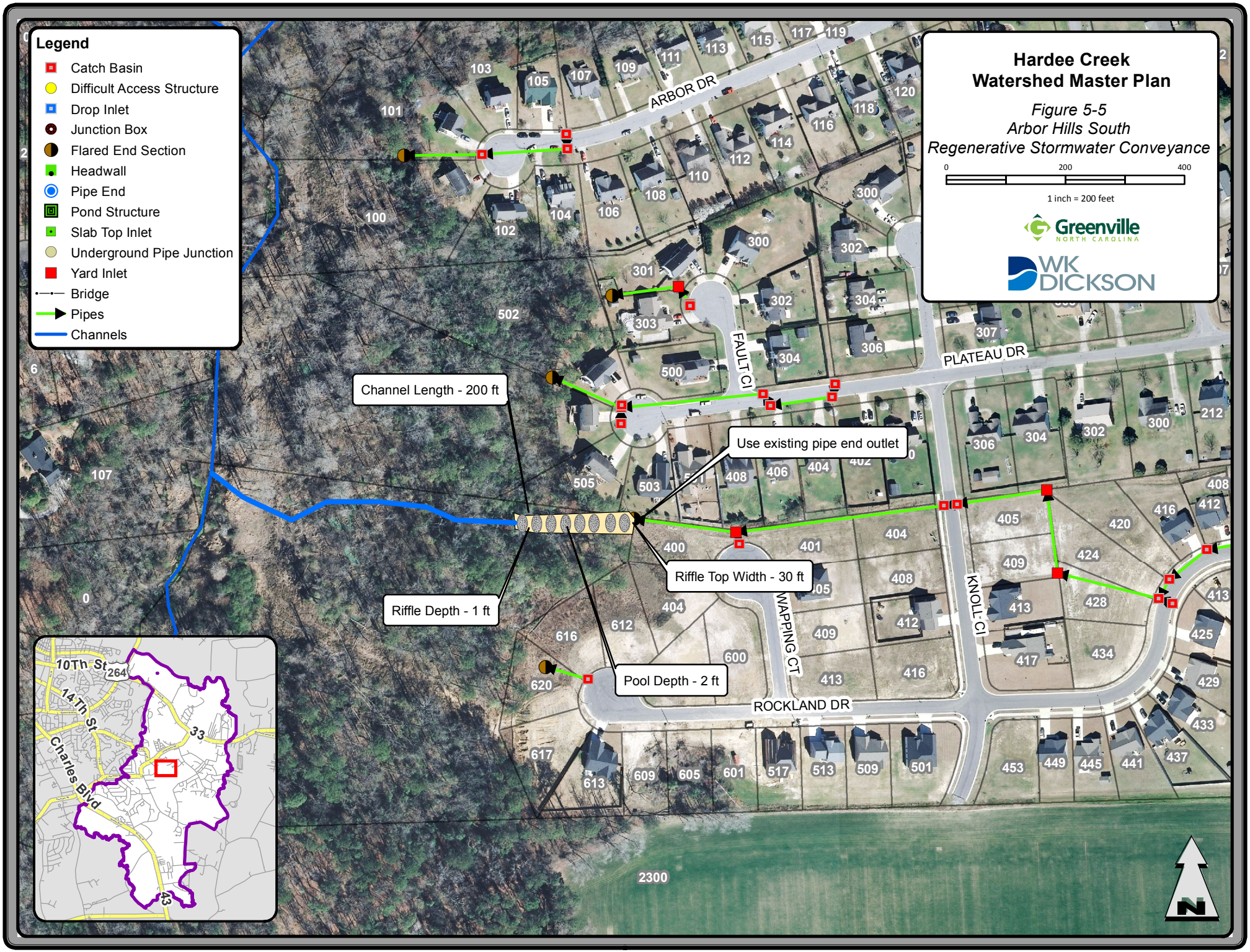
A RSC system is proposed in the open channel ditch located behind 400 Wapping Court (See Picture 5-4). This area drains several residential lots and streets. The proposed location is behind private property, and with a gentle slope. The proposed BMP would provide treatment for impervious areas that are not currently treated, however access to the site would be difficult due to private property conflicts, fencing, and vegetation. The residential development is new construction.

Picture 5-4. Proposed Location for Arbor Hills South RSC

The required surface area of the RSC is approximately 6,000 square feet. A concept level plan of the proposed improvements is shown in Figure 5-5. The proposed RSC project consists of the following improvements:

- Install RSC channel designed to treat runoff from the adjacent lots and road. The proposed impervious areas draining to the enhanced channel is approximately 3.4 acres.
- Excavate step pools and install required boulders, cobbles, and infiltration media. The quantities are specified in Appendix I.

The proposed water quality project is located on private property. In order to construct the RSC, an easement agreement would be required with the owner. The estimated construction cost for the RSC at Arbor Hills South is $160,000.


Legend
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Flared End Section
Headwall
Pipe End
Pond Structure
Slab Top Inlet
Underground Pipe Junction
Yard Inlet
Bridge
Pipes
Channels
Hardee Creek
Watershed Master Plan
Figure 5-5
Arbor Hills South
Regenerative Stormwater Conveyance
0
200
400
1 inch = 200 feet
Greenville
NORTH CAROLINA
WK DICKSON
Channel Length - 200 ft
Use existing pipe end outlet
Riffle Top Width - 30 ft
Riffle Depth - 1 ft
Pool Depth - 2 ft
ARBOR DR
PLATEAU DR
FAULT CI
WAPPING CT
KNOLL CI
ROCKLAND DR
10Th St
14Th St
Charles Blvd
264
33
43
N

5.4 NUTRIENT REMOVAL CAPACITIES

Along with determining the size and other design parameters for the proposed BMPs, nutrient removal efficiencies were calculated. These removal efficiencies were based on the TPN Calculation Sheet for Coastal Communities provided by the publicly available North Carolina DEQ website. These values are in compliance with the Tar-Pamlico Stormwater Rule, 15A NCAC 2B. 0258. Land use terms are separated by Transportation Impervious, Roof Impervious, Managed Pervious, and Wooded Pervious. Managed Pervious areas are split into further sub-categories based on lawn/landscaped, cropland, or pasture. Varying Event Mean Concentration (EMC) values are provided according to expected runoff capacities. The largest nutrient runoff loadings (TN and TP) are expected from Managed Pervious (cropland) and the least nutrient runoff loadings from Wooded Pervious areas. Total nitrogen (TN) and total phosphorus (TP) were computed based on the removal efficiencies provided in the NCDEQ BMP Manual. The quantity of nutrients removed per acre per year are provided in the table below.

Table 5-1: Proposed BMP Pollutant Removal

Project	TN Removed (lb/ac/yr)	TP Removed (lb/ac/yr)
Willow Run Bioretention	2.05	0.36
Pinebrook RSC	2.71	0.29
Oakhurst RSC	7.62	0.75
Arbor Hills South RSC	1.16	0.21

PUBLIC EDUCATION AND OUTREACH

Successful implementation of the Hardee Creek Watershed Master Plan and stormwater as a whole requires extensive public education and outreach. The City has taken important steps in public outreach within the Hardee Creek watershed through the use of direct mail questionnaires, web-based applications, and public meetings. Questionnaires were mailed to residents throughout the watershed in August of 2014 requesting feedback on flood-prone areas and any water quality concerns. Compiled results of the questionnaires can be found in Appendix D.

A public meeting was held on November 4, 2014, to introduce the project and facilitate further feedback from the public. The initial public feedback is critical to identifying flood-prone areas and validating model results. A follow-up was held on November 17, 2015 to share results of the Master Plan with the public. As selected projects proceed into design and construction continuous public outreach will be critical to the success of the projects. Additional public meeting and individual property owner meetings will help educate property owners on the benefits of the proposed projects as well as the temporary and permanent impacts from construction.

Aside from the public education and outreach completed for projects specific to the Hardee Creek Watershed Master Plan, the City has several programs dedicated to educating the public about water quality and pollution. The City's website provides information about the Stormwater Program and the development of the Stormwater Utility and associated fees. Another outreach measure that could be considered would be to target those City residents that live adjacent to streams. For this select group, quarterly newsletter could be mailed presenting information regarding the importance of not illegally discharging item (e.g. yard waste, car batteries, and other miscellaneous debris) into the stream. The newsletter should encourage the residents to keep the stream clean and report any blockage.

A different approach could be coordinating with local schools to teach the students about age appropriate stormwater issues. There are many benefits to teaching children about stormwater issues including the students relaying the information to their parents. A presentation could be done in conjunction with an afternoon spent visiting and cleaning up a nearby stream. Adding an educational BMP near a school would be another outreach opportunity. This along with the previously mentioned newsletter could be included in the Public Education section of the City's Action Report and Plan that must be completed annually to meet the requirements of the Tar-Pamlico River Basin stormwater program.

ANTICIPATED PERMITTING

The proposed improvements described in Section 4 may require local, State, and/or Federal permits or approvals prior to the onset of construction. Based on the types of projects identified in the Hardee Creek watershed, permits or approvals may be required for any of the following reasons:

- Stream and/or wetland impacts;
- FEMA floodway impacts;
- Land disturbance; and
- Potable water and sewer line adjustments.

The permitting matrix shown in Table 7-1 shows the different types of permits that are anticipated for each of the proposed flood control projects. The water quality retrofits may require erosion control permits if the area of disturbance is greater than 1.0 acres, but permits or agreements from DWQ, USACE, FEMA, and NCDOT are not anticipated for these projects.

The types of 404/401 permits are described below and may vary based on the length of stream impacts and/or acreage of wetland impacts. Wetlands will need to be delineated to determine the acreage of impacts. Permit requirements for a given project may change based on the final design and any changes to the existing regulations. The appropriate permitting agencies should be contacted during the design process to determine if permits will be required for the proposed project.

7.1 NORTH CAROLINA DIVISION OF WATER RESOURCES 401 WATER QUALITY CERTIFICATION AND US ARMY CORPS 404 PERMIT

Proposed improvements within the City of Greenville must adhere to the requirements set forth in Section 401 and 404 of the Clean Water Act. Required permitting can range from activities that are pre-authorized to those requiring pre-construction notification (PCN) for a Nationwide Permit (NWP) to those requiring an Individual Permit (IP). Individual permits may be required for projects with stream impacts greater than 300 feet and wetland impacts greater than 0.5 acres. It is anticipated that NWP #3 (Maintenance) and NWP #13 (Bank Stabilization) may be required to support the projects that include work within channels that are claimed jurisdictional by the US Army Corps of Engineers (USACE). Individual permits may be required for floodplain benches where significant wetland impacts may be encountered. More detailed explanations of the types of 404 permits are provided below.

NWP#3 – Maintenance

This permit authorizes the repair, replacement, or rehabilitation of any previously permitted or currently serviceable structure. A PCN is not required for minor deviations in the structure's configuration or filled area that occur as a result of changes in materials, construction techniques, or safety standards necessary to make repair or replacement, provided environmental impacts are minimal. A PCN to the USACE is required if a significant amount of sediment is

excavated/filled within the channel. NC Division of Water Quality (DWQ) does not typically require a PCN for NWP #3 but usually receives one as a courtesy.
Other provisions imposed by the State of North Carolina require that culvert inverts must be buried a minimum of 1-foot below the streambed for culverts greater than or equal to 48 inches in diameter to allow low flow passage of water and aquatic life. Culverts less than 48 inches in should be buried to a depth of 20 percent or greater of the culvert's diameter.

7.2 INDIVIDUAL PERMITS

Individual permits are required when stream or wetland impacts do not meet the conditions of a nationwide permit. Permit applications may be reviewed by multiple agencies including but not limited to USACE, DWQ, EPA, SHPO, NCWRC, and USFWS. The application is also made available for public review. There is no defined timeline for review of the application for an IP; therefore, the permitting process for an IP is typically significantly longer that the review time for a NWP. Typically, 404 and 401 Individual Permits are applied for jointly and their review is concurrent.

7.3 FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Streams with a drainage area greater than one square mile are typically modelled and mapped by FEMA for flood insurance purposes. The 100-year floodway and floodplain has been mapped for Hardee Creek from approximately one mile upstream of Herman Garris Road to its confluence with the Tar River. Any proposed projects that will include grading within a FEMA defined floodway will require a Conditional Letter of Map Revision (CLOMR) submitted to FEMA for pre-approval purposes and a Letter of Map Revision (LOMR) upon completion of construction. Table 7-1 identifies projects where FEMA permitting is expected.

7.4 EROSION AND SEDIMENTATION CONTROL

North Carolina Department of Environmental Quality (NCDEQ) is another agency that requires notification before proposed activities are constructed. NCDEQ requires that an erosion and sedimentation control plan be submitted to the Land Quality Section for approval before the start of construction for any disturbance greater than one acres. Erosion and Sedimentation permits are anticipated for most of the proposed projects as shown in Table 7-1.

Table 7-1: Permitting Matrix for Proposed Projects

	FEMA	NCDEQ /NPDES	404/401 (NWP)	404/401 (IP)	NCDOT	RAILROAD
PRIMARY SYSTEM PROJECTS						
Portertown Road Floodplain Benching and Stream Stabilization	X	X	X		X	
East 10th Street Floodplain Culverts	X	X	X		X	
SECONDARY SYSTEM PROJECTS						
Fox Haven Drive – Quail Hollow Road		X				
River Hills		X				
WATER QUALITY PROJECTS						
Project #1 - Willow Run Bioretention		X				
Project #2 - Pinebrook RSC		X	X			
Project #3 - Oakhurst RSC		X	X			
Project #4 - Arbor Hills South RSC		X				

FUNDING OPPORTUNITIES

8.1 WATER QUALITY IMPROVEMENT FUNDING

As the final designs of the proposed improvements are evaluated, the City is encouraged to investigate the potential funding mechanisms that are available for water quality projects. There are wide range of funding mechanisms that may be available to the City. Sources include the Clean Water Act Part 319 funds administered by the US EPA and North Carolina Cleanwater Management Trust Fund (CWMTF). CWMTF funding can include land acquisition costs, design fees, and construction costs to help finance projects that improve and protect water quality. In 2014, $24.8 million to fund projects throughout North Carolina (www.cwmtf.net).

The Clean Water State Revolving Fund (CWSRF) is another option. It offers low-interest loans that can be used to find stormwater projects with water quality components. It should be noted that typically, grants require some type of match funding. The matching requirements vary for each different type of grant. For example, the CWSRF requires a 20 percent match from the State based on the amount of Federal dollars awarded while the CWMTF does not have a specified match requirement.

The NCDEQ Division of Water Resources has a Water Resources Development Project Grant Program. The program provides cost-share grants and technical assistance. The grants are offered for the following purposes: general navigation, recreational navigation, water management, stream restoration, beach protection, land acquisition, and facility development for water-based recreation and aquatic weed control. Spring 2014, the program awarded grants ranging from $1,500 to $450,000. The total awarded across thirty-seven projects/recipients was $2,240,000 (www.ncwater.org).

8.2 FLOOD MITIGATION FUNDING

FEMA's Flood Mitigation Assistance (FMA) is a pre-disaster grant program designed to provide funding to Stated and communities in their efforts to reduce or eliminate the risk of repetitive flood damage to building and structures insured under the National Flood Insurance Program (NFIP). In order to be eligible, communities must have completed and approved Flood Mitigation Plans that assess the flood risk and identify actions to reduce that risk. Any State agency, participating NFIP community, or local agency is eligible to participate and should contact community officials.

Additional project grant eligibility criteria include a project that is:

- Cost effective;
- Cost beneficial to the National Flood Insurance Fund;
- Technically feasible; and

- Physically located in participating NFIP community or reduce future flood damages in an NFIP community.

A project must also comply with (1) the minimum standards of the NFIP Floodplain Management Regulations, (2) the applicant's Flood Mitigation Plan, and (3) all applicable laws and regulations. The State is the grantee and program administrator for FMA. FEMA distributes FMA funds to States that in turn provide funds to communities. FEMA may provide up to 75% of the total eligible costs. The remaining costs must be provided by a non-Federal source of which no more than half can be provided as in-kind contributions from third parties.

8.3 REVENUE AND GENERAL OBLIGATION BONDS

Municipalities in North Carolina have the authority to use binding for capital improvement projects under the State's General Statues. There are two types of bonds available for use – general obligation and revenue bonds. General obligation bonds are funds received after voter approval of bond referendum. A vote is required because general obligation bonds are secured using the City's taxing power. All revenues, including different taxes, can be used to pay off a general obligation debt. Revenue bonds, on the other hands, are backed by income generated by the City through fees collected (e.g., various utility fees including stormwater). Because their security is not as great as that of general obligation bonds, revenue bonds may carry a slightly higher interest rate.

8.4 UTILITY RATE STUDY

The City should consider completing a utility rate study to determine if the current rate is appropriate for funding the required operation of the Stormwater Division as well as capital projects. The enterprise fund was originally established in 2001 with collections beginning in 2003. In May 2013, City staff requested a fee increase of $0.50/ERU each year for the next five years to support capital projects and completion of the City-wide master plan. Currently as of July 1, 2015 the fee is $4.35 per ERU. Once planning is concluded the City should complete a detailed rate study based on the capital needs identified during the planning process.

COST ESTIMATES

The cost estimates provided as part of the Hardee Creek Watershed Master Plan were prepared to assist City staff in making planning level decisions and prioritizing improvements. These cost estimates are not final design cost estimates. These costs were developed using recent bid tabulations from other communities and NCDOT projects within North Carolina. They include easement acquisitions, surveying, engineering, legal, and administrative costs. A detailed breakdown of the costs for the projects listed below in Table 9-1 is included in Appendix G. Projects are not listed based on priority. See Section 10 for a prioritization list. The cost estimates are approximate and are subject to change due to local costs, materials, delivery, construction, and other factors. BMP costs are based on the size of the BMP, the estimated excavation requires, and any associated structure of planting costs.

The stormwater drainage systems evaluated in this report are composed of a series of culverts, closed drainage systems, open channels, floodplain grading, and BMPs. For these drainage systems to function as designed, they must be properly maintained.

Table 9-1: Preliminary Project Cost Estimates

Projects	Preliminary Project Cost
PRIMARY SYSTEM PROJECTS	
Portertown Road Floodplain Benching and Stream Stabilization	$3,780,000
East 10th Street Floodplain Culverts	$890,000
SECONDARY SYSTEM PROJECTS	
Fox Haven Drive – Quail Hollow Road	$410,000
River Hills	$550,000
WATER QUALITY PROJECTS	
Project #1 - Willow Run Bioretention	$250,000
Project #2 - Pinebrook RSC	$320,000
Project #3 - Oakhurst RSC	$150,000
Project #4 - Arbor Hills South RSC	$160,000

PRIORITIZATION AND RECOMMENDATIONS

As previously noted, the primary goal of this study is to make improvement recommendations to reduce flooding within the Hardee Creek Watershed. Currently, several conveyance systems do not meet the City hydraulic design requirements. WK Dickson has provided recommendations that help to reduce or eliminate the identified problems. Success criteria goals used to measure the proposed flood control project included the following:

- Providing improved level of service for roadways and structures;
- Economic feasibility;
- Minimizing stream and wetland impacts;
- Confirming physical feasibility using available GIS and survey data; and
- Minimizing easement acquisition.

Two different prioritization lists were developed for the proposed projects identified in Section 4 and 5; Flood Control Improvements and Water Quality/Stream Stabilization Improvements. Projects were prioritized using the Prioritization Matric provided in Appendix L. The improvements were prioritized based on the following factors:

- Public health and safety;
- Severity of street flooding;
- Cost effectiveness;
- Effects of improvements;
- Water quality – BMP;
- Open channel –erosion control;
- Implementation constraints;
- Grant funding; and
- Constructability.

In some instances, project prioritization will be impacted by the required sequencing of projects to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts for the proposed projects. Downstream impacts are including in the scoring for Implementation Constraints, however upon completion of the scoring process, the prioritization list should be reviewed to ensure the projects are appropriately ranked based on sequencing. Table 10-1 shows the proposed prioritizations for the Flood Control Improvements. The City should re-visit the prioritization lists annually to determine if the priorities should change.

Table 10-1: Flood Control Prioritization – Primary Systems

Prioritization	Project
1	Portertown Road Floodplain Bench
2	East 10th Street Culverts

Table 10-2: Flood Control Project Prioritization – Secondary Systems

Prioritization	Project
1	Fox Haven Drive – Quail Hollow Road
2	River Hills Drive

Table 10-3: Water Quality and Stream Stabilization Prioritization

Prioritization	Project
1	Pinebrook RSC
2	Oakhurst RSC
3	Willow Run Bioretention
4	Arbor Hills RSC

Table 10-4 shows the recommended priorities for maintenance projects in the watershed. Maintenance locations were identified based on the condition assessment completed during the stormwater inventory. Structures receiving a condition of "poor" or "repair" are listed below for maintenance. More immediate maintenance needs may present themselves if portions of a conveyance system fail. Projects were prioritized based on the consequences of flooding. Projects requiring structural improvements (i.e. in danger of failing) were given priority over those driven by sediment/vegetation removal needs. Additionally, the impact of flooding and proximity to a citizen input response were also considered in project ranking. Maintenance costs assume that City staff will complete the construction. If maintenance projects are bid to a private contractor, the City should complete a more detailed cost estimate prior to bid.

Table 10-4: Maintenance Recommendations

Prioritization	Project	Estimated Cost
1	King George Road Culvert Replacement	$13,500
2	Replace 52 LF of 15'' RCP - rusted bottom or pipe end near 2061 Portertown Road (HCUT010013)	$5,200
3	Replace 59 LF of 36'' CMP - rusted bottom of pipe end – Brook Valley Golf Crossing (HCUT010018)	$14,160
4	Replace 28 LF of 24'' CMP - rusted bottom of both pipe – Brook Valley Golf Crossing (HCUT010020 and HCUT010021)	$3,920
5	Replace 98 LF of 15'' RCP eroding around pipe end at 1050 Port Terminal Road and dredge buried pipe end at 1030 Port Terminal Rd (HCMB010001 and HCMB010003)	$11,800
6	Replace 41 LF of 15'' RCP (sinkholes) and replace catch basin HCMB010120 along East 10th Street near primary system crossing and replace catch basin	$10,100
7	Repair/replace box along Bluebill Drive, groundwater pouring in from around pipe (HCUT040011)	$6,000
8	Replace headwall near intersection of Mann Farm Road and East 10th Street (HCMB010187)	$12,000
9	Replace 270 LF of 15″ CMP near 239 Churchill Road (HCMB010174)	$27,000
10	Replace missing top slab for inlet structure near 219 Churchill Drive (HCMB010166)	$2,000
11	Replace oversized junction box lid at near 219 Churchill Drive (HCMB010165)	$2,000
12	Dredge buried pipe end at 101 Cardinal Drive (HCUT010033)	$2,000
Total		$110,000

REFERENCES

1. Hydraflow Storm Sewers Extension User's Guide Version 8, 2011.

2. Municipal Storm Water Management, by Debo and Reese, 1995

3. National Weather Service
   http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html

4. Stormwater Best Management Practices; North Carolina Department of Environment and Natural Resources, Division of Water Quality, July 2007.

5. Urban Hydrology for Small Watersheds, United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, Technical Release 55, June 1986.

6. Booth DB, Jackson CR (1997) Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation. Journal of the American Water Resources Association 33(5):1077-1090.

7. Brant, T. R. 1999. Community Perceptions of Water Quality and Management Measures in the Naamans Creek Watershed. *Masters Thesis for the Degree of Master of Marine Policy. 146 pp.*

8. Stepenuck KF, Crunkilton RL, Wang L (2002) Impacts of urban landuse on macroinvertebrate communities in southeastern Wisconsin streams. Journal of the American Water Resources Association 38(4):1041-1051.

9. Environmental Protection Agency
   http://www.epa.gov/caddis/ssr_urb_is4.html

10. North Carolina Department of Environment and Natural Resources
    http://www.ncwater.org/Financial_Assistance/

11. NC Department of Environmental Quality - Stormwater Rules
    http://portal.ncdenr.org/web/wq/ps/nps/tarpamstorm