Greenville City Council Watershed Master Plan Workshop

Thursday, August 25, 2016
6:00 p.m.
City Hall Conference Room 337
200 West Fifth Street

I. Call Meeting to Order

II. Roll Call

III. Approval of Agenda

- Public Comment Period

The Public Comment Period is a period reserved for comments by the public. Items that were or are scheduled to be the subject of public hearings conducted at the same meeting or another meeting during the same week shall not be discussed. A total of 30 minutes is allocated with each individual being allowed no more than 3 minutes. Individuals who registered with the City Clerk to speak will speak in the order registered until the allocated 30 minutes expires. If time remains after all persons who registered have spoken, individuals who did not register will have an opportunity to speak until the allocated 30 minutes expires.

IV. Presentation and discussion of Watershed Master Plans and related issues

A. Recap of the 2013 State of the Stormwater Utility Fund Presentation

B. Watershed Master Plan Overview

C. Highlights from Several Watersheds

D. Implementation

E. Operational Impacts (Maintenance/Ordinance)

F. Utility Impacts

V. Adjournment

TITLE OF ITEM: Watershed Master Plan Presentation

ABSTRACT: The Public Works Department has completed citywide watershed master planning and will use these products to assist with maintenance activities, assess capital improvement project needs, meet state and federal stormwater requirements, and aid in quality assurance of new/re-development efforts in the City of Greenville. This workshop will provide a report on the existing condition of the City's stormwater infrastructure as well as highlight the recommendations from those plans.

EXPLANATION: In October 2013, the City completed the Meetinghouse Branch Watershed Master Plan. The goals of the master plan included: (1) evaluating the watershed for existing flooding, water quality, and erosion problems; (2) recommending and prioritizing capital improvements to control existing flooding by reducing the frequency and severity of flooding for property owners; and (3) identifying stream stabilization projects to reduce the risk of property loss along streams and to reduce sediment loads as a result of erosion.

Upon the completion and presentation of the Meetinghouse Branch Watershed Master Plan, City Council recognized the importance of these plans. Council also realized the importance of gaining understanding of how best to remediate the stormwater system so as not to adversely affect other properties either upstream or downstream from where an improvement is planned. As a result, the remaining watershed plans (see Attachment A) were programmed so that the City could determine how best to expend Stormwater Utility funds in the most prudent manner.

WK Dickson, Hazen & Sawyer, and CDM Smith were selected as the firm best suited to provide the services noted above. Each firm/team was assigned an area of the City as well as a lead role based on their area of expertise. The assignments are presented below.

WK Dickson:	**South City Phase**
	Lead-Program Management
	Fork Swamp
	Swift Creek
	Hardee Creek
Hazen & Sawyer:	**Central City Phase**
	Lead-Public Involvement
	Greens Mill Run
CDM Smith:	**North City Phase**
	Lead-GIS/Inventory
	Harris Mill Run/Schoolhouse Branch
	Johnsons Mill/Parker Creek

The Public Works Department has completed the Master Plans and will use these products to assist with maintenance activities, assess capital improvement project needs, meet state and federal stormwater requirements, and aid in quality assurance of new/re-development efforts in the City of Greenville. Attached are the Executive Summaries (see Attachment B) from each of the six Master Plans. Staff and the consultants will explain the various levels of service designations found in the reports.

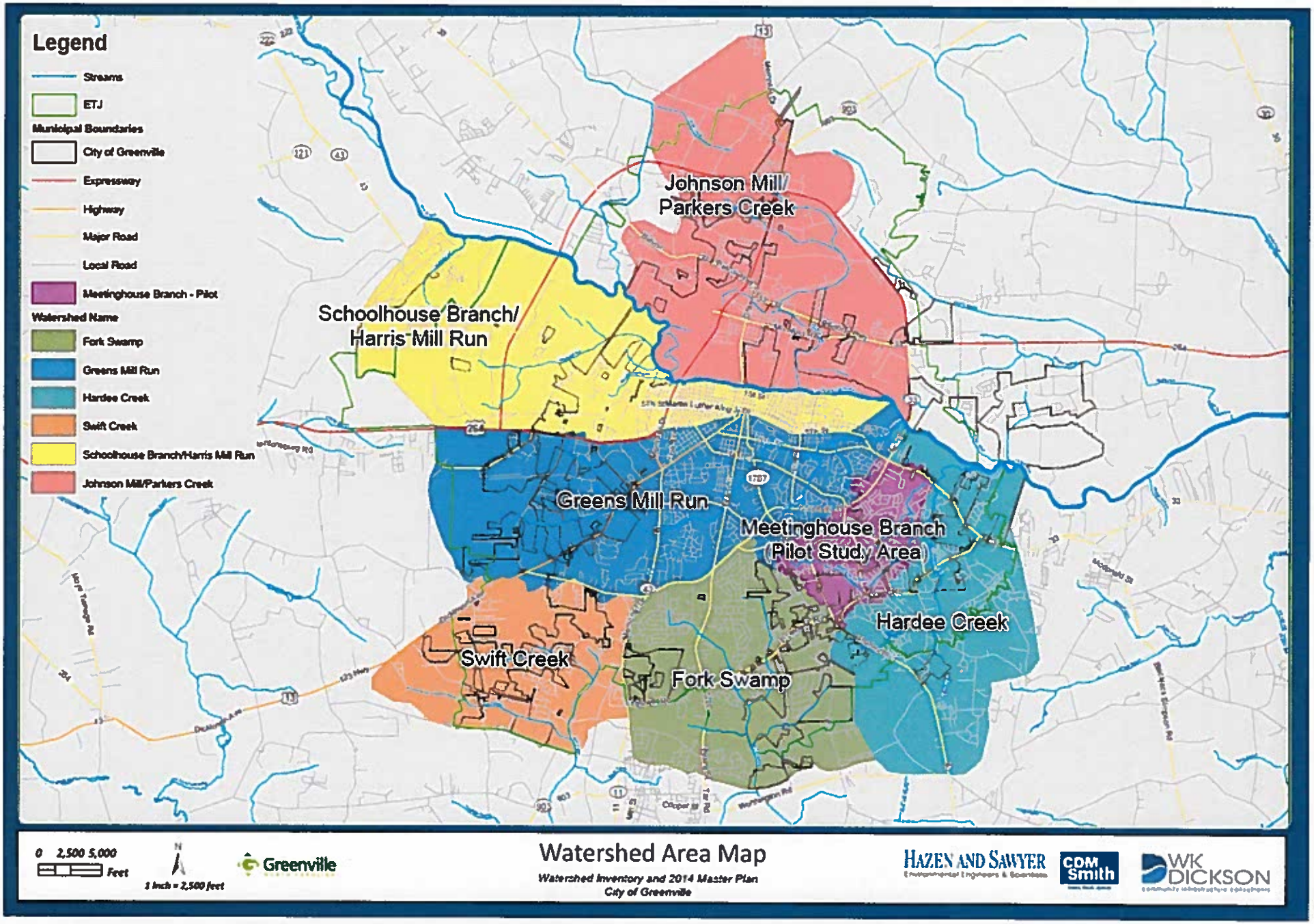
This workshop will provide insight to the existing condition of the City's stormwater infrastructure as well as highlight the recommendations from those plans. More specifically, staff will provide:

- A recap of the 2013 State of the Stormwater Utility Fund (Meetinghouse Branch Watershed Master Plan) presentation
- Watershed Master Plan Overview
- Highlights from several watersheds
- Implementation
- Operational Impacts (Maintenance/Ordinance)
- Utility Impacts

FISCAL NOTE: No fiscal impacts at this time.

RECOMMENDATION: Receive information presented.

ATTACHMENT A



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City of Greenville Greens Mill Run Watershed Master Plan

Draft Report
Hazen No. 31187
July, 2016

Executive Summary

As part of the effort to inventory and develop master plans for the City of Greenville (COG), the City retained Hazen and Sawyer to complete a Watershed Master Plan (WSMP) for Greens Mill Run (GMR). The goals of this watershed master plan (WSMP) were to: (1) evaluate the watershed for 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, and (3) identify stream stabilization projects to reduce the risk of property loss along streams and to reduce sediment loads as a result of erosion. As part of the project, Hazen and Sawyer completed an inventory of stormwater infrastructure within the GMR watershed. **Table ES-1** summarizes inventory data collected as part of the project. Surveyed structures and field information were incorporated into a geographical information system (GIS) database and provided to the City.

Table ES-1: Summary of Stormwater Inventory

Structure Type	Number Inventoried
Closed System Structure	4,708
Bridge	7
Primary Cross-Section*	101
Secondary Channel Measurement*	184
Pond Structure	9
Drainage Pipe	76 miles
Channel (Primary and Secondary)	35 miles

*See Section 1.1 for additional information.

In addition to inventory of stormwater infrastructure, the project included a robust campaign to engage stakeholders and the public through a number of mediums in order to receive information regarding problem areas within the watershed, and feedback on areas where projects were identified. Hazen and Sawyer, in collaboration with the City of Greenville's Public Information Officer (PIO), developed a Public Involvement Plan (PIP) that outlined the process by which the public and stakeholders were engaged in all COG WSMPs. The general public was engaged through use of social media, the project website (www.greenvillewsmp.com), questionnaires, public meetings, and one-on-one onsite or phone interviews.

Stakeholders were engaged at a one day meeting in which various groups met with Hazen and Sawyer team members to discuss known problem areas and various issues within the watershed. City staff served as an important stakeholder by providing information on historical flooding and erosion problems within the watershed, as well as detailed feedback on potential capital improvement projects identified as part of the WSMP. Information collected thorough the PIP process is included in **Section 2.1** and also in **Appendix D**. **Appendix D** also includes a copy of the PIP which guided the overall project across all watersheds.

The Hazen and Sawyer team included East Carolina University (ECU) to provide ambient stream monitoring for Greens Mill Run. ECU is also located within the GMR watershed and was involved in the stakeholder process discussed above. East Carolina's findings are discussed in **Section 5.3**, with the full report included in **Appendix N**.

The GMR watershed is approximately 13.75 square miles, 11.12 square miles of which are located within the City limits, and 2.63 square miles within the extraterritorial jurisdiction (ETJ). The watershed is located centrally within Greenville, and contains much of downtown Greenville and East Carolina University. The watershed is generally bounded on the north by 5th Street, on the south by Greenville Boulevard/Red Banks Road, and to the west by the agricultural area between Allen Road and Kinsaul-Willoughby Road. The watershed drains from west to east, discharging directly into the Tar River. The eastern half of the watershed area is highly developed, with the degree of urbanization / imperviousness increasing from west to east.

Flood Control Projects

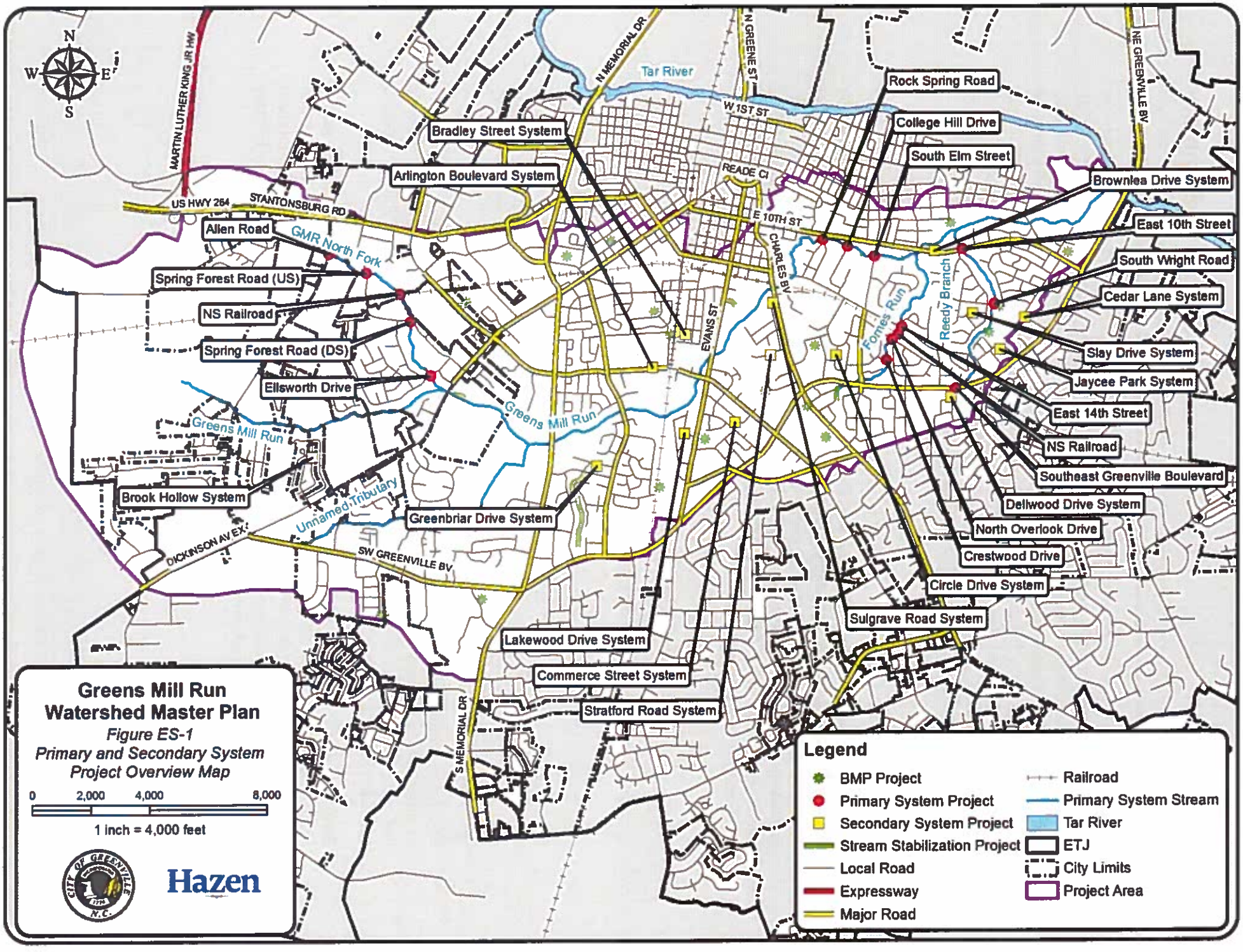
Utilizing data obtained as part of the infrastructure inventory, Hazen and Sawyer conducted an existing conditions analysis, which evaluated the hydrologic and hydraulic performance of existing conveyance infrastructure. This analysis was divided between two system types: Primary, which included culvert and bridge crossings along five streams within the watershed, and Secondary, consisting of closed pipes and small open-channels, conveying water from surrounding roads, structures, and lawns, ultimately discharging into the Primary System. The Primary System consisted of the following streams:

- Greens Mill Run – from Allen Road to the Tar River
- Reedy Branch – from Greenville Boulevard to its confluence with GMR
- Fornes Run – from Greenville Boulevard to its confluence with GMR
- Unnamed Tributary (through Greenville Country Club) – from Greenville Boulevard to its confluence with GMR
- Greens Mill Run North Fork – from Allen Road to its confluence with GMR

Each roadway crossing along the Primary System was studied in detail to determine its level of service under both existing development conditions and future development conditions (based on the City's future land-use GIS information). Improvements to crossings with an insufficient LOS were designed based upon future land-use conditions.

Secondary Systems within the watershed were evaluated, if identified by citizens or stakeholders as areas with significant flooding or erosion. The majority of Secondary System flooding issues that were identified occurred within private residential neighborhoods. The problems reported consisted primarily of street, yard, and crawl space flooding.

Based on the hydrologic and hydraulic analyses of the Primary System and Secondary Systems, Hazen and Sawyer identified a number of capital improvement and maintenance projects that reduce the severity and frequency of flooding within the GMR watershed. Following is a summary of the Primary and Secondary Systems projects, which are depicted in **Figure ES-1**. Primary System projects are presented from upstream to downstream progression, by stream.


Greens Mill Run
Watershed Master Plan
Figure ES-1
Primary and Secondary System
Project Overview Map
0 2,000 4,000 8,000
1 inch = 4,000 feet
Hazen
Legend
BMP Project
Primary System Project
Secondary System Project
Stream Stabilization Project
Local Road
Expressway
Major Road
Railroad
Primary System Stream
Tar River
ETJ
City Limits
Project Area
Bradley Street System
Arlington Boulevard System
Allen Road
Spring Forest Road (US)
NS Railroad
Spring Forest Road (DS)
Ellsworth Drive
Brook Hollow System
Greenbriar Drive System
Lakewood Drive System
Commerce Street System
Stratford Road System
Rock Spring Road
College Hill Drive
South Elm Street
Brownlea Drive System
East 10th Street
South Wright Road
Cedar Lane System
Slay Drive System
Jaycee Park System
East 14th Street
NS Railroad
Southeast Greenville Boulevard
Dellwood Drive System
North Overlook Drive
Crestwood Drive
Circle Drive System
Sulgrave Road System
Tar River
GMR North Fork
Greens Mill Run
Unnamed Tributary
Fornes Run
Reedy Branch
N MEMORIAL DR
S MEMORIAL DR
N GREENE ST
W 1ST ST
NE GREENVILLE BV
READE CI
E 10TH ST
CHARLES BV
EVANS ST
MARTIN LUTHER KING JR HW
US HWY 264
STANTONSBURG RD
DICKINSON AV EX
SW GREENVILLE BV

Greens Mill Run Primary System

Rock Spring Road – The existing twin 15' x 9.4' Corrugated Metal Pipe Arches (CMPAs) provide a 10-year level of service under existing land-use conditions, which is below the desired 25-year level of service. Meeting the desired LOS was determined to be unfeasible due to downstream channel and culvert constrictions resulting in high tailwater on the Rock Spring Road crossing. The improvements required to meet the desired 25-year LOS would include upsizing all crossings from Rock Spring Road to the East 5th Street bridge by two to four times their current size, including two crossings without LOS violations. In order to maintain a 10-year level of service under future land-use conditions, Alternative #1 is proposed to replace the existing culverts with triple 11' x 10' RCBCs. This alternative requires improvements at both College Hill Drive and South Elm Street in order to provide the stated LOS. Alternative #2 is to replace the existing culverts with quadruple 11' x 10' RCBCs, which also provides a 10-year level of service under future conditions, but requires downstream improvements only at South Elm Street.

College Hill Drive – The existing twin 12' x 10' RCBCs provide a 10-year level of service under existing land-use conditions and appear to be in good structural condition. The private roadway is owned by East Carolina University and is assumed to require a 10-year LOS. Tailwater from this crossing impacts performance of the Rock Spring Road crossing, thus Alternative #1 is proposed to supplement the existing culverts with an 8' x 4' RCBC to reduce the required upstream improvements required at Rock Spring Road. This improvement provides a 10-year LOS under future land-use conditions and reduces tailwater on Rock Spring Road. Alternative #1 requires downstream improvements at South Elm Street. Alternative #2 is to not improve this crossing and rely solely on improvements at South Elm Street and Rock Spring Road for reduction of overtopping frequency at Rock Spring Road and College Hill Drive. This alternative also results in a 10-year LOS at College Hill Drive.

South Elm Street – The existing twin 16.5' x 10.5' CMPAs provide a 25-year level of service under existing land-use conditions, which is below the desired 50-year level of service. The existing culverts appear to be in good structural condition; however, because they do not provide the desired level of service and need to be significantly upsized, replacing the culverts is proposed. The improvement at this crossing is to replace the existing culverts with quadruple 11' x 11' RCBCs, which will maintain the 25-year level of service under future land-use conditions. Meeting the desired 50-year LOS was determined to be unfeasible, as it required all crossings at and downstream of South Elm Street to be upsized two to four times their current size, including two crossings without LOS violations.

Greens Mill Run Floodplain Modifications – As a result of implementing the improvements at each of the GMR crossings presented above, the downstream reaches of the stream were shown to experience water surface elevation increases of up to 0.13 feet (average of 0.09 feet). To mitigate the increases due to implementation of Alternative #1 improvements, unmaintained floodplain benching, for approximately 2,125 feet long and 60 - 70 feet wide, is proposed to be constructed downstream of East 5th Street. The same benching is also required with GMR Alternative #2 improvements, in addition to an approximately 300 foot long by 10 foot wide unmaintained bench downstream of Rock Spring Road.

Reedy Branch Primary System

Southeast Greenville Boulevard – The existing 36" Corrugated Metal Pipe (CMP) provides a 2-year level of service under existing land-use conditions, which is below the desired 50-year level of service for the NCDOT roadway. The existing culvert appears to be in fair structural condition. Replacing the culvert with a 60" reinforced concrete pipe (RCP) is proposed to provide a 50-year level of service under future land-use conditions.

South Wright Road – The existing 48" CMP, which is in fair structural condition, provides a 2-year level of service under existing land-use conditions, which is below the desired 25-year LOS. Proposed Alternative #1 is to replace the existing culvert with twin 6' x 5' RCBCs, providing a 25-year level of service under future land-use conditions. This improvement requires downstream improvements at East 10th Street, as described below. Alternative #2 involves replacement of the existing culvert with a 7' x 5' RCBC to provide a 10-year level of service under future land-use conditions, with no required downstream improvements.

East 10th Street – The existing 48" and 54" RCPs meet the desired 50-year level of service for the NCDOT roadway under existing land-use conditions. However, in order to decrease upstream tailwater and limit the magnitude of upstream improvements, Alternative #1 is proposed to supplement the existing culverts with a 48" RCP located in the floodplain overbank. This will maintain the 50-year level of service under future land-use conditions and decrease tailwater at South Wright Road to permit achieving a 25-year LOS under future land-use conditions at South Wright Road. The second alternative is to not improve this crossing and provide 10-year level of service under future land-use conditions at South Wright Road.

Fornes Run Primary System

Crestwood Drive – The existing 9' x 6' CMPA and 48" CMP provide a 10-year level of service under existing land-use conditions, which is below the desired 25-year level of service. The existing culverts appear to be in good structure condition. In order to provide an increased level of service under future land-use conditions, Alternative #1 is proposed to supplement the existing culverts with a 60" RCP, providing a 25-year LOS. This improvement requires downstream improvements at East 14th Street, the Norfolk Southern (NS) Railway, and North Overlook Drive. Alternative #2 is to not improve the crossing, and instead rely on downstream improvements at the Norfolk Southern Railway, and North Overlook Drive to allow a 10-year level of service at Crestwood Drive.

North Overlook Drive – The existing 9' x 6' CMPA and 48" CMP provide a 10-year level of service under existing land-use conditions, which is below the desired 25-year level of service. Both Alternative #1 and Alternative #2 propose to replace the existing culverts with twin 7' x 7' RCBCs. For Alternative #1, which provides a 25-year level of service under future land-use conditions, requires downstream improvements at East 14th Street and the Norfolk Southern Railway. Alternative #2 provides a 10-year level of service, with required downstream improvements only at the Norfolk Southern Railway.

Norfolk Southern Railway – The existing 72" CMP and twin 48" RCPs meet a 100-year level of service under existing land-use conditions. However, to decrease tailwater on North Overlook

Drive, improvements are proposed. Alternative #1 involves replacing the existing culverts with twin 10' x 8' RCBCs. Alternative #2 proposes replacing the existing culverts with twin 8' x 8' RCBCs. Both alternatives provide a 100-year level of service under future conditions at the railroad; however, the first allows for a 25-year level of service at North Overlook Drive, while the second allows a 10-year level of service, both for future land-use conditions.

East 14th Street – The existing twin 72" CMPs meet the desired 25-year level of service for the NCDOT roadway under existing land-use conditions. The existing culverts appear to be in poor structural condition. In order to reduce upstream tailwater Alternative #1 is proposed to replace the existing culverts with twin 10' x 8' RCBCs. This provides a 50-year level of service under future land-use conditions and reduces upstream tailwater conditions to allow for a 25-year level of service at North Overlook Drive. Alternative #2 is to not improve this crossing, which allows for a 10-year level of service under future land-use conditions at North Overlook Drive.

Unnamed Tributary Primary System

With the exception of golf course car path bridges, no Primary System crossings with a deficient level of service were identified in the existing land-use conditions analysis; therefore, no improvements are recommended for the Unnamed Tributary crossings.

Greens Mill Run North Fork Primary System

Allen Road – The existing 72" CMP provides a 25-year level of service under existing land-use conditions, which is below the desired 50-year level of service. To provide the full 50-year LOS under future land-use conditions, an alternative is proposed to replace the existing culvert with twin 7' x 7' RCBCs. The NCDOT is planning to replace this culvert with a plated aluminum 14'-8" x 9'-8" arch pipe, which according to this WSMP's hydraulic model, also provides a 50-year LOS. Once the NCDOT project is implemented, the Allen Road improvements may be removed from this WSMP.

Spring Forest Road (US) – The existing twin 60" CMPs provide a 10-year level of service under existing land-use conditions, which is below the desired 25-year level of service. Alternative #1 is proposed to replace the existing culverts with triple 8' x 6' RCBCs. Alternative #2 proposes to supplement the existing culverts with triple 60" RCPs, for a total of five barrels. Both alternatives require improvements at all three downstream crossings on Greens Mill Run North Fork (Norfolk Southern Railway (NS), Spring Forest Road (Downstream), and Ellsworth Drive), and maintain a 10-year level of service under future land-use conditions. Meeting the desired LOS was determined unfeasible due to requiring the Spring Forest Road (US) culvert to be upsized by twice its current size and upsizing the downstream Norfolk South Railway crossing by more than 5 times its current size. Additionally, by significantly upsizing the railway crossing capacity, outflows from the crossing would be substantially increased, adversely impacting the hydraulic performance of all downstream crossings, including those on GMR, and exacerbating downstream water surface elevations, requiring additional floodplain benching.

Norfolk Southern Railway – The existing twin 48" RCPs meet the desired 100-year level of service under existing land-use conditions; however, in order to reduce tailwater on Spring Forest Road (US) supplementing the existing culverts with a 60" RCP located in the floodplain is

proposed. This provides a 100-year level of service under future land-use conditions, and requires downstream improvements at Spring Forest Road (DS) and Ellsworth Drive.

Spring Forest Road (DS) – The existing triple 60" RCPs provide a 2-year level of service under existing land-use conditions, which is below the desired 25-year level of service. To provide an improved future level of service, Alternative #1 replaces the existing culverts with triple 8' x 6' RCBCs; Alternative #2 requires supplementing the existing culverts with twin 60" RCPs. Either alternative provides a 10-year level of service under future land-use conditions, provided downstream improvements at Ellsworth Drive are implemented. Meeting the desired 25-year level of service was determined to be unfeasible as required improvements included increasing the size of the Spring Forest Road (DS) culvert by nearly three times its current size, upsizing the Ellsworth Lake principal and emergency spillways, and upsizing the Dickinson Avenue Extension crossing along GMR.

Ellsworth Drive – The existing crossing consists of an earthen dam, impounding a lake with a surface area of 6 acres. Ellsworth Drive is located along the crest of the dam. The principal spillway consists of a riser and 42" CMP barrel; the emergency spillway contains triple 30" CMPs. The dam, outlets, and lake are all located on private property, except for the City-owned roadway and right-of-way. Combined, the outlets provide a 2-year level of service under existing land-use conditions, which is less than the desired 25-year level of service. Any improvements to the dam's outlets likely initiates dam safety requirements, such as clearing of trees on the embankments, embankment stability improvements, hydrological and hydraulic analyses for large storm events, and other maintenance items. Improvements proposed in this WSMP address only the roadway LOS and do not include considerations related to dam safety requirements. Improvements at this crossing require the City to obtain an agreement to enter private property, or the City may wish to investigate assuming ownership of the lake and dam. The proposed improvement to provide a future 10-year level of service is to replace the existing emergency spillway culverts with quadruple 8' x 2.5' RCBCs. Meeting the desired LOS was determined to be unfeasible, requiring improvements to the outlet structure to nearly eight times the current capacity. Such improvements would also result in increased outflows from the lake, causing additional downstream water surface elevation increases.

Greens Mill Run North Fork Floodplain Modifications – As a result of implementing the GMR North Fork improvements presented above, portions of both North Fork and GMR were shown to experience water surface elevation increases of up to 0.13 feet (average of 0.07 feet). To mitigate the increases due to either alternative, a combination of maintained and unmaintained floodplain benching and leveling is proposed, ranging from 10 to 330 feet wide, for approximately 8,025 LF along the streams. Alternative #1 includes 2,450 LF of maintained floodplain benching; Alternative #2 includes 3,900 LF. Specific to North Fork, 750 LF of benching is required downstream of the Norfolk Southern Railway; the remainder of the floodplain modifications are proposed along portions of GMR, between Dickinson Avenue Extension and the Norfolk Southern Railway.

Secondary Systems

Arlington Boulevard System – This system is located along Arlington Road and is bounded to the north by J.H. Rose High School, to the south by Evans Park, and to the east by the CSX Railroad. Most stormwater structures in this system experience surface surcharging in the 10-year event. Improvements include installation of a parallel piping system, primarily along the south side of Arlington Boulevard (size ranging from 24" - 36" in diameter) with a shorter section of parallel 15" diameter piping along the north side. The improvements also include additional discharge capacity in the form of a new pipe from the constructed wetland on the J.H. Rose site, crossing Arlington Boulevard, to an independent discharge to the channel adjacent to Evans Park.

Bradley Street System – This system drains the Bradley Street stub as well as inlet bypass flows from upgradient drainage in Norcott Circle and Kennedy Circle. The stub street curbing discharges to a concrete channel which flows into a 36" diameter pipe under the CSX railroad and continues into a closed system to its discharge point below Greene Street. Models showed that most of the system upstream of the railroad crossing experiences surcharging in the 10-year event. Improvements include upsizing the railroad crossing and removing closed conduits downstream of the railroad and replacing with open channels, while increasing road crossing culvert sizes.

Brook Hollow System – Brook Hollow is a comparatively recent development consisting of duplexes. The system model indicated surface surcharging at ten stormwater structures in the 10-year event. Various runs of pipe within the system were identified as constricting flows, thus pipe sizes were adjusted to allow greater flow through the system. Generally, the system has significant depth throughout the development, allowing for increases in pipe sizes where necessary. Modifications include adding an additional discharge from the system (48" diameter), increasing the diameter of most of the main branch of the system (sizes ranging from 18" - 54" in diameter), and adding an additional 18" discharge at the upper end of one of the system branches.

Brownlea Drive System – The majority of this system is within East 10th Street, a NCDOT roadway, near its intersection with Brownlea Drive. The model indicated surface surcharging at two inlets during the 10-year event. The two inlets are located on the north side of East 10th Street. Eliminating surface surcharging at these inlets requires replacement of three runs of 24" with 30" pipe, as well as one run of 18" diameter pipe with 24" diameter pipe. Reconstruction of one commercial driveway is also recommended.

Cedar Lane System – The Cedar Lane system is located along Cedar Lane between Jaycee Park and Tryon Drive. This system drains runoff along Cedar Lane, with deficiencies noted in the area of the Cedar Lane / Wright Road intersection, as well as at the entrance to Eastern Elementary School. System capacity is proposed to be increased by replacing the existing single-barrel storm pipes with double-barrel pipes ranging from 15" - 36" in diameter.

Circle Drive System – This system originates on East Berkley Road, travels down Forest Hill Drive, across private property to Circle Drive, along Birch Street to Rosewood Drive, then discharges to a dry detention pond adjacent to ECU athletic facilities. Modeling results showed widespread surface surcharging at various system inlets during the 10-year storm event. The drainage system is shallow, and therefore, larger diameter pipes are challenging to install without

major impacts to the neighborhood. Additionally, many utilities are shown to be impacted by improvements, including water, sanitary sewer, gas, and electric. Improvements within this neighborhood generally propose adding system capacity through use of multi-barrel pipe systems. A significant portion of the system requires replacement in order to mitigate flooded areas. Proposed piping ranges 24" - 48" in diameter.

Commerce Street System – The Commerce Street system extends from Commerce Street to Kirkland Drive. The model showed the upstream-most inlets (within Commerce Street) experience surface surcharging in the 10-year event. Improvements to this system include the addition of a 42" diameter parallel pipe, starting at Commerce Street and extending below Kirkland Drive to the system discharge point.

Dellwood Drive System – This Secondary System begins at Azalea Drive and extends downstream through Dellwood Drive, ultimately discharging onto private property south of Greenville Boulevard. Most of the inlets in this system exhibited surface surcharging when modeled for a 10-year rainfall event. Proposed improvements include addition of a second pipe system (24" - 36" in diameter) extending north along Dellwood, then turning east and following Greenville Boulevard, ultimately tying into the Greenville Boulevard culvert.

Greenbriar Drive System – This system has two branches, including both open channel and closed pipe systems. One branch flows perpendicular to the roadways, extending from upstream of Fairlane Road, to downstream of Greenbriar Drive, where it converges with the second branch. The second branch starts at Hooker Road and travels between homes on Greenbriar and Fairlane Roads. The branch then crosses Greenbriar where it begins to parallel the road until the confluence with the first branch. The system discharge point is an open channel north of Greenbriar Drive. Improvements to this system include channel widening and new piping ranging in diameter from 48" - 72".

Lakewood Drive System – This system is directly downstream of the University Commons shopping center located at the intersection of Evans Street and Southeast Greenville Boulevard. The system receives runoff from two drainage systems: 1) the University Commons shopping center and 2) Evans Road and Greenville Boulevard, from their intersection north to Red Banks Road. From 2009 to 2014, the City initiated a study and design project in which the system was analyzed and a solution proposed to divert offsite drainage coming into the Lakewood system to another location. The design, which was never implemented, significantly reduced the amount of runoff being conveyed through the channel which was the source of many of the problems reported. The project was delayed until it could be further studied as part of this WSMP.

The Storm Water Management Model (SWMM) for this system indicated that six nodes within the system surcharge in the 10-year event, including an area with reported yard and street flooding (Lindell Drive). Citizen feedback, past studies, and a field investigation indicated that the detention pond behind the Target shopping center is not being fully utilized. Improvements to this system include eliminating the pond's bypass orifice (located in the control structure) and creating a new outlet structure that discharges adjacent to the CSX railroad right-of-way. This is similar to the designs proposed under the previous study, but prioritizes making the commercial detention pond operate more efficiently, eliminating bypass discharge into the Lakewood system. In order to

alleviate the Lakewood system problems, the flow therein must be reduced, which requires pond outflows to be discharged elsewhere. It is not possible to solve these drainage problems without impacting unaffected private properties. Improvements include a new outlet structure in the commercial pond with 2,000 LF of 24" diameter discharge piping.

Jaycee Park System – This system drains the road at the entry to Jaycee Park and lacks the capacity to pass the 10-year storm event according to model results. Maintaining existing pipe sizes, but lowering the invert elevations to gain clearance from the 10-year water surface elevation provides a feasible solution. The lowered pipes are proposed to be 30" - 36" in diameter.

Slay Drive System – This system runs along Slay Drive from Ragsdale Road to East Wright Road. The model showed six structures with surface surcharging in the 10-year event. System improvements to address this are extensive, as nearly the entire system is proposed to be upgraded. Upgraded pipes range in size from 18" - 42" in diameter.

Stratford Road System – This system is located in a portion of Stratford Road and drains most of Stratford Road, west of Sulgrave Road. The model indicated that a single inlet experiences 0.04 feet of surface surcharging in the 10-year event. This system was modeled based on stakeholder reports; there were no resident reports of flooding in the area. Because of the small amount of flooding shown in the model, no improvements are proposed for this system.

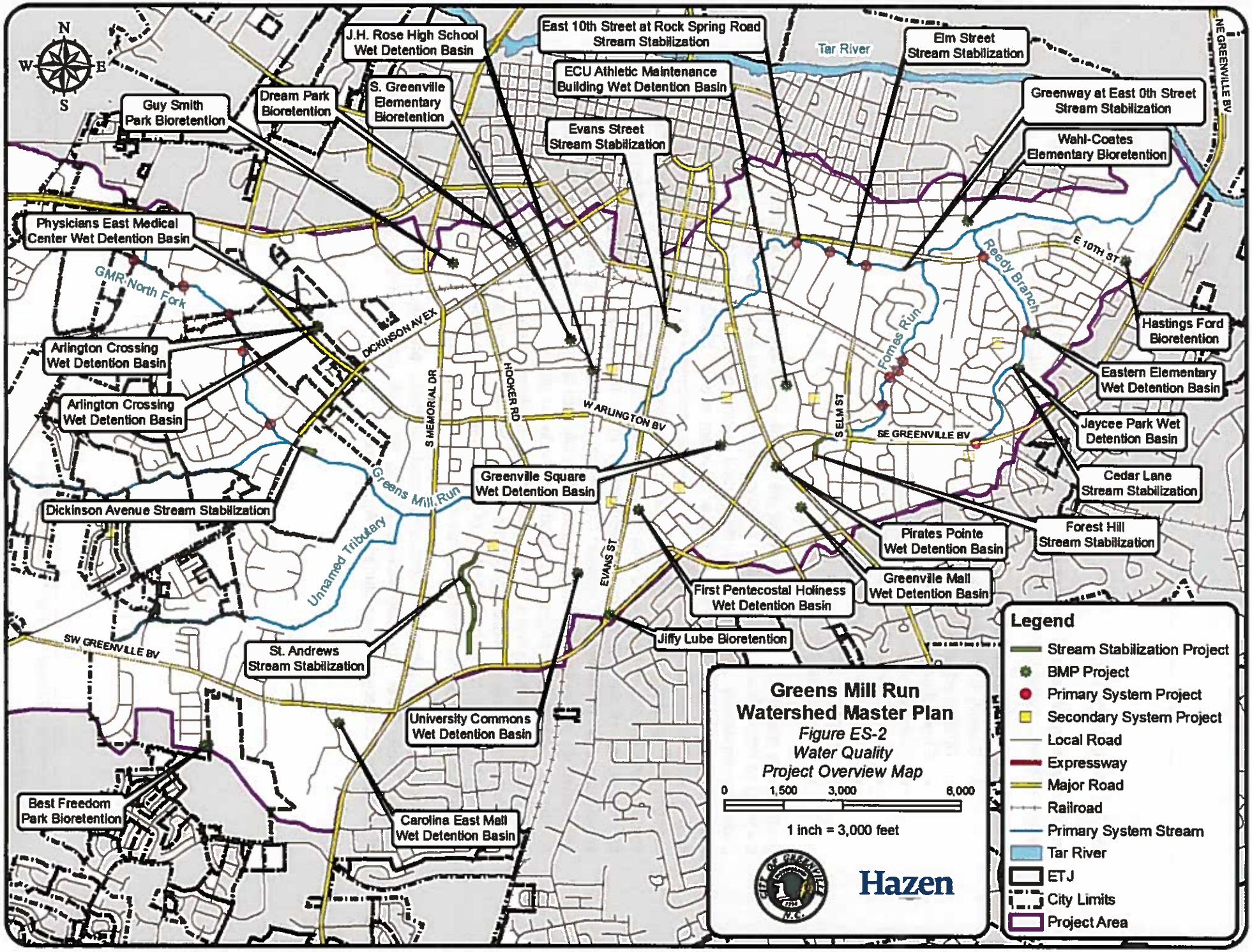
Sulgrave Road System – Citizen reports indicated flooding at the north end of Sulgrave Road. This system directly ties into culverts conveying Greens Mill Run under Charles Boulevard. Modeling the system independently of tailwater effects of Greens Mill Run indicated only minor capacity deficiencies in the 10-year storm event at a location which does not impact roads or structures. Modeling system performance independently of Greens Mill Run was appropriate because the time to peak for the subject system is hours prior to the Greens Mill Run peak.

The system was also evaluated to determine what, if any, events may result in flooding as a result of Greens Mill Run tailwater. Under existing land-use conditions, GMR was determined to overtop Charles Boulevard in the 10-year event. This resulted in surcharging of the Sulgrave Road system. Since the root cause of the reported flooding is GMR, no localized drainage system improvements are proposed to address the issue.

Water Quality Projects

The Greens Mill Run watershed was evaluated for water quality project opportunities. Using a multitude of sources, including public and City input, the Primary System streams and tributaries were assessed to identify locations of stream instability. In all, 39 locations were identified and examined. Ultimately, 29 locations were selected for further investigation, and seven were chosen for stream stabilization projects. These projects incorporate natural stream design techniques, including stream bank grading to address vertical/dilapidated banks, floodplain benching, installation of vegetated soil lifts or imbricated riprap walls, and establishing appropriate floodplain vegetation. The stream stabilization measures are intended to improve water quality by decreasing stream sedimentation and bank erosion, and to protect private and public infrastructure and structures.

The watershed was also examined for opportunities to install new, and retrofit existing, stormwater best management practices (BMP) to provide water quantity improvements within the watershed. While determining locations for implementation of new BMPs was part of this process, identifying opportunities to retrofit existing BMPs was a primary focus. Retrofits typically present lower cost but highly effective improvements. Other parameters considered in the BMP identification process included: amount of imperviousness, availability of space for implementation, proximity to existing drainage infrastructure, land ownership, and topography. Based on these assessments, 19 BMPs are proposed, 11 of which are retrofit projects. The water quality project locations are depicted in **Figure ES-2**.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J.H. Rose High School Wet Detention Basin
East 10th Street at Rock Spring Road Stream Stabilization
Tar River
Elm Street Stream Stabilization
NE GREENVILLE BV
ECU Athletic Maintenance Building Wet Detention Basin
Guy Smith Park Bioretention
Dream Park Bioretention
S. Greenville Elementary Bioretention
Greenway at East 0th Street Stream Stabilization
Evans Street Stream Stabilization
Wahl-Coates Elementary Bioretention
Physicians East Medical Center Wet Detention Basin
GMR North Fork
E 10TH ST
Reedy Branch
Fomes Run
DICKINSON AV EX
S MEMORIAL DR
HOOKER RD
Hastings Ford Bioretention
Arlington Crossing Wet Detention Basin
Arlington Crossing Wet Detention Basin
W ARLINGTON BV
S ELM ST
SE GREENVILLE BV
Eastern Elementary Wet Detention Basin
Jaycee Park Wet Detention Basin
Greens Mill Run
Greenville Square Wet Detention Basin
Cedar Lane Stream Stabilization
Dickinson Avenue Stream Stabilization
Unnamed Tributary
Pirates Pointe Wet Detention Basin
Forest Hill Stream Stabilization
EVANS ST
Greenville Mall Wet Detention Basin
First Pentecostal Holiness Wet Detention Basin
Jiffy Lube Bioretention
SW GREENVILLE BV
St. Andrews Stream Stabilization
University Commons Wet Detention Basin
Best Freedom Park Bioretention
Carolina East Mall Wet Detention Basin
Greens Mill Run
Watershed Master Plan
Figure ES-2
Water Quality
Project Overview Map
0
1,500
3,000
6,000
1 inch = 3,000 feet
Hazen
Legend
Stream Stabilization Project
BMP Project
Primary System Project
Secondary System Project
Local Road
Expressway
Major Road
Railroad
Primary System Stream
Tar River
ETJ
City Limits
Project Area

Project Prioritization

To appropriately allocate City resources, the flood control and water quality projects were prioritized based on the following categories as described in Appendix M:

- Public health and safety
- Severity of street flooding
- Cost effectiveness
- Effect of improvements
- Water quality – Best Management Practice
- Open Channel – Stream Stabilization
- Implementation constraints
- Grant funding
- Constructability

Scores were assigned to each project for the factors listed above, then weighted, and lastly summed to determine the prioritization rankings. Flood control and water quality projects were prioritized separately. The Primary System flood control projects include two alternatives, of which, only one may be selected per Primary System stream. Selection of projects from more than one alternative per stream may not provide the improvements and performance described in this WSMP, as projects within each alternative were evaluated assuming cumulative effects. In some instances, one or both of the alternatives did not result in the desired level of service due to infeasibility of the improvements required to meet this LOS. Generally, Alternative #1 improvements incorporated the highest LOS feasibly attainable, ideally meeting the desired LOS. Alternative #2 improvements, if presented, generally had a lower LOS due to minimizing the number or magnitude of projects required to provide an improved LOS under future land-use conditions. Improvements were not proposed for any locations where a 10-year LOS could not be achieved. Additionally, prioritization of the Primary System improvements incorporated project dependency, where the implementation of one Primary System project is dependent upon the implementation of another/others to achieve the stated performance.

The proposed prioritization and conceptual cost estimates are summarized in **Tables ES-2** through **Table ES-5.** The prioritization scoring for each project, and a description of the aforementioned categories, is included in **Appendix M.**

Table ES-2: Primary System Flood Control Project Prioritization

Project	Total Weighted Score	Raw Rank	Tie-Break Rank	Estimated Cost
Allen Road - North Fork Greens Mill Run (Alternative #1 / #2)	187	1	1	$800,000
Southeast Greenville Boulevard - Reedy Branch (Alternative #1 / #2)	181	2	2	$680,000
Reedy Branch Project Group (Alternative #1)	169	3	3	$1,280,000
South Wright Road - Reedy Branch (Alternative #1)				$620,000
East 10th Street - Reedy Branch (Alternative #1)				$660,000
Greens Mill Run Project Group (Alternative #2)	149	4	4	$5,170,000
Rock Spring Road - Greens Mill Run (Alternative #2)				$2,100,000
South Elm Street - Greens Mill Run (Alternative #2)				$3,070,000
Greens Mill Run Project Group (Alternative #1)	149	4	5	$5,320,000
Rock Spring Road - Greens Mill Run (Alternative #1)				$1,590,000
College Hill Road - Greens Mill Run (Alternative #1)				$920,000
South Elm Street - Greens Mill Run (Alternative #1)				$2,810,000
North Fork Project Group (Alternative #2)	141	6	6	$4,860,000
Spring Forest Road (US) - North Fork Greens Mill Run (Alternative #2)				$620,000
Norfolk Southern Railway (NF) - North Fork Greens Mill Run (Alternative #2)				$1,190,000
Spring Forest Road (DS) - North Fork Greens Mill Run (Alternative #2)				$1,390,000
Ellsworth Drive - North Fork Greens Mill Run (Alternative #2)				$1,660,000
Fornes Run Project Group (Alternative #1)	139	7	7	$15,540,000
Crestwood Drive - Fornes Run (Alternative #1)				$260,000
North Overlook Drive - Fornes Run (Alternative #1)				$780,000
Norfolk Southern Railway (FR) - Fornes Run (Alternative #1)				$13,300,000
East 14th Street - Fornes Run (Alternative #1)				$1,200,000
South Wright Road - Reedy Branch (Alternative #2)	135	8	8	$490,000
North Fork Project Group (Alternative #1)	131	9	9	$6,700,000
Spring Forest Road (US) - North Fork Greens Mill Run (Alternative #1)				$1,100,000
Norfolk Southern Railway (NF) - North Fork Greens Mill Run (Alternative #1)				$1,400,000
Spring Forest Road (DS) - North Fork Greens Mill Run (Alternative #1)				$2,330,000
Ellsworth Drive - North Fork Greens Mill Run (Alternative #1)				$1,870,000
Fornes Run Project Group (Alternative #2)	115	10	10	$13,430,000
North Overlook Drive - Fornes Run (Alternative #2)				$780,000
Norfolk Southern Railway (FR) - Fornes Run (Alternative #2)				$12,650,000
Primary System Alternative #1 Total				**$ 30,320,000**
Primary System Alternative #2 Total				**$ 25,430,000**

*Project groups indicate project-dependency. Only one set of alternatives may be chosen per Primary System stream in order to achieve stated performance.

**Tie-break rank reflects tie-breaking of projects with tied raw ranks, based on cost effectiveness benefit ratios, with higher ratios receiving a higher tie-breaking rank.

Table ES-3: Secondary System Flood Control Project Prioritization

Project	Total Weighted Score	Raw Rank	Tie-Break Rank	Estimated Cost
Greenbriar Drive System	151	1	1	$770,000
Cedar Lane System	143	2	2	$650,000
Dellwood Drive System	135	3	3	$750,000
Circle Drive System	133	4	4	$1,680,000
Jaycee Park System	125	5	5	$480,000
Arlington Boulevard System	123	6	6	$920,000
Slay Drive System	121	7	7	$1,640,000
Commerce Street System	113	8	8	$430,000
Brownlea Drive System	105	9	9	$650,000
Bradley Street System	81	10	10	$970,000
Lakewood Drive System	77	11	11	$550,000
Brook Hollow System	69	12	12	$2,550,000
Secondary System Total				**$12,040,000**

*Tie-break rank reflects tie-breaking of projects with tied raw ranks, based on cost effectiveness benefit ratios, with higher ratios receiving a higher tie-breaking rank.

Table ES-4: Stream Stabilization Project Prioritization

Project	Total Weighted Score	Raw Rank	Tie-Break Rank	Estimated Cost
Forest Hill Drive	131	1	1	$820,000
St Andrews Drive	119	2	2	$3,430,000
East 10th Street at Rock Spring Road	119	2	3	$240,000
Dickinson Avenue	91	4	4	$500,000
South Evans Street	75	5	5	$1,110,000
Cedar Lane	69	6	6	$400,000
South Elm Street	69	6	7	$440,000
Greenway at East 10th Street	63	8	8	$320,000
Stream Stabilization System Total				**$7,260,000**

*Tie-break rank reflects tie-breaking of projects with tied raw ranks, based on cost per linear foot, with lower costs receiving a higher tie-breaking rank.

Table ES-5: Stormwater Best Management Practice Project Prioritization

Project	Total Weighted Score	Raw Rank	Tie-Break Rank	Estimated Cost
Jaycee Park	143	1	1	$180,000
Eastern Elementary School	143	1	2	$890,000
University Commons Shopping Center	131	3	3	$300,000
ECU Athletic Maintenance Building	131	3	4	$150,000
Greenville Square Shopping Center	131	3	5	$440,000
Carolina East Mall	131	3	6	$340,000
Pirates Pointe Shopping Center	131	3	7	$76,000
First Pentecostal Holiness Church	131	3	8	$170,000
Physicians East Medical Center	131	3	9	$330,000
J.H. Rose High School	125	10	10	$170,000
Jiffy Lube	125	10	11	$110,000
Greenville Mall	119	12	12	$470,000
Arlington Crossing Shopping Center	119	12	13	$130,000
Guy Smith Park	111	14	14	$160,000
Dream Park	111	14	15	$140,000
Andrew A. Best Freedom Park	111	14	16	$99,000
S. Greenville Elementary School	105	17	17	$170,000
Hastings Ford Dealership	101	18	18	$260,000
Wahl Coates Elementary School	75	19	19	$130,000
Stormwater BMP Total				**$4,720,000**

*Tie-break rank reflects tie-breaking of projects with tied raw ranks, based on cost effectiveness benefit ratios, with higher ratios receiving a higher tie-breaking rank.

25-Year Special Risk Areas

In 2014, the City of Greenville passed an ordinance 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 GMR WSMP, an analysis was completed to determine if areas within the watershed should be considered to have "well documented water quantity problems". 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 become floodprone during the 25-year design storm based on future conditions flows when compared to existing conditions flows.

As discussed in this WSMP document, a number of crossings do not meet the desired LOS based upon the existing conditions model results, which have been corroborated by City staff (therefore constituting a "well documented water quantity problem"). Of 33 crossings evaluated, 14 (42%) exhibited substandard performance in the existing condition. Several of these LOS violation crossings are located along GMR proper, in the lower portions of the watershed, and downstream of all undeveloped areas within the watershed. As discussed in this WSMP, meeting the required level of service at these locations is not feasible, however a reduced level of service is proposed. Additionally, three other crossings (East 14th Street, Charles Boulevard, and Evans Street) along GMR exhibit such severe LOS violations that no feasible solutions exist, even for a reduced LOS. For those crossings, future development within the watershed will continue to degrade their performance beyond current conditions. For all crossings along GMR which exhibit level of service violations, either a reduced LOS is proposed or there is no feasible solution, therefore undeveloped areas upstream of these crossings (which includes all undeveloped area within the watershed) are recommended to be designated 25-year special risk based on criteria #2, above.

In all GMR proper locations with "well documented water quantity problems", predicted future flows during the 25-year event increase by significantly greater than 10%, further confirming that all undeveloped areas upstream of these locations should be considered "special risk" based on criteria #1, above.

Finally, future conditions flows (and the associated expansion of the floodplain) for the 25-year event result in 142 additional structures being classified as "floodprone" (note that this analysis focuses on Greens Mill Run, as all undeveloped areas ultimately flow into GMR, thus if GMR Implementation of the 25-year Special Risk Area throughout the GMR watershed aids in reducing the frequency of flooding along the Primary System streams and negate the need to implement future capital improvement projects at several roadway crossings. The hydraulic model was analyzed to identify crossings meeting the desired 25-year LOS under existing land-use conditions, but in violation under future land-use conditions. Crossings that showed this change were those that may benefit from the special risk designation. This analysis identified three

crossings: Hooker Road on GMR, Dalebrook Circle on Fornes Run, and Williams Road on the Unnamed Tributary to GMR. The estimated cost to address potential future LOS violations at these crossings, should the 25-year Special Risk designation not be implemented, is approximately $3,430,000.

Based on the above discussion and justification, it is recommended that the entire Greens Mill Run watershed be classified as Special Risk, requiring 25-year detention for all new development.

Assessment and Management of Impaired Waters

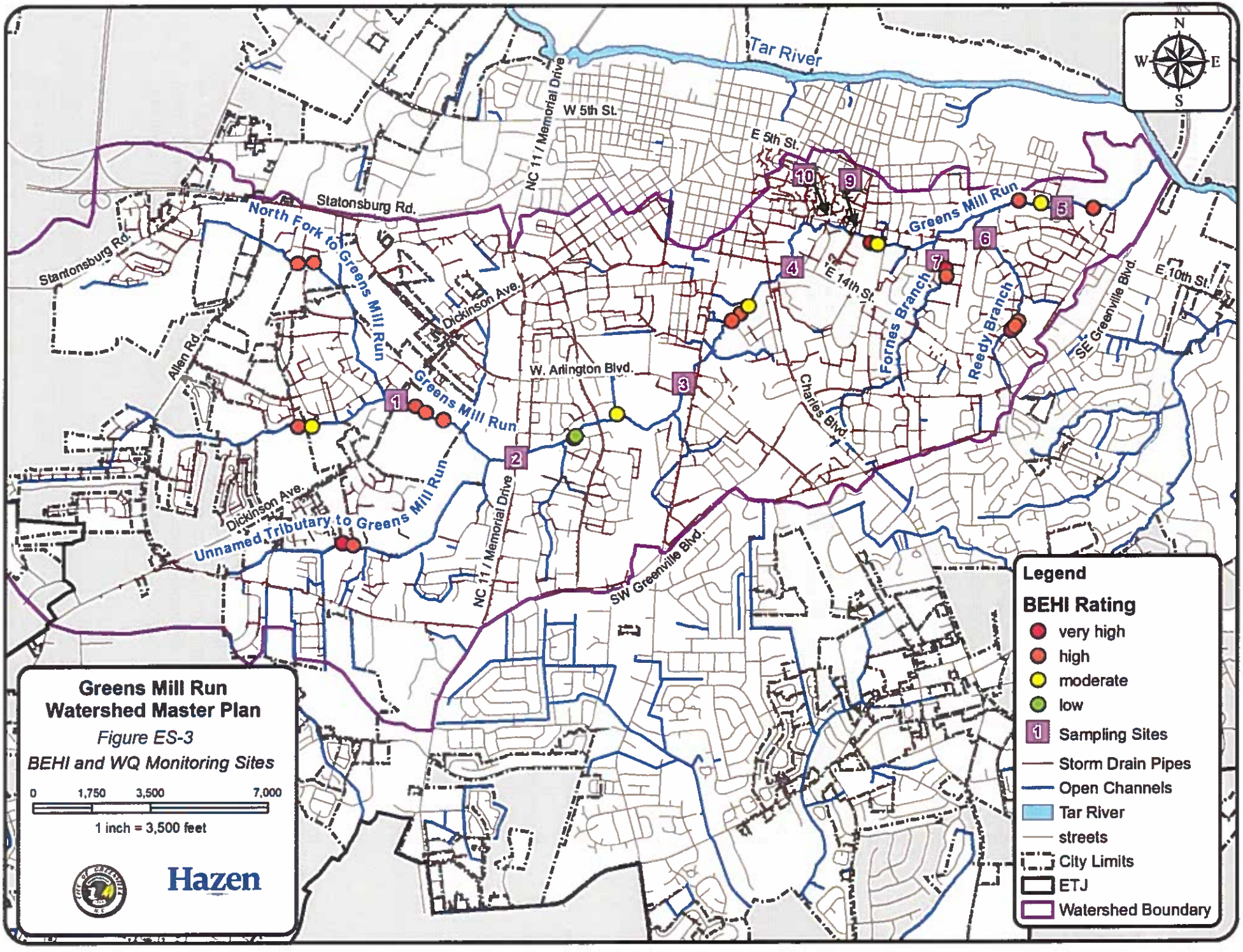
Based on a single benthic macroinvertebrate community sampling event in 2004 performed in conjunction with the NCEEP Local Watershed Plan, NCDEQ has placed the entirety of Greens Mill Run (from source to the Tar River) in Category 5 of the 303(d) List of Impaired Waters. Unless they are de-listed, or re-categorized on the List, waters in Category 5 are subject to development of a Total Maximum Daily Load which will identify the primary stressors (pollutants) which are causing the impairment and determine the pollutant load reductions necessary to achieve compliance with water quality standards and eliminate the impairment.

Water Quality Assessment

As a subcontractor on the Hazen Team, East Carolina University conducted an 18-month monitoring program to assess water quality in the Greens Mill Run (GMR) watershed. The assessment of water quality in the GMR watershed was of particular interest given the 303d list status of GMR as Impaired. The goals of the water quality monitoring program were to determine whether nutrients, pathogens, sediments, or metals are impairing GMR, and if so, to locate any potential sources of degradation.

Nine sampling and monitoring sites were selected along Greens Mill Run, including five on the main stem, two on its tributary streams, Reedy Branch and Fornes Run, and two at stormwater outfalls (Figure ES-3). Baseflow and wet weather flow samples were collected across seasons. The water quality parameters sampled included temperature, pH, dissolved oxygen, conductivity, turbidity, total suspended solids, numerous chemical species of nitrogen and phosphorus, dissolved organic carbon, chlorides, key indicator bacteria, and several metals. The full Water Quality Monitoring Report is presented in Appendix N.

To summarize the results of the water quality monitoring effort, several indicators suggested that pollutant and sediment inputs increased downstream. Overall, the water quality data suggested that urban and agricultural land-uses in the watershed have contributed non-point source pollution resulting in increases in nutrient, sediment, and bacteria inputs to Greens Mill Run. Most water quality parameters, with the exception of nitrate and dissolved oxygen, increased with storm flow suggesting that improved stormwater management could help reduce water quality degradation. The nitrate decline during storm events, suggests a groundwater source of nitrate, presumably related to agricultural fertilizer inputs as the increases correspond to the upper portions of the watershed that contain extensive agricultural drainage. Turbidity and totals suspended solids (TSS) data indicated that agricultural land uses within the headwaters of GMR may be contributi


Tar River
W 5th St.
E 5th St.
NC 11 / Memorial Drive
Statonsburg Rd.
North Fork to Greens Mill Run
Greens Mill Run
Dickinson Ave.
Allen Rd
W. Arlington Blvd.
E 14th St.
Fornes Branch
Reedy Branch
Charles Blvd.
SE Greenville Blvd.
E 10th St.
Unnamed Tributary to Greens Mill Run
SW Greenville Blvd.
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Legend
BEHI Rating
very high
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moderate
low
Sampling Sites
Storm Drain Pipes
Open Channels
Tar River
streets
City Limits
ETJ
Watershed Boundary
Greens Mill Run
Watershed Master Plan
Figure ES-3
BEHI and WQ Monitoring Sites
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7,000
1 inch = 3,500 feet
Hazen

sediment to the stream, and that instream sources of sediment play an important role. However, it should be noted that the BEHI analysis also identified areas with high rates of bank erosion in the upper reaches of GMR, so instream sources are likely to be significant contributors there as well.

Taken collectively, the monitoring effort in this study shows that water quality is not as degraded as might be expected in such a heavily urbanized stream. While sediment and nutrient levels are elevated, especially during storm events, only two parameters were found to exceed water quality standards which are applicable to Greens Mill Run, turbidity (three instances in one storm) and E. coli (which is not a contributor to the impairment for which GMR is listed). Given that none of the toxicant (metals) parameters that were sampled exceeded established water quality standards and dissolved oxygen levels in the stream were never shown to be below the water quality standards which reflect the level necessary to sustain healthy aquatic ecosystems, the water quality monitoring effort in this study has indicated that it is highly unlikely that the physical/chemical water quality parameters are causing the degradation of the benthic macroinvertebrate population in Greens Mill Run. Rather, as discussed in the other parts of this Section, the 303(d)-listed impairment of Greens Mill Run (resulting from poor health of the benthic macroinvertebrate community) is far more likely to be the result of the excess sediment moving through the system and the associated physical degradation of the benthic habitat.

Recommendations to Improve Water Quality

- Continue effort to retrofit structural BMPs to existing built landscapes.
- Conduct a more detailed source investigation into watersheds contributing to the GMR 9 and GMR 10 outfalls monitored in this study.
- Initiate a Pet Waste Awareness Program.

Assessment of Existing Benthic Macroinvertebrate Community

Given that Greens Mill Run was listed as impaired because of poor benthic community ratings, as part of this overall stormwater master planning effort, WK Dickson, was engaged to perform benthic macroinvertebrate sampling to evaluate the current conditions of the aquatic ecology in the watershed. In August 2014, seven sites were sampled in the GMR watershed. In addition, the Hardee Creek watershed, near Greenville was identified as an appropriate reference reach and also sampled.

Overall, the sampling results in GMR were consistently worse than the sampling results from Hardee Creek, and those results would not support a proposal for delisting GMR on the basis of sampling data alone. Additional conclusions from the WK Dickson report included the following: "Ambient data results do not indicate that water quality is the primary contributor to low benthic diversity and associated impairment. The lack of adequate habitat conditions throughout the watershed is likely to be the primary contributor to the benthic community's low diversity."

Benthic Monitoring Recommendations

- Continue benthic community monitoring at sites in the middle and lower GMR mainstem.
- Establish additional benthic community monitoring sites between the existing sites in middle and lower GMR mainstem.

- If the improved bioclassification from the middle GMR site is found to be persistent, submit data to NCDEQ with a request for delisting a portion of Greens Mill Run.

Strategy to Address Impairment of Greens Mill Run

The water quality monitoring program for this master planning effort has shown that sediment levels are elevated in all streams within the GMR watershed, especially during storm events. The geomorphic assessment has shown that stream banks erosion in numerous locations throughout the watershed is a significant source of sediment in the system.

All the available lines of evidence in that master planning effort indicate that habitat degradation is the primary stressor on the health of the GMR aquatic ecosystem, and the benthic macroinvertebrate community in particular, and that excessive sedimentation and channel modification are the sources.

Recommended Measures to Improve Habitat and Alleviate Impairment

- Identify opportunities and implement stream restoration projects.
- Continue implementation of stream bank stabilization projects within a cycle of adaptive management.
- Introduce woody structures and debris to the stream.
- Identify appropriate sources for the capture of desired benthic macroinvertebrate species and relocate organisms to the Greens Mill Run watershed.

Recommended Strategy to Address 303(d) Listing Status

Request a Category 4C designation on the 303(d) List of Impaired Waters developed by NCDEQ – Category 4C on the list comprises waters that are impaired by pollution, not specific pollutants, and a recent USEPA technical memorandum to the directors of the Water Divisions within the 10 USEPA Regions specifically mentions waters where excessive runoff and stream scour have contributed to habitat degradation. The memo is available online here:

https://www.epa.gov/sites/production/files/2015-10/documents/2016-ir-memo-and-cover-memo-8_13_2015.pdf

As noted in the description of Category 4C, water bodies designated in this category will not be subject to TMDL development. However states are given the latitude to apply other watershed restoration tools to address the problem.

Through this recent clarification, the USEPA now allows States to utilize the 4C option when plans are developed to address specific circumstances in a watershed which include adaptive management and approaches to pollutant reduction which are better suited to achieving results than the TMDL approach. The specific circumstances in Greens Mill Run are ideally suited for a 4C designation. With this recent clarification on Category 4C available from USEPA, the Water Planning Branch at NCDEQ may begin to exercise the latitude to apply the category to streams like Greens Mill Run.

If NCDEQ is unwilling to consider movement to Category 4C, request a Category 4b designation – Category 4b of the 303(d) list comprises impaired waters that are expected to meet water quality criteria within a reasonable period of time as a result of pollution controls implemented voluntarily. In the case of Greens Mill Run, a 4b designation would be an alternative to having a Total Maximum Daily Load (TMDL) developed and documented, most likely by NCDEQ, which would require pollution controls to be implemented on a mandatory basis.

As discussed in the above sections of recommendations for implementation of measures to address the sources of impairment in Greens Mill Run, the guidance for Category 4b designation indicates that it would still require a quantifiable pollutant load reduction to be established.

Re-assignment of Greens Mill Run to another category of the 303(d) list, thereby avoiding the mandatory efforts to implement a TMDL (which would likely be developed by NCDEQ, or a third party on their behalf), could represent a significant potential cost savings to the City of Greenville. The estimated cost of all structural measures required as part of a TMDL implementation plan to address sediment and bacteria pollution in the Crab Creek watershed, a 19 square mile catchment in western Virginia, was $10.4M. However, this example does not represent clear indication of savings that might be realized by the City of Greenville by not having to implement a TMDL; the absence of the formal TMDL would not mean the City would take no action to address the degradation of Greens Mill Run. Perhaps the greater benefit to the City in avoiding the imposition of a TMDL would be to have greater control its own approach regarding how, where, and when capital expenditures will be invested toward the improvement and rehabilitation of the stream.

Impaired Waters Conclusion

The assessments of geomorphology and water quality performed for this WSMP, and the stormwater management and stream stabilization projects set forth within it, are a strong step toward alleviating the impairment. The water quality monitoring program was sufficiently robust to indicate that water quality, in and of itself, is not likely to be an important driver of the impairment of Greens Mill Run. Rather, the lines of evidence, as well as numerous field observations, point directly to habitat degradation through past channel modification and excess sediment deposition stemming from channel instability and stream bank erosion as the main driver of the substandard benthic community bioclassifications.

With this beginning in place, the City of Greenville can avoid the imposition of a TMDL by pursuing and documenting a deliberate program aimed at stabilizing and restoring streams, and reducing the excessive sediment loads coming from eroding banks and potential upland sources. If the program exhibits principles of adaptive management with ongoing monitoring to provide the necessary feedback for continued implementation and adaptation, it will provide the justification to move Greens Mill Run from Category 5, to Category 4B or, ideally, to 4C (should that be the designation of the new alternate category).

CITY OF GREENVILLE

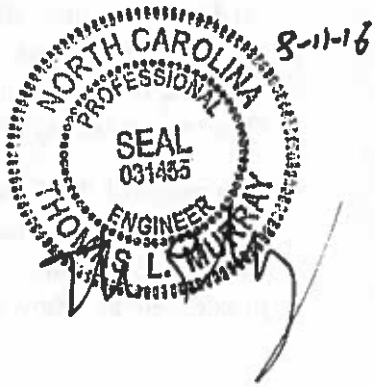
HARDEE CREEK
WATERSHED MASTER PLAN

WKD # 20140067.00.RA

August 2016

Prepared for

City of Greenville
1500 Beatty Street
Greenville, NC 27834



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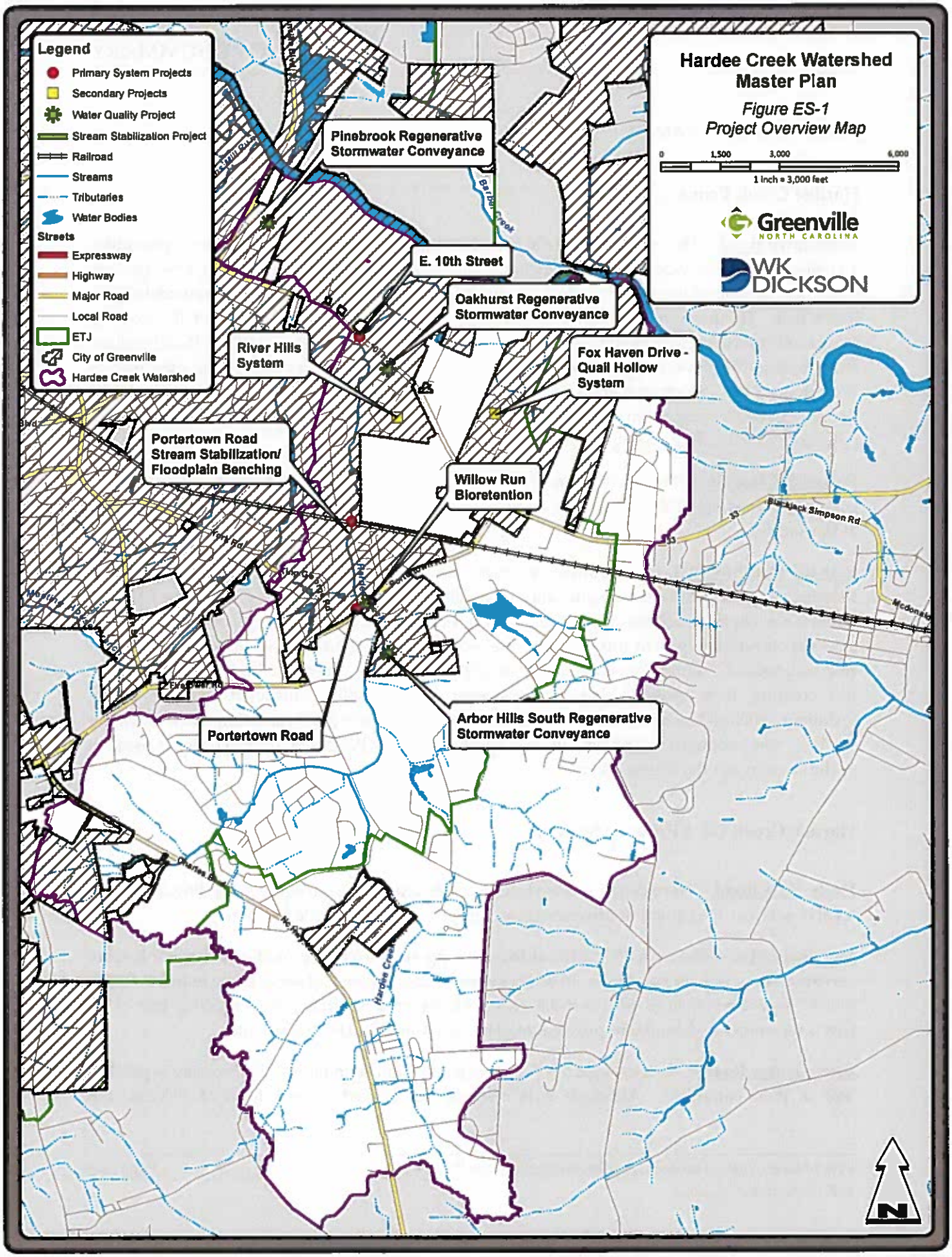
EXECUTIVE SUMMARY

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
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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
Arbor Hills South Regenerative Stormwater Conveyance
Portertown Road
Blue Jack Simpson Rd
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

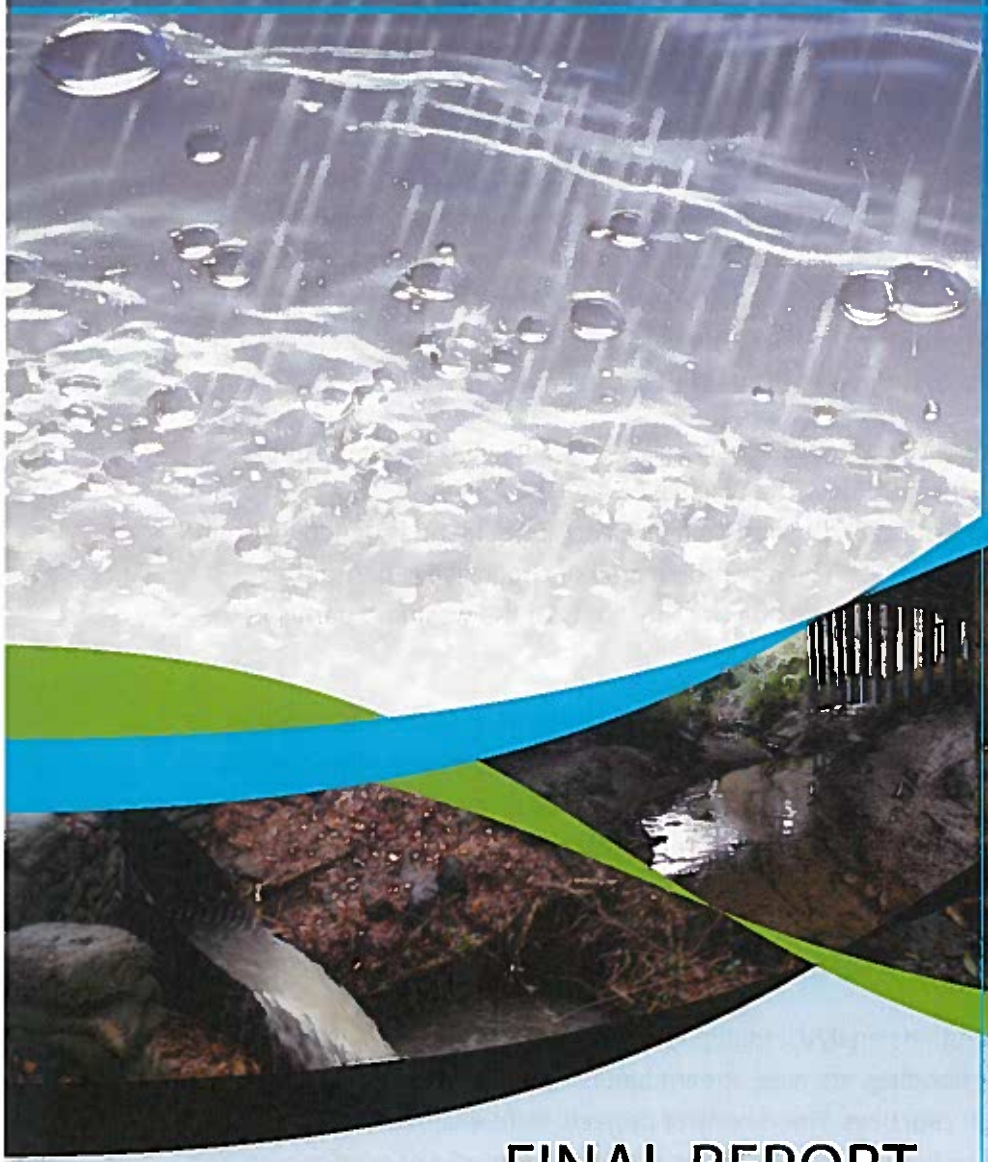
The City of Greenville's 25-year detention requirement for new development and redevelopment requires analysis for areas within the watershed and ETJ that require detention based on "well documented water quantity problems." The watershed was analyzed for historical cases of structural flooding and roadway 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.

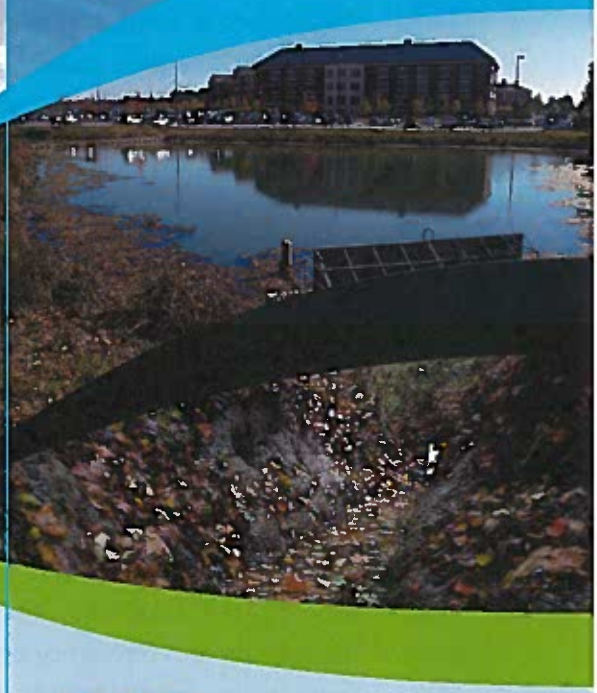
CITY OF GREENVILLE

Greenville
NORTH CAROLINA

Harris Mill Run / Schoolhouse Branch Watershed Master Plan

July 2016





FINAL REPORT

CDM Smith

EXECUTIVE SUMMARY – HMR/SHB WATERSHEDS

The City of Greenville has retained CDM Smith to complete a Master Plan for the Harris Mill Run/Schoolhouse Branch (HMR/SHB) watersheds. The goals of this master plan include: (1) evaluate the watershed for 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 to reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, CDM Smith also completed a stormwater drainage infrastructure inventory for drainage structures and features within the HMR/SHB watersheds. The project included a broad range of stakeholders to collect as much data, information and tacit knowledge of the watershed as possible. The general public was solicited through questionnaires mailed to all property owners in the watershed and two open house public meetings where residents and business owners were encouraged to provide feedback on stormwater issues in the watershed. CDM Smith coordinated with residents that provided site-specific drainage concerns to gather additional information that could be used to both confirm the existing system evaluation and aid in developing improvement recommendations. Information collected from the questionnaires and public meetings can be found in Section 2.1 and Appendix D. City staff served as a critical stakeholder by providing valuable information on historical flooding and erosion problems in the watershed, as well as providing feedback on potential capital improvements and the prioritization of those improvements.

The HMR/SHB watershed is approximately 12 square miles and is located in the northern portion of Greenville south of the Tar River. The collective watershed extends west to encompass the Ironwood Golf Course and Country Club, east to near Beech Street, and is generally bound by Stantonsburg Road to the southwest. The downtown area of Greenville is part of this watershed. A portion of this watershed is outside the City limits to the west and part is in the undeveloped Tar River floodplain.

CDM Smith conducted an Existing and Future Conditions Analysis in order to evaluate the existing hydrologic and hydraulic characteristics of the HMR/SHB watersheds. Noted in this report as the primary systems, HMR, SHB, Sams Branch, and Sains Branch were hydraulically studied in detail to evaluate flooding of residential areas and roadways. In addition to the primary systems, select conveyance systems that drain directly to the Tar River were analyzed to determine if those systems met the desired City design requirements outlined in Section 1.2. Those secondary systems were identified based on feedback from public residents and City staff.

As a result of the existing conditions analysis, multiple capital projects were identified to reduce the severity and frequency of flooding, stabilize stream banks, and improve water quality through stormwater treatment practices. Flood control projects were evaluated to improve the desired level of service (LOS) or frequency of flooding achieved for roadway overtopping and roadway/structure flooding. The proposed capital projects are described below with the locations of each project shown in **Figure ES-1**.

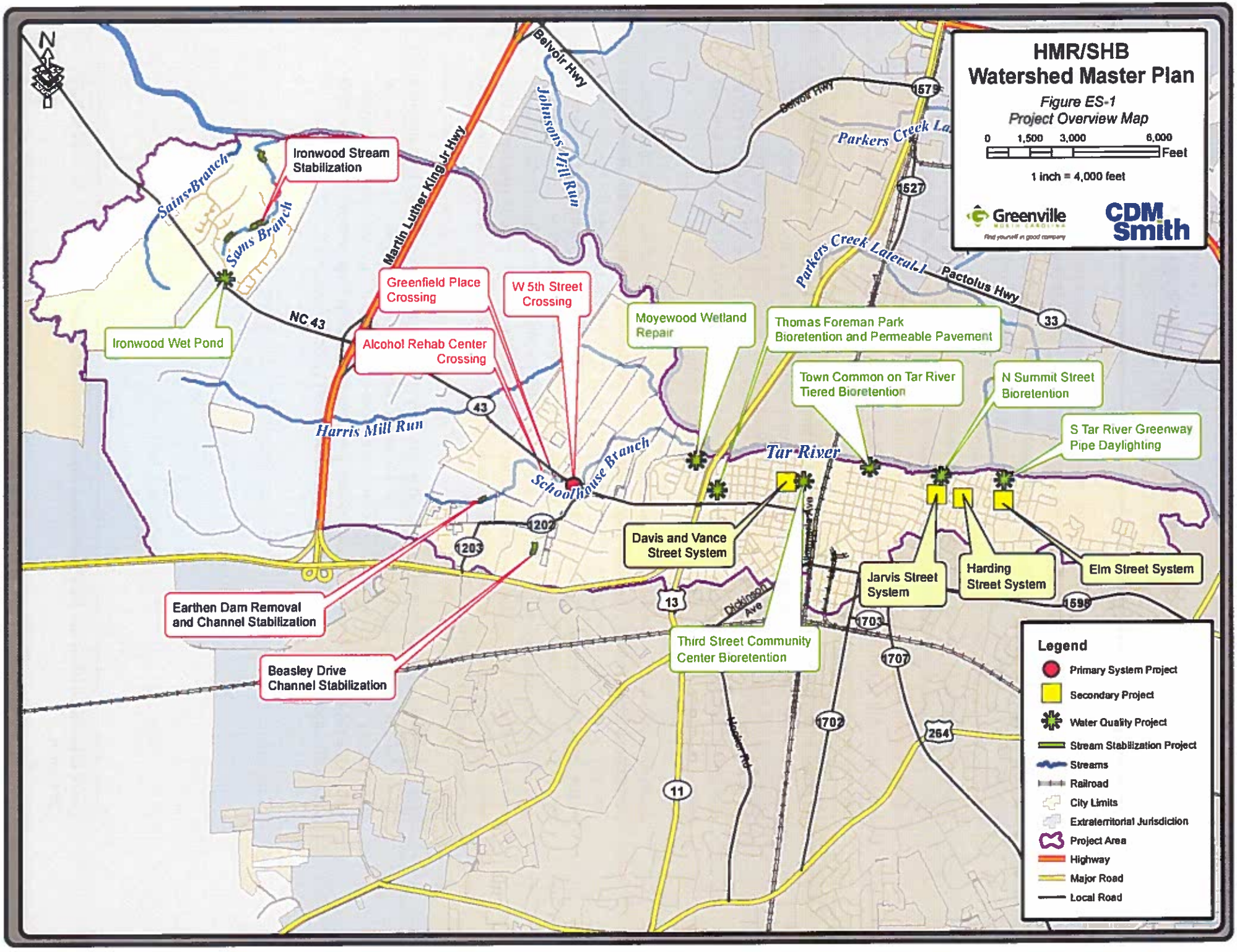
Watershed Conditions

The HMR/SHB Watershed is a 12.2 square mile collection of multiple smaller watersheds each draining to the Tar River. Beginning on the west side of the City, Sams Branch and Sains Branch drain the area including the Ironwood Golf Course. Proceeding toward the east, HMR drains the western edge of the City and SHB drains the area north of Stantonsburg Road to 5th Street, including the Vidant Medical Center and East Carolina University Health Sciences. Additional smaller tributaries to the Tar River drain the downtown area and areas to the east along the Tar River. Town Creek is the only named stream draining the downtown area and is comprised almost entirely of underground piped conveyance. With the exception of Sams Branch and Town Creek, each of the HMR/SHB streams enter the Tar River floodplain where their channels become less defined as they are dispersed through expansive wetlands.

All of the HMR/SHB watersheds are inside the City limits or extraterritorial jurisdiction (ETJ) except for part of the Sains Branch watershed on the west boundary of the City. Almost all of HMR watershed is within the City's ETJ, while almost all of SHB is within City limits. Only 34 acres of HMR are within the City limits. Conversely, only 0.2 of the 1.6 square mile SHB watershed extend outside City limits. Sains and Sams Branch drain the Ironwood Golf Course Subdivision which is part of the City, albeit disconnected from the main City limits.

Approximately half of the HMR/SHB watersheds are developed. Except for the undeveloped floodplain of the Tar River, the areas east of downtown, the downtown area, and the Vidant areas are built-out to Arlington Boulevard. The areas to the west of Arlington Boulevard in the City's ETJ in the HMR/SHB watersheds are expected to experience significant development of remaining open space in the near future. In HMR, the 50 percent of the watershed that is open space is expected to be developed into medium and high density residential land use. In SHB, the 25 percent of the watershed that is currently open space is zoned for high density residential and multi-family land uses according to the zoning. Similar percentages are expected to be developed in Sams and Sains Branches.

The topography of HMR/SHB is relatively flat with gentle slopes except for a steep embankment along the Tar River floodplain west of the downtown area. Within the City limits, many natural channels are maintained ditches and others are more natural channels with forested buffers. Within the City, channel conditions are occasionally unstable where large impervious areas have increased runoff and erosion occurs associated with high velocity flows.


HMR/SHB
Watershed Master Plan
Figure ES-1
Project Overview Map
0 1,500 3,000 6,000
Feet
1 inch = 4,000 feet
Greenville
CDM Smith
Ironwood Stream Stabilization
Greenfield Place Crossing
W 5th Street Crossing
Alcohol Rehab Center Crossing
Ironwood Wet Pond
Moyewood Wetland Repair
Thomas Foreman Park Bioretention and Permeable Pavement
Town Common on Tar River Tiered Bioretention
N Summit Street Bioretention
S Tar River Greenway Pipe Daylighting
Davis and Vance Street System
Jarvis Street System
Harding Street System
Elm Street System
Third Street Community Center Bioretention
Earthen Dam Removal and Channel Stabilization
Beasley Drive Channel Stabilization
Sains Branch
Martin Luther King Jr Hwy
Belvoir Hwy
Johnsons Mill Run
Parkers Creek Lateral 1
Pactolus Hwy
NC 43
Harris Mill Run
Schoolhouse Branch
Tar River
Dickinson Ave
Legend
Primary System Project
Secondary Project
Water Quality Project
Stream Stabilization Project
Streams
Railroad
City Limits
Extraterritorial Jurisdiction
Project Area
Highway
Major Road
Local Road

Stormwater infrastructure throughout the watersheds was collected by survey personnel to compile a geographical information system (GIS) stormwater inventory database for the City. This was accomplished by using 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 other attributes such as dimensions, material, slope, and length. The data was collected using horizontal datum NAD 1983 and vertical datum NAVD 1988. A total of 2,948 closed system structures and 41 miles of pipe were collected as part of the City-wide inventory in the HMR/SHB watersheds.

Analysis

CDM Smith conducted an existing conditions analysis in order to evaluate the existing hydrologic and hydraulic characteristics of the HMR/SHB watersheds. Noted in this report as the primary systems, HMR and SHB were hydraulically studied. The main stems of these creeks were modeled as open channels with culverted and bridged crossings. There are 7 creek crossings in the HMR/SHB watersheds, 4 of which are crossing major thoroughfares, 2 minor thoroughfares, and 1 crossing of Highway 264.

In addition to the primary systems, select closed pipe drainage systems that drain to HMR, SHB, Sains Branch and Sams Branch tributaries were analyzed to determine if those systems meet the City's desired design requirements outlined in Section 1.2. Along with City staff input, those secondary systems were identified as part of the public education and outreach efforts conducted at key milestones. Initially, the City distributed and collected questionnaires to gather citizen information on flooding and erosion issues throughout the City. Existing conditions and proposed improvements were presented to the public during open meetings. The results and comments from the citizens' input contributed to the identification and prioritization of problem areas, and the validation of model results. Based on feedback from City residents and City staff, Davis and Vance, 1st Street and Jarvis, 1st Street and N. Harding Street, and 4th Street and Elm Street systems were included as part of the secondary system analysis.

The modeling analysis consisted of hydrologic and hydraulic modeling in standard public domain software. The US Army Corps of Engineers (USACE) HEC-HMS model was used to develop design flows for the primary systems. The USACE HEC-RAS model was used to model the channels and floodplains of the primary systems. The secondary systems were modeled in the EPA's Storm Water Management Model (SWMM).

According to the model results, structural flooding and roadway crossing overtopping occurs at multiple locations. Potential structural flooding was identified for buildings in the modeled floodplains for the 25- and 100-year design storms. Existing flood stages were compared with the City's desired LOS as designated in the standard operating procedure (SOP) manual. Proposed improvements were developed with the models to attain the LOS.

Regional detention was also evaluated as a solution to existing and future flooding issues in SHB.

Additionally, as part of the HMR/SHB Watershed 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. This evaluation yielded no such areas in HMR/SHB meeting the criteria, particularly the criteria for "well documented water quantity problems".

As a result of the existing and future conditions analyses and input from residents and City staff, multiple capital projects were identified to reduce the severity and frequency of flooding, stabilize stream banks, and improve water quality through stormwater treatment practices. Flood control projects were evaluated to meet the desired LOS for roadway overtopping and roadway/structure flooding.

Costs for each project were estimated using approved unit costs from the SOP with engineering, administrative, and contingency costs included for construction implementation. Anticipated permitting and funding opportunities were also evaluated for each project. The proposed capital projects are as follows with the locations of each project shown in **Figure ES-1**.

Flood Control Projects

Harris Mill Run Primary System

There are no crossings which flood for the modeled design storms and therefore no improvements are recommended.

Sams Branch and Sains Branch Primary Systems

There are no crossings which flood for the modeled design storms. Therefore, no improvements are recommended for the primary channels in the Sams Branch or Sains Branch watersheds, except for sediment removal maintenance at the Golf View Road culvert crossing.

Schoolhouse Branch Primary System

The crossing at W 5th Street is the only major City owned crossing of SHB. Immediately upstream, two access driveways also cross SHB, which provides access from W 5th Street to the NC Alcohol and Drug Abuse Treatment Center (ADATC) and the Greenfield Place, LLC, long-term care (LTC) facility. Neither roadway currently meets the 25-year assigned LOS, with the Rehab Center exceeding only a 2-year LOS and the LTC entrance not passing any modeled design storm (<2-year) without overtopping. The proposed improvements for the two service driveway crossings of SHB are a set of three 48-inch diameter reinforced concrete pipe (RCP) for each and are on private property, and therefore not included in the prioritization.

The W 5th Street crossing of SHB is comprised of twin 5.5 foot (ft) by 5.5 ft reinforced concrete box culverts (RCBC) and a 60-inch corrugated metal pipe (CMP) only meeting a 10-year LOS without overtopping the roadway. To attain the designated LOS, the recommended upgrade to the culverts includes three 8 ft by 5 ft RCBC or four 6 ft RCP culverts. .

Secondary Systems

Davis and Vance Street System – The Davis and Vance Street System shares a single outfall since the outfall at Davis Street was buried. The upstream portion of this system is cross-connected with the drainage system to the east near the 3rd Street Community Center. The upstream portion of the drainage area is part of the 10th Street connector which when constructed, will divert flows from this system to the Town Creek Culvert drainage system to the east.

City maintenance personnel report flooding in this area along the northern portions of both Davis Street and Vance Street, as well as near the intersection of Davis Street and Ward Street. Model results show that parts of the system operate at or below a 2-year LOS. Installation of a connecting pipe to allow the Davis Street line to flow into the Vance Street line is recommended along with multiple pipe upgrades.

Jarvis Street – 1st Street – Woodlawn Avenue System – The conveyance system is comprised of a combination of RCP and CMP ranging from 12 to 36 inches in diameter is in good condition based on data collected during the inventory. Model results show that the majority of the system exceeds a 10-year LOS, with only the last 500 feet of pipe approaching the outfall at or below the 10-year LOS. Recommended improvements are limited to replacement of downstream pipes with slightly larger size pipe and involve relocation of the drainage pipe outside private property onto City owned parcels and the right-of-way.

Harding Street and 1st Street System – Model results show that the majority of the system, particularly along E 1st Street operates below a 2-year LOS. This is consistent with the report by a resident on Harding Street that street flooding occurs frequently and the general report from City maintenance staff that flooding occurs in the area of 1st Street. Replacement pipes ranging in size from 24 to 36 inches are recommended to improve the LOS to 10-year, thereby alleviating recurrent flooding of roadways and yards.

Elm Street – 4th Street System – Flooding in this area was reported by City maintenance staff and confirmed by the modeling which shows that the majority of the system operates at or below a 2-year LOS. The downstream run of pipe at the north end of Elm Street right before the Tar River outfall was previously planned for replacement due to joint separation. Improvements to the Elm Street – 4th Street System include the addition of a parallel line along Elm Street to supplement capacity through the existing portion of the system on the Wilson Acres Apartment property, and remove the public water from flowing through private property. Moving the stormwater line into the public right-of-way will facilitate regular maintenance and repair of the public drainage system. Additionally, daylighting of the pipe at the end of the system is recommended as a water quality improvement project, which is discussed in Section 5.

Flood Control Prioritization

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

- Public health and safety
- Severity of street flooding
- Cost-effectiveness
- Effect of improvements
- Water quality best management practice (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 greatest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. While both alternatives are shown for some projects, it is acknowledged that only one of the two alternatives would need to be constructed. Once an alternative has been selected, the remaining alternative for the same project can be removed from the prioritization list. **Table ES-1** shows the proposed prioritizations and conceptual cost estimates for the flood control improvements. The prioritization scoring for each project and a description of the aforementioned categories is included in Appendix M. The total cost for primary and secondary system improvements is approximately $7.7 million. Projects outside the City limits or on private property, as identified in the report, are not included in the City's prioritization for inclusion in the list of Capital Improvement Projects for implementation.

Table ES-1: Flood Control Prioritization

Prioritization	Project	Cost
1	W 5th Street Crossing (Schoolhouse Branch)	$1,010,000
2	Davis Street and Vance Street System (Tar River)	$1,130,000
3	Harding Street System (Tar River)	$1,240,000
4	Elm Street System (Tar River)	$3,310,000
5	Jarvis Street System (Tar River)	$990,000
	Total	$7,680,000

Stream Stabilization and Water Quality Projects

During the existing conditions analysis, the major streams were quantitatively assessed for stability. Based on this assessment, three stream stabilization projects were identified for Sams Branch, SHB, and an unnamed tributary to SHB as shown in Figure ES-1. Potential components of the stabilization projects include flattening the slope of the channel banks, installing erosion control matting and plantings, rock grade control structures, log grade control structures, retaining walls, and riprap. The stabilization projects will protect the stream banks from further erosion, and substantially decrease the instream sediment loads to downstream receiving waters.

In addition to the stream stability projects, water qualityBMP retrofit projects were also identified. Potential project locations were initially identified using available GIS data by focusing on locations with contributing drainage areas that are highly impervious and ideally on publically owned land. Impervious areas typically generate the highest concentration of pollutants, so treating the runoff from these areas would provide more pollutant removal 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 inspected to determine if the site conditions were conducive to a BMP. This inspection typically included verifying that GIS data and aerial photography were accurate and current, and to determine if there were project constraints present that may not be visible from GIS data, such as utility conflicts, private property conflicts, or limited access to the site. Where possible, retrofit projects were located on public property to reduce potential land acquisition costs. A total of 10 BMP retrofit sites were evaluated for implementation of BMPs throughout the HMR/SHB watersheds, with 7 candidate sites included in the prioritization. Potential sites at Vidant, Greenville Utilities Commission, Lake Laupus, and Cypress Glen Retirement Community were considered, but not included due to criteria associated with on-site conditions and/or property ownership.

The stream stabilization projects and water quality retrofit projects were prioritized using similar categories as the flood control projects described above, which are located in Appendix M. Cost-effectiveness for stream stabilization projects was calculated based on a cost per linear foot of stabilized stream. Cost-effectiveness for water quality retrofit projects was calculated based on an estimated cost per pound of pollutant removed. **Tables ES-2 and ES-3** show the prioritization of the Stream Stabilization and Water Quality projects along with preliminary cost estimates. Additionally, several recommended maintenance locations were identified throughout the watershed, as listed in Section 10. The maintenance items are based on the condition assessment completed during the stormwater inventory and stream assessment.

Table ES-2 Stream Stabilization Prioritization

Prioritization	Project	Cost
1	Earthen Dam Removal and Stabilization (Schoolhouse Branch)	$250,000
2	Beasley Drive Channel Stabilization	$330,000
3	Ironwood Golf and Country Club Stream Stabilization	$730,000
	Total	$1,310,000

Table ES-3: Water Quality Prioritization

Prioritization	Project	Cost
1	Moyewood Wetland Retrofit	$42,000
2	Third Street Community Center Bioretention	$120,000
3	Town Common on Tar River Tiered Bioretention	$150,000
4	N. Summit Street Bioretention	$270,000
5	S. Tar River Greenway Pipe Daylighting	$150,000
6	Thomas Foreman Park Bioretention and Permeable Pavement	$390,000
7	Ironwood Golf and Country Club Wet Retention Pond	$320,000
	Total	$1,440,000

CITY OF GREENVILLE

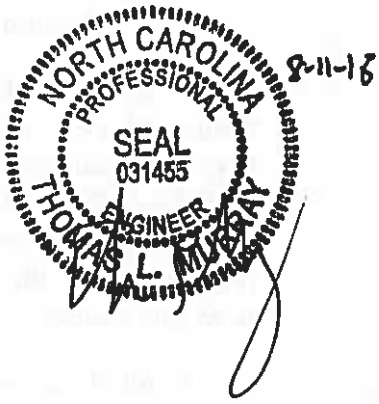
SWIFT CREEK
WATERSHED MASTER PLAN

WKD # 20140067.00.RA

August 2016

Prepared for

City of Greenville
1500 Beatty Street
Greenville, NC 27834



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EXECUTIVE SUMMARY

The City of Greenville retained WK Dickson to complete a Master Plan for the Swift 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 Swift Creek watershed. Over 700 drainage structures and approximately 19 miles of drainage pipe 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 6.4 square miles and is located in the southwestern corner of Greenville. Approximately 33% of the watershed is contained in the City limits, and it is 55% 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 Swift Creek watershed. Noted in this report as the Primary System are the following:

- Swift Creek Main Branch;
- Unnamed Tributary to Swift Creek (referred to as SCUT1); and
- Gum Swamp (Tributary to Swift Creek).

These Primary Systems 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, a conveyance system (referred to as secondary system) in the Swift Creek watershed was analyzed to determine if it met the desired City design requirements outlined in Section 1.2. The secondary system was 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.

Flood Control Projects

Swift Creek Main Branch Primary System

Alternative #1

Two alternatives are presented to improve flooding along Swift Creek Main Branch. Alternative #1 predominantly focuses on culvert improvements and floodplain benching to reduce the severity, frequency, and duration of flooding along Swift Creek. The proposed projects for Alternative #1 will require easements on private property in some instances, although entire property acquisition is not anticipated. The proposed projects for Alternative #1 are described below.

Thomas Langston Road – The existing 84" corrugated metal pipe (CMP) at this crossing is in fair condition and currently provides a 2-year level of service. In order to meet the desired 25-year level of service, the 84" CMP would need to be upsized.

Alternative #1 includes replacing the existing culvert with a 10' x 6' reinforced concrete box culvert (RCBC) and grading approximately 1,350 linear feet of floodplain benches in the left and right overbanks between Thomas Langston Road and Sterling Trace Drive. The floodplain benching will lower the tailwater for the culvert crossing reducing the proposed size of the new culverts. The proposed stream stabilization downstream of Thomas Langston Road could be incorporated into the floodplain benching. The maximum reduction in the 25-year WSEL upstream of Thomas Langston Road for this alternative is 1.94 feet. This alternative removes nine (9) properties from the 25-year floodplain and four (4) properties from the 100-year floodplain within the vicinity of Thomas Langston Road. Thomas Langston Road is maintained by NCDOT, therefore coordination with NCDOT would be required for any improvements within the right-of-way (ROW).

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project.

Sterling Trace Drive – Currently, the twin 54" CMPs at this crossing provides a 2-year level of service. To meet the desired 25-year level of service, the CMPs will need to be replaced with twin 10' x 6' RCBCs. In addition to the culvert upgrade, Alternative #1 will include 1,690 linear feet of proposed floodplain benching downstream of Sterling Trace Drive in the left and right overbanks. The maximum reduction in the 25-year WSEL upstream of Sterling Trace Drive for this alternative is 1.51 feet for the 25-year event. Alternative #1 removes twelve (12) properties

from the 25-year floodplain, and nine (9) properties from the 100-year floodplain. Sterling Trace Drive is currently privately maintained. Many of the properties south of the crossing are located outside of the City limits.

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project.

Alternative# 2

Alternative #2 evaluates the potential for creating upstream storage areas to detain runoff and lower peak flows, thereby reducing the size of downstream infrastructure improvements. Property acquisition will likely be required for the proposed detention area, although the extent of easements along Swift Creek will be less than those required for Alternative #1 as the limits of floodplain benching can be reduced as a result of the proposed detention area. The proposed projects for Alternative #2 are described below.

Megan Drive – The detention facility proposed near Megan Drive is located in the northwest corner of the Swift Creek Main Branch watershed. This thirty-two (32) acre wet detention pond is expected to reduce peak flows in the vicinity of Thomas Langston Road, and would subsequently eliminate the need for floodplain benching (as proposed for the Thomas Langston Road improvements, Alternative #1). The parcel is currently owned by Roberson Land Development and Blackwood Strickland LLC. Based on tax value the estimated land acquisition cost for this parcel would exceed $900,000. The large field at the east end of Megan Drive would be an ideal location for a 25-year facility because it has not been developed, and may be an aesthetic point of interest for future residents in addition to providing flood control. The regional detention facility will not impact the size of culverts along Swift Creek Main Branch but will reduce flows downstream to pre-project conditions.

Thomas Langston Road – The existing 84" CMP at this crossing is in fair condition and currently provides a 2-year level of service. In order to meet the desired 25-year level of service, the 84" CMP would need to be upsized.

Alternative #2 includes replacing the existing culvert with a 10' x 6' RCBC similar to Alternative #1, however floodplain benching will not be required as part of this alternative. The proposed stream stabilization downstream of Thomas Langston Road could be incorporated into the culvert improvements or completed separately. The maximum reduction in the 25-year WSEL upstream of Thomas Langston Road for this alternative is 1.92 feet. This alternative removes twelve (12) properties from the 25-year floodplain and one (1) property from the 100-year floodplain within the vicinity of Thomas Langston Road. Thomas Langston Road is maintained by NCDOT, therefore coordination with NCDOT would be required for any improvements within the right-of-way (ROW).

Sterling Trace Drive – Currently, the twin 54" CMPs at this crossing provides a 2-year level of service. To meet the desired 25-year level of service, the CMPs will need to be replaced with twin 10' x 6' RCBCs. In addition to the culvert upgrade, Alternative #2 will include 1,690 linear feet of proposed floodplain benching downstream of Sterling Trace Drive in the left and right overbanks, although the width of the proposed benching is less than that proposed in Alternative #1. The maximum reduction in the 25-year WSEL upstream of Sterling Trace Drive for this alternative is 1.47 feet for the 25-year event. Alternative #2 removes thirteen (13) properties from the 25-year floodplain, and ten (10) properties from the 100-year floodplain. Sterling Trace Drive is currently privately maintained. Many of the properties south of the crossing are located outside of the City limits.

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project.

Swift Creek UT 1 (SCUT1) Primary System

Alternative #1

Two alternatives are presented to improve flooding along Swift Creek UT1. Alternative #1 predominantly focuses on culvert improvements and floodplain benching to reduce the severity, frequency, and duration of flooding along SCUT1. The proposed projects for Alternative #1 will require easements on private property in some instances, although entire property acquisition is not anticipated. The proposed projects for Alternative #1 are described below.

Thomas Langston Road – The existing 42" reinforced concrete pipe (RCP) at this crossing is undersized and only passes a 2-year storm event. The desired level of service at Thomas Langston Road is a 25-year storm.

Alternative #1 entails increasing the capacity of the culverts crossing by adding twin 42" floodplain culverts. The existing 42" RCP is in good condition and will remain in place. However, a field investigation revealed that the edge of the road and the edge of the culvert are eroding in this location, therefore the City should consider installing endwalls as part of the proposed improvements. In addition, 530 linear feet of floodplain benching is proposed downstream of Thomas Langston Road in the left and right overbanks. The maximum decrease in WSEL as a result of these improvements at Thomas Langston Road is 1.51 feet for the 25-year event. Additionally, eight (8) properties are removed from the 25-year floodplain and eleven (11) properties are removed from the 100-year floodplain. Thomas Langston Road is maintained by NCDOT, therefore coordination with NCDOT would be required for any improvements within the right-of-way (ROW).

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. Additionally, the floodplain benching could be coordinated with the proposed Swift Creek Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

Belfair Drive – Currently, the twin 48" RCPs at this crossing provides a 10-year level of service. To meet the desired 25-year level of service, the existing RCPs will need to be replaced with twin 6' x 4' RCBCs. The increased culvert capacity will provide the desired level of service. The maximum decrease in WSEL is 0.74 feet for the 25-year event just upstream of Belfair Drive as a result of the proposed improvements. There are no properties affected by the 25 or 100-year floodplains in the vicinity of Belfair Drive, therefore there were no properties removed as a result of these improvements.

Sterling Pointe Drive – The twin 42" RCPs at this crossing are undersized and only provide a 2-year level of service. The desired level of service at Sterling Pointe Drive is a 25-year storm.

Alternative #1 entails replacing the existing twin 42" RCPs with twin 11' x 4' RCBCs. In addition, 1,200 linear feet of floodplain benching is proposed downstream of Sterling Point Drive in the left and right overbanks. The maximum decrease in WSEL as a result of these improvements is 1.56 feet for the 25-year event. Three (3) properties are removed from the 25-year floodplain and twelve (12) properties are removed from the 100-year floodplain.

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. Additionally, the floodplain benching could be coordinated with the proposed Swift Creek Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

Alternative #2

Alternative #2 evaluates the potential for creating upstream storage areas to detain runoff and lower peak flows, thereby reducing the size of downstream infrastructure improvements. Property acquisition will likely be required for the proposed detention area, although the extent of easements along Swift Creek will be less than those required for Alternative #1 as the limits of floodplain benching can be reduced as a result of the proposed detention area. The proposed projects for Alternative #2 are described below.

Thomas Langston Road Detention – The Thomas Langston Road facility is proposed at the northern upstream section of the Swift Creek Tributary 1 watershed near Providence Place and is included in Alternative #2 for Swift Creek Tributary 1. The fifteen (15) acre wet detention

pond if implemented will require limited additional improvements at the Thomas Langston Road crossing. The parcel is currently owned by TMH Properties LLC and is slated for residential development. Based on tax value, the estimated land acquisition cost for this parcel would exceed $330,000. Passive recreational facilities could be added to the detention area to provide a community amenity.

Thomas Langston Road – The existing 42" RCP at this crossing is undersized and only passes a 2-year storm event. The desired level of service at Thomas Langston Road is a 25-year storm.

As a result of the proposed detention area upstream of Thomas Langston Road, the existing culvert crossing at Thomas Langston Road would convey the 25-year flow. A field investigation revealed that the edge of the road and the edge of the culvert are eroding in this location, therefore the City should consider installing endwalls on the existing culvert to stabilize the road. Floodplain benching is not required as part of Alternative #2. The maximum decrease in WSEL as a result of these improvements at Thomas Langston Road is 1.73 feet for the 25-year event. Additionally, eight (8) properties are removed from the 25-year floodplain and thirteen (13) properties are removed from the 100-year floodplain. Thomas Langston Road is maintained by NCDOT, therefore coordination with NCDOT would be required for any improvements within the right-of-way (ROW).

Belfair Drive – Currently, the twin 48" RCPs at this crossing provides a 10-year level of service. As a result of the proposed detention area upstream of Thomas Langston Road, the existing culvert crossing at Belfair Drive would convey the 25-year flow. The maximum decrease in WSEL is 2.38 feet for the 25-year event just upstream of Belfair Drive as a result of the proposed detention upstream of Thomas Langston Road. There are no properties affected by the 25-year or 100-year floodplains in the vicinity of Belfair Drive, therefore there were no properties removed as a result of these improvements.

Sterling Pointe Drive – The twin 42" RCPs at this crossing are undersized and only provide a 2-year level of service. The desired level of service at Sterling Pointe Drive is a 25-year storm.

Alternative #2 takes into account the implementation of the detention area proposed upstream of the Thomas Langston Road crossing. With the proposed detention area, the proposed culvert for Alternative #2 is twin 10' x 4' RCBCs which will provide the desired 25-year level of service. This alternative will not include the floodplain benching proposed as part of Alternative #1. The maximum decrease in WSEL during the 25-year storm as a result of these improvements is 1.42 feet for the 25-year event. Two (2) properties are removed from the 25-year floodplain and twelve (12) properties are removed from the 100-year floodplain.

Gum Swamp Primary System

Frog Level Road – The twin 78" CMPs at this crossing are currently operating at a 10-year level of service. In order to meet the desired 25-year level of service, the existing CMPs will need to

be replaced with twin 7' x 6' RCBCs. Additionally, 495 linear feet of floodplain benching along the left bank is required to lower the tailwater at the downstream end of Frog Level Road and allow the new culverts to convey the 25-year storm. The maximum decrease in WSEL as a result of these improvements is 0.83 feet for the 25-year event just upstream of the Frog Level Road crossing. Upstream of Frog Level Road, four (4) properties are removed from the 25-year floodplain and one (1) property is removed from the 100-year floodplain.

Frog Level Road is currently maintained by NCDOT and is located outside of the existing City limits. However, improvements to the culvert crossing will directly reduce water surface elevations for City residents located along Ashmoor Lane.

Gum Swamp Floodplain Benching - A total of 4,660 linear feet of floodplain benching is proposed in the left and right overbanks approximately 1,000 linear feet downstream of Frog Level Road. The floodplain benching lowers water surface elevations along the stream which will reduce the risk of flooding for properties along Sawgrass Drive as well as address the documented stream erosion problems along Gum Swamp. The maximum decrease in WSEL as a result of these improvements is 3.8 feet during the 25-year event. Along the studied reach of Gum Swamp, forty-three (43) properties are removed from the 25-year floodplain and seven (7) properties are removed from the 100-year floodplain.

The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project.

Secondary Systems

Davenport Farm Road – The downstream portion of this system is operating below the desired 10-year level of service due to the backwater from Gum Swamp. With the improvements proposed for the Frog Level Road crossing including the floodplain benching, the tailwater will be lowered and the Davenport Road system will operate at the desired level of service. Therefore, no capital improvements are proposed at this location.

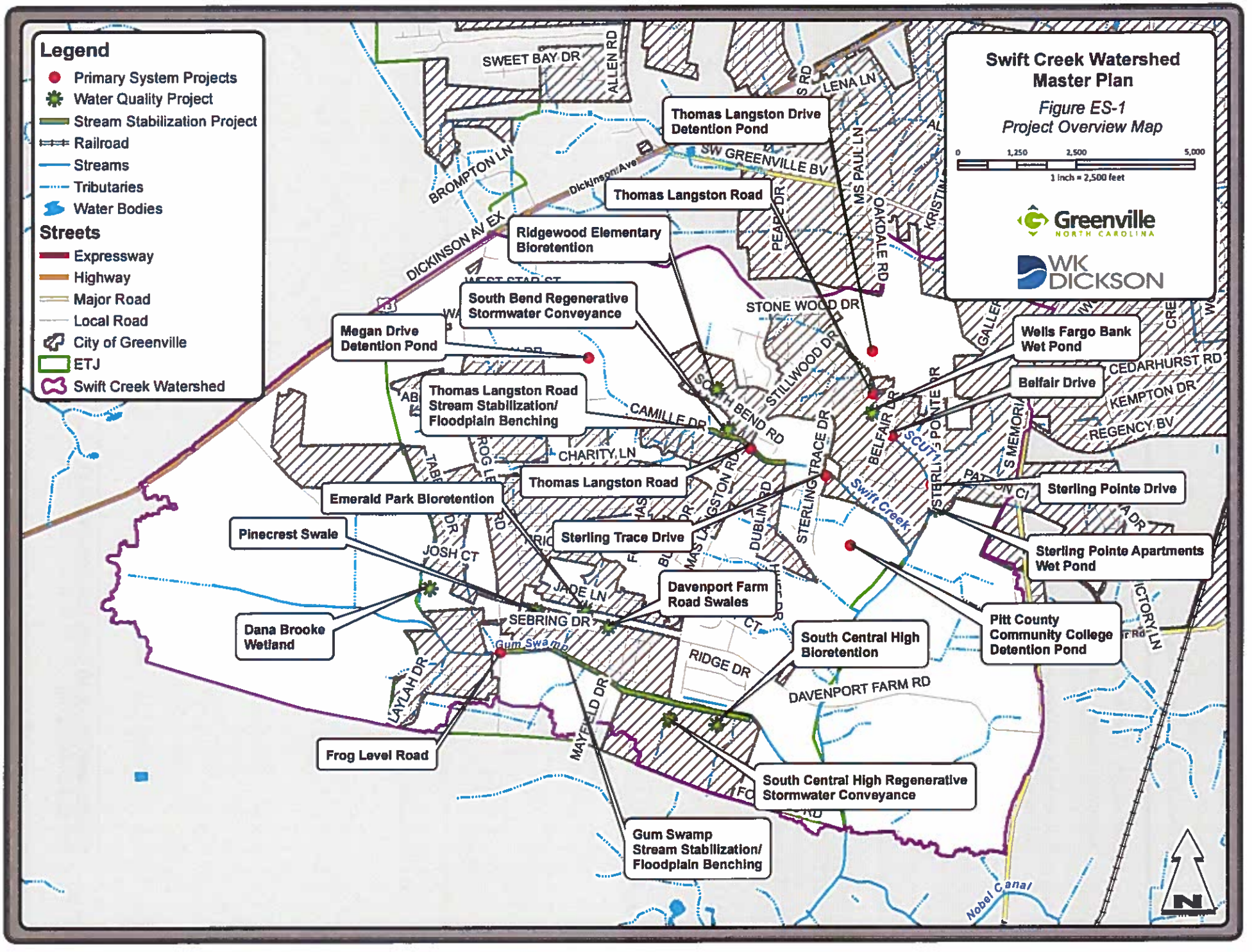
Regional Detention

If all of the proposed primary system improvements are completed as outlined in "Flood Control Projects" section, runoff will be conveyed more efficiently through the Swift Creek watershed, but will result in a 6% increase in the 25-year storm at the outlet of the watershed for Alternative #1 for future build out conditions when compared to existing conditions flows. To offset this increase in peak flow, a regional detention facility is proposed on a portion of the Pitt County Community College property east of Sterling Trace Drive near the confluence of Swift Creek and the unnamed tributary to Swift Creek. The 32-acre wet detention pond would reduce peak flows to below the pre-project conditions. For Alternative #2, the Pitt County

Community College Detention Pond would not be required due to the detention from the Megan Drive and Thomas Langston detention ponds.

If 25-year detention is required in the areas shown in Section 4.3, then the Pitt County Community College Detention Pond could be reduced to 20 acres in size for Alternative #1 resulting in no increase in peak flow at the outlet during the 25-year event during built out conditions.

For Alternative #2, 25-year detention for future development in the areas shown in Section 4.3 would allow the Megan Drive and Pitt County Community College Detention Pond to be eliminated. The Thomas Langston Pond would be required as proposed above for Alternative #2.


Legend
Primary System Projects
Water Quality Project
Stream Stabilization Project
Railroad
Streams
Tributaries
Water Bodies
Streets
Expressway
Highway
Major Road
Local Road
City of Greenville
ETJ
Swift Creek Watershed
Swift Creek Watershed Master Plan
Figure ES-1
Project Overview Map
0 1,250 2,500 5,000
1 Inch = 2,500 feet
Greenville NORTH CAROLINA
WK DICKSON
Thomas Langston Drive Detention Pond
Thomas Langston Road
Ridgewood Elementary Bioretention
South Bend Regenerative Stormwater Conveyance
Megan Drive Detention Pond
Thomas Langston Road Stream Stabilization/ Floodplain Benching
Emerald Park Bioretention
Thomas Langston Road
Pinecrest Swale
Sterling Trace Drive
Davenport Farm Road Swales
Dana Brooke Wetland
Frog Level Road
Gum Swamp Stream Stabilization/ Floodplain Benching
South Central High Regenerative Stormwater Conveyance
South Central High Bioretention
Pitt County Community College Detention Pond
Sterling Pointe Apartments Wet Pond
Sterling Pointe Drive
Belfair Drive
Wells Fargo Bank Wet Pond
SWEET BAY DR
ALLEN RD
LENA LN
SW GREENVILLE BV
BROMPTON LN
DICKINSON AV EX
Dickinson Ave
MS PAUL LN
OAKDALE RD
PEAR DR
STONE WOOD DR
STILLWOOD DR
SOUTH BEND RD
CAMILLE DR
CHARITY LN
STERLING TRACE DR
DUBLIN RD
CEDARHURST RD
KEMPTON DR
REGENCY BV
JOSH CT
JADE LN
SEBRING DR
RIDGE DR
DAVENPORT FARM RD
LAYLAH DR
MAYFIELD DR
Swift Creek
Gum Swamp
Nobel Canal
N

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 system improvements for Alternative #1 in the Swift Creek watershed is approximately $11,230,000. The total cost for all of the recommended primary and secondary system improvements for Alternative #2 in the Swift Creek watershed is approximately $30,910,000. The additional cost to construct the Pitt County Community College Detention Pond would be $18,280,000, which would only be required for Alternative #1.

Table ES-1: Flood Control Project Prioritization

Prioritization	Project	Cost
1	Thomas Langston Road (Swift Creek Main Branch) – Alt #1	$1,050,000
2	Alternative #2 – SCUT1	$8,050,000
3	Thomas Langston Road (SCUT1) – Alt #1	$370,000
4	Alternative #2 – Swift Creek Main Branch	$16,990,000
5	Frog Level Road (Gum Swamp)	$710,000
6	Gum Swamp Floodplain Benching	$5,160,000
7	Belfair Drive (SCUT1) – Alt #1	$380,000
8	Sterling Pointe Drive (SCUT1) – Alt #1	$1,190,000
9	Sterling Trace Drive (Swift Creek Main Branch) – Alt #1	$2,370,000

See Appendix L for prioritization details.

Stream Stabilization and Water Quality Projects

During the Existing Conditions Analysis, the majority of the streams were quantitatively assessed for stability. Based on this assessment, two (2) stream stabilization projects were identified as shown on Figure ES-1. Potential components of the stabilization project include, flattening the slope of the channel banks, installing erosion control matting and plantings, rock grade control structures, retaining walls, and rip-rap. Stream restoration projects typically include changing the pattern of the stream which can be difficult in urban areas due to the impacts on multiple property owners. Additionally, property boundaries are often defined by the stream centerline, further complicating urban stream restoration. The stabilization projects will protect residential yards, fences, and structures from further erosion, and substantially decrease the in-stream sediment loads to downstream receiving waters. Additionally, the floodplain benching along Gum Swamp could be combined with the stream stabilization proposed in the Upper Swift Creek and Fork Swamp Watershed Action Plan completed by Pitt County in 2012. The portion of Gum Swamp that was identified in the Action Plan for stabilization is outside the City limits, but in close proximity to the proposed floodplain benching. This project may be an opportunity for the City to partner with Pitt County.

The City should also work closely with the Pitt County Drainage District to determine the most effective ways to maintain streams in the watershed without impacting the stability of streambanks and habitat for macroinvertebrates. The maintenance activities that are keeping the streams clear from blockages have the unintended consequences of removing vegetation from the streambanks that can be vital to stabilizing the banks. As development continues to occur in this area, peak flows will increase and high flows will be longer in duration which could further erode the banks if they are not vegetated. Secondly, Swift Creek is currently listed as impaired for benthic macroinvertebrates. While the monitoring results summarized in Section 5.5 indicate it may be possible to delist Swift Creek from the Category 5 list, there is limited habitat within the streams for the macroinvertebrates to thrive. Some woody debris should remain in the stream to allow these organisms to thrive which will improve the water quality of the stream.

In addition to the stream stability projects, ten (10) water quality BMP retrofit projects were recommended. 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 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 stream stabilization and 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 stream stabilization project was calculated based on a cost per linear foot of stabilized stream, while for water quality projects were calculated based on a cost per impervious acre treated. Tables ES-2 and ES-3 show the prioritization of the stream stabilization and water quality projects along with estimates of their preliminary cost.

Table ES-2: Stream Stabilization Project Prioritization

Prioritization	Project	Cost
1	Thomas Langston (Swift Creek Main Branch)	$810,000
2	Thomas Langston (SCUT1)	$70,000
	Total	$880,000

Table ES-3 Water Quality Project Prioritization

Prioritization	Project	Cost
1	Sterling Pointe Apartments Wet Pond Retrofit	$100,000
2	Ridgewood Elementary School Bioretention	$330,000
3	Emerald Park Bioretention	$240,000
4	South Bend RSC	$220,000
5	Pinecrest Water Quality Swale	$50,000
6	Wells Fargo Wet Pond Retrofit	$200,000
7	Davenport Farm Road Water Quality Swale	$100,000
8	South Central High School Bioretention	$1,300,000
9	Dana Brooke Wetland	$930,000
10	South Central High School RSC	$140,000
	Total	$3,610,000

See Appendix L for prioritization details.

25-Year Detention Analysis

As part of the Swift Creek Master Plan, an analysis was completed to determine if there are areas within the watershed that should be considered "well documented water quantity problems" requiring detention for the 25-year, 24-hour storm event. As noted in Section 3.1, documented flooding issues are located along Swift Creek Main Branch, Swift Creek Unnamed Tributary 1, and Gum Swamp in the vicinity of Thomas Langston Road and Frog Level Road. Large portions of the Swift Creek watershed remain undeveloped and could potentially cause increased flows greater than 10% higher than the current existing flows. These areas are outlined in Section 4.3.

If 25-year detention is required in the proposed areas, the need for infrastructure improvements will not be eliminated but the recommended improvements could be reduced in magnitude.

For Alternative #1, 25-year detention in the areas outlined in Section 4.3 will provide the following changes in the proposed improvements:

- Remove floodplain benching downstream of Thomas Langston Road ($650,000 reduction in cost);
- Reduce floodplain benching downstream of Sterling Trace Drive ($280,000 reduction in cost;
- Reduce size of Pitt County Community College Regional Detention to 20 acres ($6,850,000 reduction in cost); and
- Total potential cost savings in capital infrastructure - $7,780,000.

For Alternative #2, 25-year detention in the areas outlined in Section 4.3 will provide the following changes in the proposed improvements:

- Remove Megan Drive Detention Pond ($14,490,000 reduction in cost); and
- Total potential cost savings in capital infrastructure - $14,490,000

CITY OF GREENVILLE

FORK SWAMP WATERSHED MASTER PLAN

WKD # 20140067.00.RA

August 2016

Prepared for

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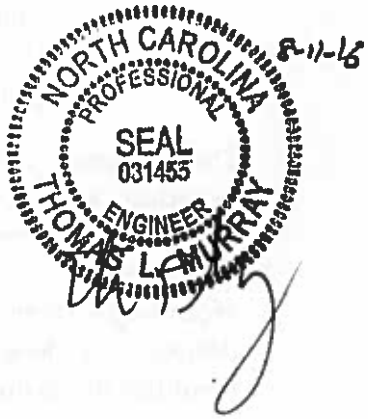
1500 Beatty Street
Greenville, NC 27834



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EXECUTIVE SUMMARY

The City of Greenville retained WK Dickson to complete a Master Plan for the Fork Swamp 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 Fork Swamp watershed. Over 2,350 drainage structures and approximately 40 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 ten (10) square miles and is located in the south central portion of Greenville. Approximately 60% of the watershed is contained in the City limits, and it is 75% 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 Fork Swamp watershed. Noted in this report as the Primary System are the following:

- Fork Swamp Main Branch;
- Unnamed Tributary 1 to Fork Swamp (referred to as FSUT1);
- Unnamed Tributary 2 to Fork Swamp Reach 1(referred to as FSUT2R1);
- Unnamed Tributary 2 to Fork Swamp Reach 2(referred to as FSUT2R2); and
- Unnamed Tributary 3 to Fork Swamp (referred to as FSUT3).

These Primary Systems were hydraulically studied in detail and were selected 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 Fork Swamp 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. Additionally, the identified projects meet the City's design requirements outlined in Section 1.2 for future conditions.

The proposed capital projects are as follows with the locations of each project shown on Figure ES-1.

Flood Control Projects

Fork Swamp Main Branch Primary System

East Baywood Lane – The existing twin 72" corrugated metal pipes (CMPs) at this crossing are currently providing a 2-year level of service. The water surface elevations (WSELs) at East Baywood Lane are controlled by the backwater from the downstream railroad crossing. With the proposed downstream improvements, the resultant 25-year WSEL is reduced by over 2 feet. However, East Baywood Lane still does not meet the required 25-year level of service and will operate just below a 10-year level of service. Increasing the capacity at the crossing does not impact the WSEL since the culvert is in outlet control. Furthermore, there is no room available to incorporate floodplain benching immediately downstream of the crossing to try to lower the tailwater. Therefore, no capital improvements are proposed at this location. Reductions in flooding in the vicinity of East Baywood Lane will occur as a result of the railroad crossing and Evans Street projects described below.

Railroad Crossing – The existing twin 84" CMPs at this crossing are currently operating at a 25-year level of service. In order to aid in lowering the tailwater at East Baywood Lane, floodplain benches downstream of the railroad crossing in the left overbank are proposed for approximately 770 linear feet. The floodplain benching will improve the performance of the existing CMPs at the railroad crossing and bring it up to the desired 100-year level of service while also reducing water surface elevations in the Westhaven neighborhood upstream by increasing the cross-sectional area of flow. The proposed improvements would result in up to a 2.3-foot decrease in WSEL for the 25-year event. Lowering the tailwater at the railroad by installing floodplain benching is the only feasible alternative for reducing the water surface elevations in the upstream Westhaven neighborhood. Based on the model results 121 properties are at risk for lowest adjacent grade (LAG) flooding during the 25-year storm upstream of the railroad crossing. The combination of the Evans Street project and the railroad project will remove 15 of these properties from the 25-year floodplain. Approximately 25% of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. Additionally, the floodplain benching could be

coordinated with the proposed Fork Swamp Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

Evans Street – The existing twin 84" CMPs at this crossing are currently providing a 25-year level of service. Since Evans Street is classified as a major thoroughfare, the desired level of service is the 50-year storm. This alternative entails replacing the existing CMPs with twin 7' x 7' RCBCs coupled with floodplain benching downstream of the crossing to lower the tailwater. The floodplain benching is proposed in the left overbank for approximately 1,200 linear feet. The improvements proposed will bring Evans Street up to the desired 50-year level of service. It should be noted that NCDOT has an upcoming widening project planned for Evans Street. In order to implement the culvert improvements with this planned roadway widening project, coordination with NCDOT will be required. Depending upon the timing, another option would be to complete this project in phases. Phase 1 would be the installation of the proposed floodplain benching followed by Phase 2, the culvert upgrades. The proposed improvements would result in up to a 2.9-foot decrease in WSEL for the 25-year event. As noted above, 15 out of the 121 properties are expected to be removed from the 25-year floodplain as a result of implementing the railroad and Evans Street improvements. The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. Additionally, the floodplain benching could be coordinated with the proposed Fork Swamp Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

East Fire Tower Road – The existing bridge at this crossing is in good condition and currently performs at a 25-year level or service. Since East Fire Tower Road 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 is to reduce the tailwater by grading floodplain benches downstream of East Fire Tower Road. This alternative entails proposed floodplain benching in the right overbank for approximately 2,000 linear feet. The proposed improvements will bring East Fire Tower Road up to the desired 50-year level of service and provide a reduction in the severity, frequency, and duration of flooding for several properties along Treetops Circle. The proposed improvements would result in up to a 2.3-foot reduction in WSEL for the 25-year event. Additionally, four (4) out of six (6) properties may expect to be removed from the 25-year floodplain and twelve (12) properties from the 100-year floodplain. The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. The floodplain benching could be coordinated with the proposed Fork Swamp Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

Fork Swamp Main Branch Floodplain Benching – In addition to the improvements proposed at and near the individual road crossings, there is a proposed floodplain bench and stream stabilization project located along the main branch of Fork Swamp downstream of FSUT1 and

FSUT2. Approximately 2,670 linear feet of floodplain benching is proposed in the left and right overbank. The proposed project will reduce tailwater for FSUT1 and FSUT2, provide additional floodplain storage and remove four (4) and one (1) properties from the 25-year and 100-year floodplains, respectively. The majority of the proposed floodplain bench appears to be located within a Pitt County Drainage District easement based on the Pitt County OPIS website. Coordination with the Drainage District will be required to implement the proposed project. The floodplain benching could be coordinated with the proposed Fork Swamp Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

The total length of the proposed Fork Swamp Greenway is 3.3 miles. Approximately 1.25 miles of the proposed greenway overlaps with the floodplain benching limits. If possible construction of the benching and greenway should be coordinated.

Fork Swamp UT1 (FSUT1) Primary System

Trafalgar Drive – South – The twin 60" CMPs at this crossing are currently providing a 2-year level of service. In order to meet a 25-year level of service, the twin 60" CMPs will remain in place and an additional 60" floodplain culvert will be required along with a new headwall. The proposed improvements will WSEL for the 25-year storm by up to 0.67 feet upstream of Trafalgar Drive- South and remove one property from the 25-year floodplain.

Trafalgar Drive – North – The 60" and 66" CMPs at this crossing are operating at a 2-year level of service. To meet the desired 25-year level of service, it is proposed that the existing CMPs be removed and replaced with twin 8' x 5' RCBCs. The resulting upstream WSEL will be reduced by as much as 0.95 feet in the 25-year if improvements are completed in conjunction with those proposed at Corey Road as described below. This will bring two (2) properties out of the 25-year floodplain and two (2) additional properties out of the 100-year floodplain.

Corey Road – The existing twin 13' x 4.5' corrugated metal arch pipes at this crossing are relatively new and meet the desired 25-year level of service. However, the WSEL at the upstream Trafalgar Drive – North is impacted by the tailwater from Corey Road. In order to lower the tailwater, it is proposed that twin 48" floodplain culverts be installed along with approximately 2,300 linear feet of floodplain benching in the left and right overbanks downstream of Corey Road. The Corey Road improvements should be constructed prior to culvert upgrades at Trafalgar Drive to provide the desired level of service noted above. The proposed improvements would result in up to 2-foot reduction in WSEL for the 25-year event. This will bring one property out of the 25-year floodplain and an additional property out of the 100-year floodplain.

Fork Swamp UT2 Reach 1 (FSUT2R1) Primary System

Old Tar Road – The existing 72" CMP at this crossing is currently operating at a 2-year level of service. In order to meet the desired 50-year level of service, the existing CMP will need to be replaced with twin 7' x 8' RCBCs with 230 linear feet of floodplain benching in the left and right overbanks proposed downstream of Old Tar Road. The NCDOT maintained Old Tar Road is located immediately west of the existing City limits and the City's ETJ. A portion of the proposed floodplain benching along the left bank would be inside the City limits. Based on the location of the road crossing outside the City limits, the Old Tar Road project is not included as a capital project for the City of Greenville.

Fork Swamp UT2 Reach 2 (FSUT2R2) Primary System

West Fire Tower Road – The existing 10' x 8' reinforced concrete box culvert (RCBC) at this crossing is in good condition and is currently exceeding a 100-year level of service. Therefore, no capital improvements are proposed for West Fire Tower Road.

Fork Swamp UT3 (FSUT3) Primary System

Coleman Drive – The existing triple 10' x 4' RCBCs at this crossing are in good condition and currently meet the desired 25-year level of service. With the downstream improvements recommended along FSUT3, the RCBCs will continue to pass the 25-year storm. Therefore, no capital improvements are proposed at this location.

County Home Road – The twin 48" reinforced concrete pipes (RCPs) at this crossing currently pass a 10-year storm event. Based on its classification as a major thoroughfare, it is required to meet a 50-year level of service. It is proposed that the twin 48" RCPs remain in place and an additional 42" floodplain culvert be installed with approximately 240 linear feet of floodplain benching in the left overbank downstream of Country Home Road. The proposed improvements will bring the crossing up to a 50-year level of service and result in up to a 1.3-foot reduction in WSEL for the 25-year event. This will bring two (2) properties out of the 25-year floodplain and two (2) additional properties out of the 100-year floodplain.

East Fire Tower Road – U/S – The existing twin 54" RCPs at this crossing are currently providing a 2-year level of service. In order to meet the desired 50-year level of service, the twin 54" RCPs under East Fire Tower Road will be replaced with twin 6'x 6' RCBCs. The proposed improvements would result in up to a 1.5-foot reduction in WSEL for the 25-year event and one (1) property being removed from the 25-year floodplain.

Wimbledon Drive – The twin 60" CMPs at this crossing are currently providing a 2-year level of service. In order to meet a 25-year level of service, the twin 60" CMPs will be replaced with twin 10' x 5' RCBCs. Additionally, 245 linear feet of floodplain benching is proposed in the right overbank downstream of Wimbledon Drive. Final limits of the proposed benching may

change to minimize impacts to private property owners. The proposed improvements would result in up to a 1.2-foot reduction in WSEL for the 25-year event and removal of one property from the 25-year floodplain.

Tower Place – The twin 66" CMPs at this crossing are currently operating at a 2-year level of service. In order to meet a 25-year level of service, the twin 66" CMPs will be replaced with twin 10' x 5' RCBCs. The proposed improvements would result in up to a 1.0-foot reduction in WSEL for the 25-year event. This will bring two (2) properties out of the 25-year floodplain and one additional property out of the 100-year floodplain.

Summerhaven Drive – Currently, the twin 66" CMPs at this crossing provides a 2-year level of service. To meet a 25-year level of service, the twin 66" CMPs will be replaced with quad 6' x 6' RCBCs. It is proposed that 115 linear feet of floodplain benching be graded downstream of Summerhaven Drive to help lower the tailwater. The proposed improvements would result in up to a 1.2-foot reduction in WSEL for the 25-year event and seven (7) properties being removed from the 25-year floodplain.

East Fire Tower Road – D/S – The existing twin 10' x 7' corrugated metal ellipse pipes only pass the 2-year storm. To meet a 50-year level of service, it is proposed that the existing culverts be removed and replaced with quad 6' x 7' RCBCs. In addition to the culvert upgrade, a total of 3,240 linear feet of floodplain benching is proposed (990 linear feet upstream of the crossing in the left overbank and 2,250 linear feet downstream of the crossing in the left and right overbanks). The proposed improvements would result in up to 1.9 feet reduction in WSEL for the 25-year event. Additionally, forty-two (42) properties will be removed from the 25- and 100-year floodplain.

The floodplain benching could be coordinated with the proposed Fire Tower to Hub - Connector Greenway referenced in the 2004 Greenway Master Plan. Economy of savings could be provided if both projects are constructed at the same time.

Secondary Systems

Corey Road Closed System – The majority of the system is operating at or above the required 10-year level or service. Therefore, the proposed improvements consist of minimal upgrades including upsizing the downstream discharge pipes along Southlea Drive. The proposed pipe improvements range in size from 24" to 48" RCP. The proposed improvements are expected to decrease WSELs by up to 1.7 feet for the 25-year event.

Trafalgar Drive Closed System – All segments of this system located in the Farrington subdivision are operating above the required 10-year level of service. Therefore, no capital improvements are proposed at this location.

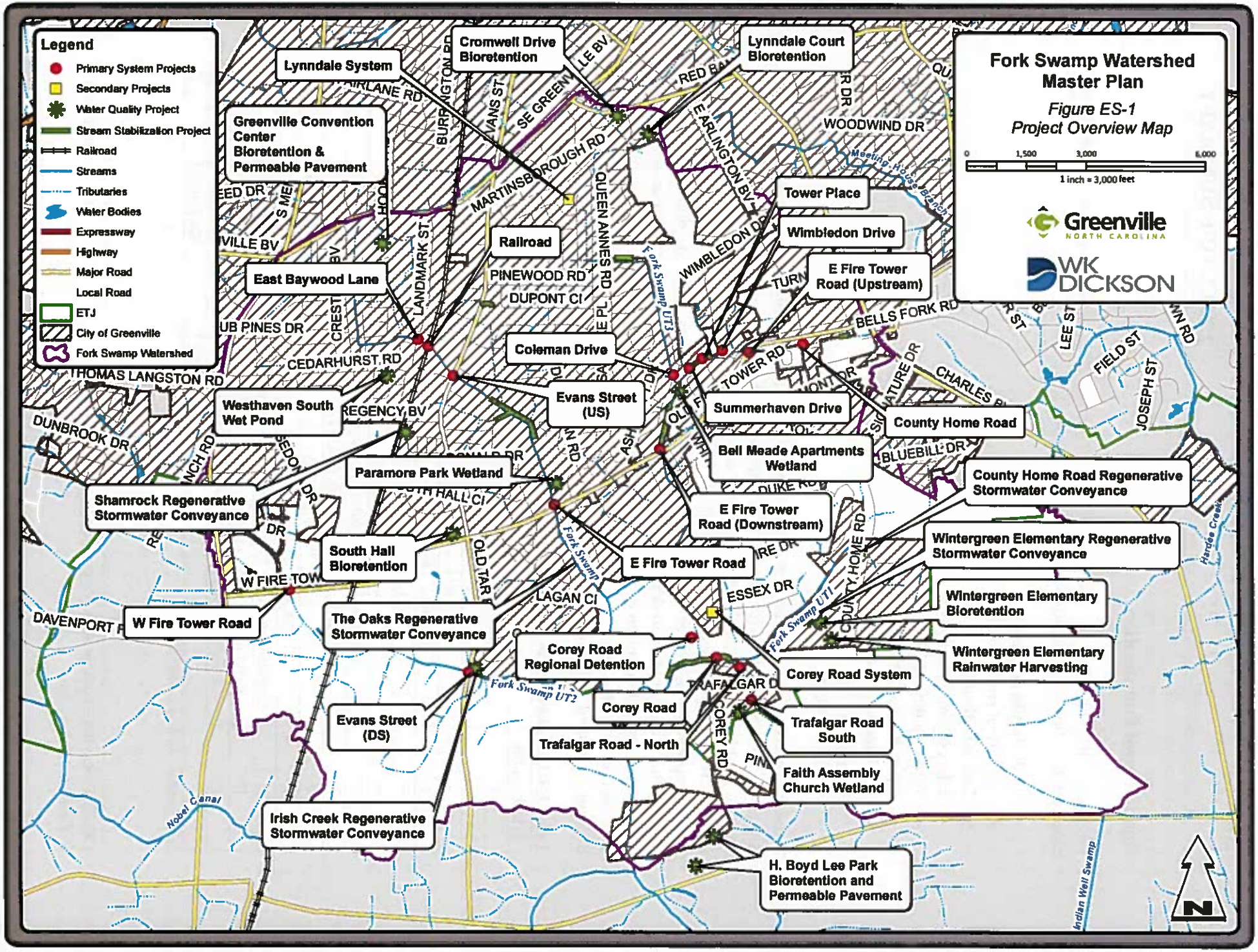
Lynndale System – Seven (7) questionnaires were received from the residents in the Lynndale subdivision reporting yard and street flooding. A study for this area has been completed with

proposed recommendations by River & Associates. The proposed design is included as part of this report. Due to the size of the project, it is recommended that the Lynndale system be completed in three (3) separate phases.

Evans Street Channels – Two (2) channel sections east of Evans Street and south of Pinewood Drive were reported by City staff as being eroded. The channel velocities calculated by the model range between 0.2 and 3.3 feet per second in the 10-year storm event. These channel sections were walked and evaluated by WK Dickson personnel. Based on this evaluation, a stream stabilization project (Project #7) is proposed along the upstream segment.

Regional Detention

A Corey Road facility is proposed in the southern part of the Fork Swamp watershed along FSUT1 adjacent to Corey Road. It is recommended to help offset peak flow increases that will be created as a result of the proposed upstream culvert upgrades. Based on the development of a cursory model, the proposed 20-acre detention pond would lower the flows in the 2-, 10-, 25-, 50-, and 100-year storms by 20 to 25 percent at the confluence of FSUT1 with Fork Swamp. These flow reductions continue through the downstream modeling limits of the Fork Swamp watershed. The regional detention facility will not impact the size of culverts along FSUT1 but will reduce the downstream flows (and therefore the water surface elevations) along the main branch of Fork Swamp. The location of this facility is close to the border of Winterville and outside of the existing City limits, although City residents upstream and downstream of this facility would benefit from the project. The proposed detention facility would be an opportunity to partner with this Winterville and potentially Pitt County. If 25-year detention is required in the areas shown in Section 4.3, then the size of the regional detention area can be substantially reduced to maintain no net increase in the 25-year storm at the study area limits for the future conditions.


Legend
Primary System Projects
Secondary Projects
Water Quality Project
Stream Stabilization Project
Railroad
Streams
Tributaries
Water Bodies
Expressway
Highway
Major Road
Local Road
ETJ
City of Greenville
Fork Swamp Watershed
Fork Swamp 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
Lynndale System
Cromwell Drive Bioretention
Lynndale Court Bioretention
Greenville Convention Center Bioretention & Permeable Pavement
Tower Place
Wimbledon Drive
E Fire Tower Road (Upstream)
Railroad
East Baywood Lane
Coleman Drive
Evans Street (US)
Summerhaven Drive
County Home Road
Westhaven South Wet Pond
Bell Meade Apartments Wetland
County Home Road Regenerative Stormwater Conveyance
Paramore Park Wetland
Shamrock Regenerative Stormwater Conveyance
E Fire Tower Road (Downstream)
Wintergreen Elementary Regenerative Stormwater Conveyance
South Hall Bioretention
E Fire Tower Road
Wintergreen Elementary Bioretention
W Fire Tower Road
The Oaks Regenerative Stormwater Conveyance
Corey Road Regional Detention
Wintergreen Elementary Rainwater Harvesting
Corey Road System
Corey Road
Trafalgar Road South
Evans Street (DS)
Trafalgar Road - North
Faith Assembly Church Wetland
Irish Creek Regenerative Stormwater Conveyance
H. Boyd Lee Park Bioretention and Permeable Pavement
MARTINSBOROUGH RD
QUEEN ANNES RD
PINEWOOD RD
DUPONT CI
WIMBLEDON DR
ARLINGTON BV
WOODWIND DR
BELLS FORK RD
TOWER RD
CEDARHURST RD
THOMAS LANGSTON RD
REGENCY BV
DUNBROOK DR
SOUTH HALL CI
OLD TAR
LAGAN CI
ESSEX DR
DUKE RD
BLUEBILL DR
TRAFALGAR D
COREY RD
DAVENPORT
W FIRE TOW
Fork Swamp UT1
Fork Swamp UT2
Fork Swamp
Meeting House Branch
Nobel Canal
Indian Well Swamp
Hardee Creek
N

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. Tables ES-1 and ES-2 show 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 improvements in the Fork Swamp watershed is approximately $31,730,000.

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

Prioritization	Project	Cost
1	Railroad Crossing (Fork Swamp)	$1,000,000
2	Summerhaven Drive (FSUT3)	$650,000
3	Evans Street (Fork Swamp)	$1,920,000
4	Trafalgar Drive - South (FSUT1)	$180,000
5	County Home Road (FSUT3)	$210,000
6	Tower Place (FSUT3)	$640,000
7	East Fire Tower Road (Fork Swamp)	$1,740,000
8	Trafalgar Drive - North (FSUT1)	$440,000
9	Corey Road (FSUT1)	$6,870,000
10	Wimbledon Drive (FSUT3)	$610,000
11	Fork Swamp Main Branch Floodplain Benching	$5,240,000
12	East Fire Tower Road - Downstream (FSUT3)	$4,000,000
13	East Fire Tower Road - Upstream (FSUT3)	$680,000
	Total	$24,180,000

See Appendix L for prioritization details.

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

Prioritization	Project	Cost
1	Lynndale Closed System Phase I	$1,010,000
2	Lynndale Closed System Phase II	$3,420,000
3	Lynndale Closed System Phase III	$2,750,000
4	Corey Road Closed System	$370,000
	Total	$7,550,000

See Appendix L for prioritization details.

The additional cost to construct the Corey Road Regional Detention Facility would be $9,500,000 which would include anticipated land acquisition costs.

Stream Stabilization and Water Quality Projects

During the Existing Conditions Analysis, the majority of the streams were quantitatively assessed for stability. Based on this assessment, seven (7) stream stabilization projects were identified as shown on Figure ES-1. Potential components of the stabilization project include, flattening the slope of the channel banks, installing erosion control matting and plantings, rock grade control structures, retaining walls, and rip-rap. The stabilization project will protect residential yards, fences, and structures from further erosion, and substantially decrease the in-stream sediment loads to downstream receiving waters.

In additions to the stream stability projects, eighteen (18) water quality BMP retrofit projects were recommended. 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 stream stabilization and 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 stream stabilization project was calculated based on a cost per linear foot of stabilized stream while for water quality projects, it was calculated based on a cost per impervious acre treated. Tables ES-3 and ES-4 show the prioritization of the stream stabilization and water quality projects along with estimates of their preliminary cost.

Table ES-3: Stream Stabilization Prioritization

Prioritization	Project	Cost
5	Evans Street	$130,000
1	Live Oak Lane	$280,000
3	Tower Place	$140,000
4	Charles Boulevard	$90,000
2	East Fire Tower Road	$230,000
6	Queen Annes Road	$220,000
N/A*	Corey Road*	$590,000
	Total	$1,090,000*

*The Corey Road Stream Project is located outside City Limits and therefore was not ranked or included in the total cost. However, improvements will benefit residents in the City limits. See Appendix L for prioritization details.

Table ES-4: Water Quality Project Prioritization

Prioritization	Project	Cost
1	WGP Properties Regenerative Stormwater Conveyance	$60,000
2	H. Boyd Lee Park Bioretention	$340,000
3	Wintergreen Elementary Rainwater Harvesting	$20,000
4	Wintergreen Elementary Bioretention	$310,000
5	South Hall Bioretention	$240,000
6	Lynndale Court Bioretention	$150,000
7	Shamrock Regenerative Stormwater Conveyance	$130,000
8	Paramore Park Wetland	$210,000
9	H. Boyd Lee Park Permeable Pavement	$970,000
10	County Home Road Regenerative Stormwater Conveyance	$490,000
11	The Oaks Regenerative Stormwater Conveyance	$200,000
12	Wintergreen Elementary Regenerative Stormwater Conveyance	$180,000
13	Cromwell Drive Bioretention	$350,000
14	Belle Meade Apartments Wetland	$570,000
15	Faith Assembly Church Pond Retrofit	$270,000
16	Westhaven South Wetland	$820,000
17	Irish Creek Regenerative Stormwater Conveyance	$250,000
18	Greenville Convention Center Permeable Pavement	$2,870,000
	Total	$8,430,000

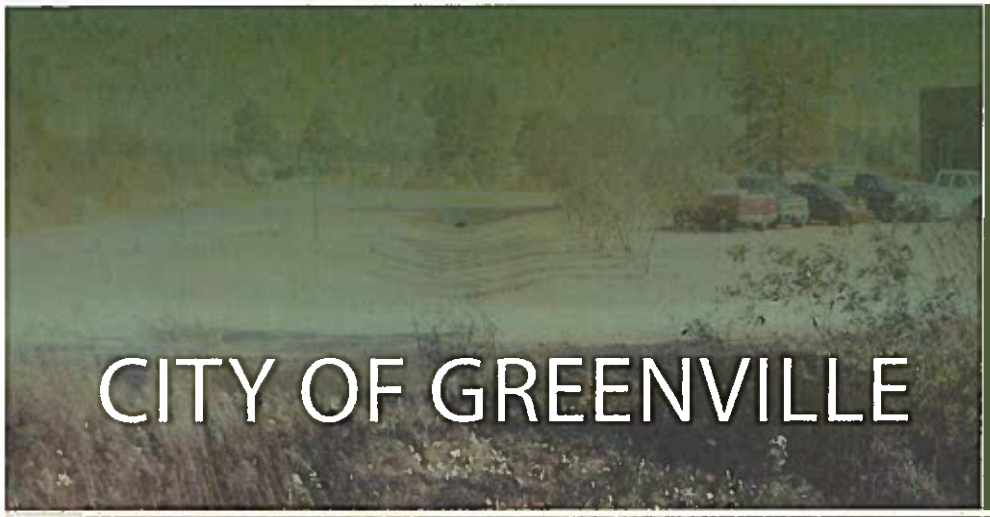
See Appendix L for prioritization details.

25-Year Detention Analysis

As part of the Fork Swamp Master Plan, an analysis was completed to determine if there are areas within the watershed that should be considered "well documented water quantity problems" requiring detention for the 25-year, 24-hour storm event. As noted in Section 3.1, documented flooding issues are located along Fork Swamp Main Branch, Unnamed Tributary 3, and Unnamed Tributary 1 including the area between Baywood Lane and Treetops Circle along Fork Swamp Main Branch, the area between Corey Road and Trafalgar Drive along Unnamed Tributary 1, and the area between East Fire Tower Road and County Home Road along Unnamed Tributary 3. Large portions of the Fork Swamp watershed are already fully developed, however there are some areas of the watershed where the future conditions 25-year flows could be greater than 10% higher than the current existing flows. These areas are outlined in Section 4.3.

If 25-year detention is required in the proposed areas, the need for culvert improvements will not be eliminated but the recommended culvert sizes could be decreased. Although the cost savings to the City would not be substantial, the severity, frequency, and duration of flooding would be reduced, which would in return provide savings to the property owners.

The Corey Road Regional Detention area is the largest portion of the overall cost for flood control projects in the Fork Swamp watershed ($9,500,000). As previously noted, this project is proposed to address increases in the 25-year flows as a result of increasing upstream capacity and proposed future development. If the City requires 25-year detention for portions of the watershed as shown in Section 4.3, the size of the Corey Road regional detention area can be reduced, which would substantially lower the cost of the proposed detention area by approximately $5 million.

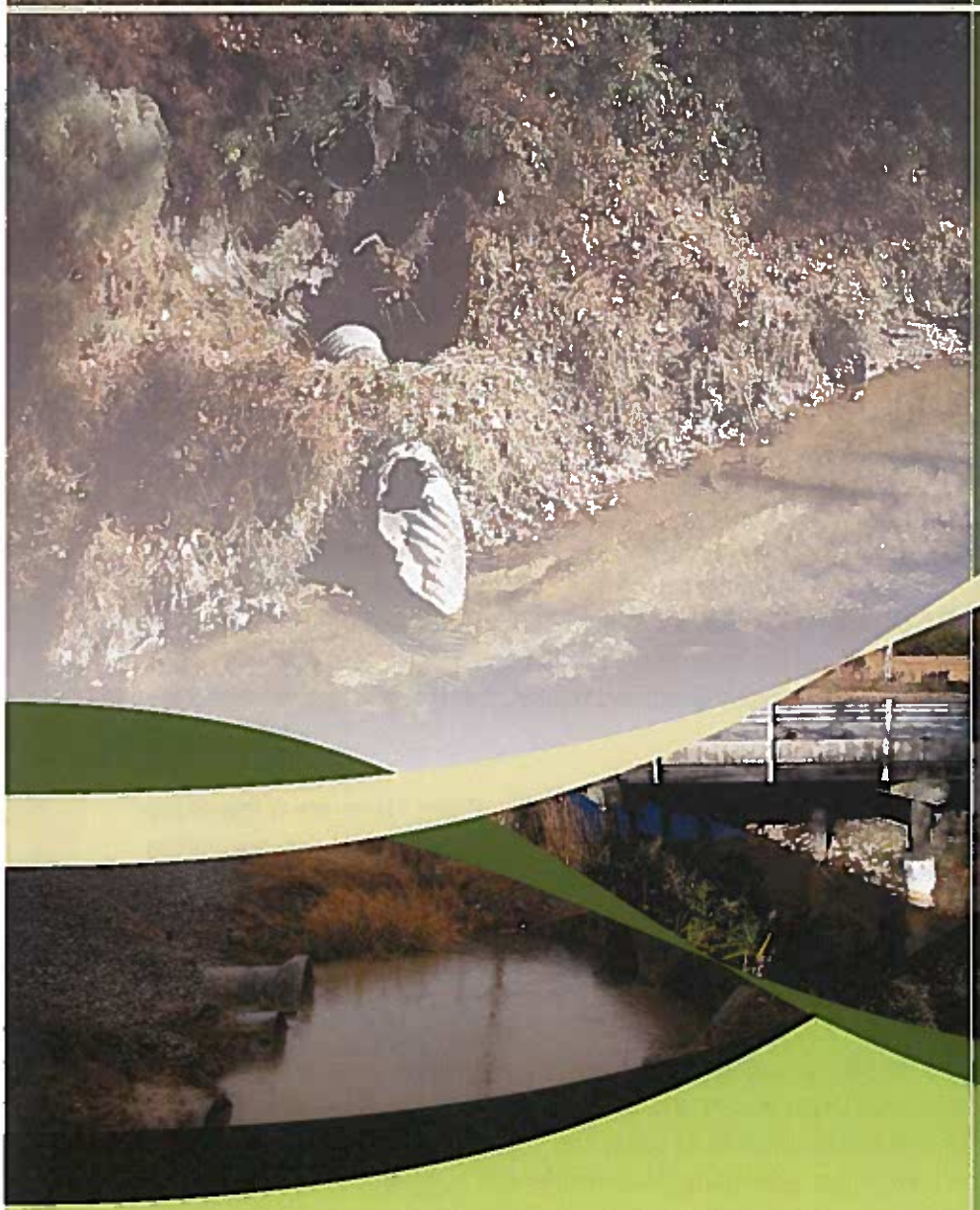


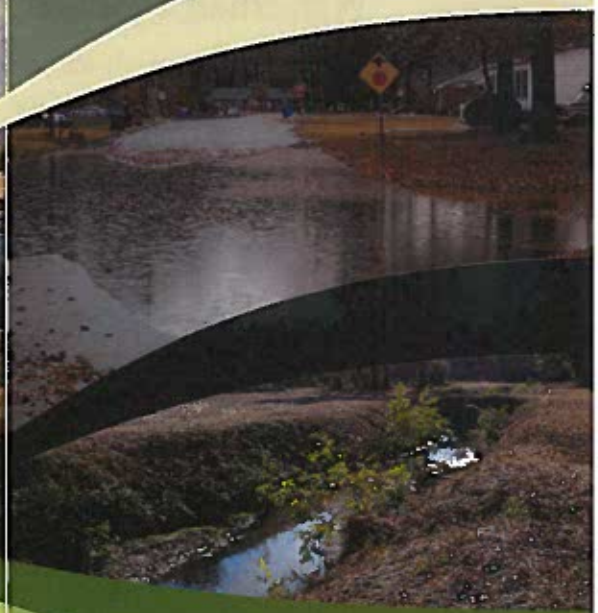
CITY OF GREENVILLE

Greenville
NORTH CAROLINA

Parker Creek / Johnson's Mill Run Watershed Master Plan

July 2016





FINAL REPORT

CDM Smith

The City of Greenville has retained CDM Smith to complete a Master Plan for the Parkers Creek and Johnsons Mill Run (PC/JMR) watersheds. The goals of this master plan include: (1) evaluate the watershed for 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 to reduce sediment loads as a result of erosion. To assist in achieving the goals listed above, CDM Smith also completed a stormwater infrastructure inventory for drainage structures and features within the PC/JMR watersheds.

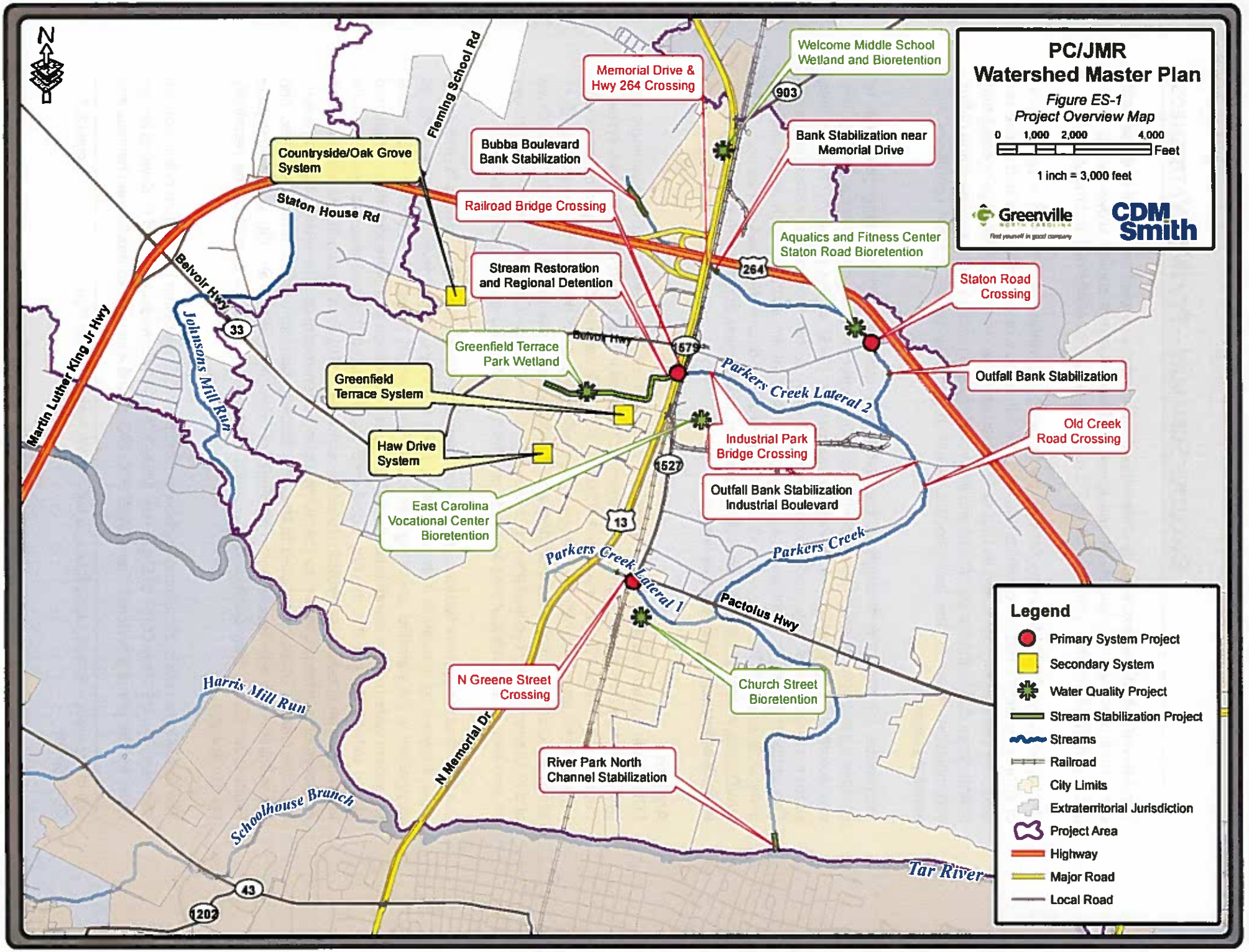
The project included a broad range of stakeholders to collect as much data, information and tacit knowledge of the watershed as possible. The general public was solicited through questionnaires mailed to all property owners in the watershed and two open house public meetings where residents and business owners were encouraged to provide feedback on stormwater issues in the watershed. CDM Smith coordinated with residents that provided site-specific drainage concerns to gather additional information that could be used to both confirm the existing system evaluation and aid in developing improvement recommendations. Information collected from the questionnaires and public meetings can be found in Section 2.1 and Appendix D. City staff served as a critical stakeholder by providing valuable information on historical flooding and erosion problems in the watershed, as well as providing feedback on potential capital improvements and the prioritization of those improvements.

Watershed Conditions

The PC/JMR project watersheds drain approximately 40 square miles and are located in the northern portion of the City. The PC/JMR watersheds share a common boundary near Fleming School Road, running north to south, with both creeks draining south into the Tar River, as shown on **Figure ES-1**. The PC watershed is generally bounded by I-264 to the east and Allpine-Taylor Road to the north. The JMR watershed is generally bounded near Porter Road to the west and US Highway 64 to the north.

The PC/JMR watersheds drain a majority of the City north of the Tar River. There are a few areas within the City limits north of the Tar River and to the east of Highway 264 that are not within these watersheds. These disconnected areas were included in the stormwater inventory, but not in the watershed master plan. Approximately 87 percent of the PC watershed is within the City's extraterritorial jurisdiction (ETJ), 24 percent in the City limits. Approximately 2 percent of the JMR watershed is within the City's ETJ, and 0.15 percent in the City limits.

The PC watershed is comprised mostly of open space with an industrial area and dispersed residential subdivisions. The Memorial Drive and N. Greene Street corridor split the north side of the City with some commercial and institutional land uses. The Tar River floodplain accounts for much of the open space in the watershed, especially since residential homes in the flood buyout zone have been abandoned following the flooding of 1997. Subdivisions such as Greenfield Terrace and Countryside Estates extend the City limits towards the northwest. The PC watershed is currently about 40 percent developed and projected to be closer to 90 percent when fully built-out according to current zoning.


PC/JMR
Watershed Master Plan
Figure ES-1
Project Overview Map
0 1,000 2,000 4,000
Feet
1 inch = 3,000 feet
Greenville
CDM Smith
N
Welcome Middle School Wetland and Bioretention
Memorial Drive & Hwy 264 Crossing
Bank Stabilization near Memorial Drive
Bubba Boulevard Bank Stabilization
Countryside/Oak Grove System
Railroad Bridge Crossing
Aquatics and Fitness Center Staton Road Bioretention
Staton Road Crossing
Stream Restoration and Regional Detention
Greenfield Terrace Park Wetland
Outfall Bank Stabilization
Greenfield Terrace System
Industrial Park Bridge Crossing
Old Creek Road Crossing
Haw Drive System
Outfall Bank Stabilization Industrial Boulevard
East Carolina Vocational Center Bioretention
N Greene Street Crossing
Church Street Bioretention
River Park North Channel Stabilization
Fleming School Rd
Staton House Rd
Belvoir Hwy
Martin Luther King Jr Hwy
Johnsons Mill Run
Parkers Creek Lateral 2
Parkers Creek
Parkers Creek Lateral 1
Pactolus Hwy
Harris Mill Run
Schoolhouse Branch
Tar River
N Memorial Dr
903
264
33
579
1527
13
43
1202
Legend
Primary System Project
Secondary System
Water Quality Project
Stream Stabilization Project
Streams
Railroad
City Limits
Extraterritorial Jurisdiction
Project Area
Highway
Major Road
Local Road

The JMR watershed is almost entirely undeveloped, with about 1 percent residential land uses and some rural uses such as agricultural and forest land uses. Current zoning allows for up to 20 percent of the watershed within the City's ETJ to be developed as residential and mixed use.

The topography of PC/JMR is very flat with the highest point within the City limits at an elevation of approximately 42 feet, all of which drains to the Tar River, which is only a few feet above sea level. The vast majority of PC and its tributaries are trapezoidal channels, which require consistent maintenance due to the flat conditions and low velocities and result in heavy sediment and debris accumulation. However, the low velocities result in generally stable channel conditions with minimal erosion.

Stormwater infrastructure throughout the watersheds was collected by survey personnel to compile a geographical information system (GIS) stormwater inventory database for the City. This was accomplished by using 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 other attributes such as dimensions, material, and length. The data was collected using horizontal datum NAD 1983 and vertical datum NAVD 1988. A total of 1,046 closed system structures and 15 miles of pipe were inventoried in the PC/JMR watersheds within the City limits.

Analysis

CDM Smith conducted an existing conditions analysis in order to evaluate the hydrologic and hydraulic characteristics of the PC/JMR watersheds. Noted in this report as the primary systems, the JMR main stem, PC main stem, and PC Laterals 1 and 2 were modeled as open channels with culverted and bridged crossings. There are 21 creek crossings in the PC/JMR watersheds, 10 of which are crossing a major thoroughfare and 3 crossings of a railroad. Only the Memorial Drive and N. Greene Street crossings are major thoroughfares within the City limits. The railroad crosses PC and each of its two tributaries as it runs parallel to Memorial Drive from south to north.

In addition to the primary systems, select closed pipe drainage systems that drain to PC tributaries were analyzed to determine if those systems meet the City's desired level of service (LOS), as designated in the standard operating procedure (SOP) manual. Along with City staff input, those secondary systems were identified as part of the public education and outreach efforts conducted at key milestones. Initially, the City distributed and collected questionnaires to gather citizen information on flooding and erosion issues throughout the City. Existing conditions and proposed improvements were presented to the public during open meetings. The results and comments from the citizens' input contributed to the identification and prioritization of problem areas, and the validation of model results. Based on feedback from City residents and City staff, Countryside Estates/Oak Grove, Haw Drive, and Greenfield Terrace were included as part of the secondary system analysis.

The modeling analysis consisted of hydrologic and hydraulic modeling in standard public domain software. The US Army Corps of Engineers' (USACE) HEC-HMS model was used to develop design flows for the primary systems. The USACE HEC-RAS model was used to model the channels and

floodplains of the primary systems. The secondary systems were modeled in EPA's Storm Water Management Model (SWMM).

Structural flooding and roadway crossing overtopping occurs at multiple locations according to the modeling. Crossings of N. Greene Street and Memorial Drive are shown to overtop for less than a 50-year design storm and potential structures at-risk for flooding were identified in the modeled floodplains for the 25- and 100-year design storms. Existing flood stages were compared with the City's desired LOS. Proposed improvements were developed with the models to attain the designated LOS.

Regional detention was also evaluated as a solution to existing and future flooding issues. Additionally, as part of this project, 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. This evaluation yielded no such areas in PC/JMR that meet the criteria, particularly the criteria for "well documented water quantity problems".

As a result of the existing and future conditions analyses, multiple capital projects were identified to reduce the severity and frequency of flooding, stabilize stream banks, and improve water quality through stormwater treatment practices. Flood control projects were evaluated to meet the desired LOS of roadway overtopping and roadway/structure flooding. Costs for each project were estimated using approved unit costs from the SOP with engineering, administrative, and contingency costs included for construction implementation. Anticipated permitting and funding opportunities were also evaluated for each project. The proposed capital projects are as follows, with the locations of each project shown in Figure ES-1.

Flood Control Projects

Parkers Creek Main Branch Primary System

Staton Road – The Staton Road crossing of the PC main branch does not currently meet the 50-year LOS requirement, overtopping during storm events greater than the 25-year. The crossing currently includes twin 7 foot (ft) diameter corrugated metal pipe. In order to meet the 50-year LOS, the existing culvert should be replaced with twin 9 ft by 9 ft reinforced concrete box culverts (RCBC). It should be noted that the crossing is outside the City limits, but within the ETJ.

Structural Flooding – Several industrial and commercial buildings are located within the 100-year floodplain for PC, based on GIS topography. In order to eliminate the structural flooding, a 60-acre regional detention pond is required, at a cost of approximately $24 million.

Parkers Creek Lateral 1 Primary System

N. Greene Street – The N. Greene Street crossing of PC Lateral 1 does not currently meet the 50-year LOS requirement, overtopping during storm events greater than the 25-year. The crossing currently includes a 7 ft by 5 ft RCBC. In order to meet the 50-year LOS, the existing culvert should be replaced with twin 7 ft by 7 ft RCBCs. It should be noted that the existing culvert appears to be

in good condition based on a preliminary visual inspection. There may be an opportunity to reduce project cost by adding a second culvert to the existing, instead of replacing.

Parkers Creek Lateral 2 Primary System

Memorial Drive and Railroad Crossing – The Memorial Drive and railroad crossing of PC Lateral 2 are presented together herein due to their close proximity to each other, approximately 20 feet apart. The crossing of Memorial Drive does not currently meet the 50-year LOS requirement, overtopping during storm events greater than the 25-year. The railroad crossing currently includes three 66-inch diameter reinforced concrete pipe (RCP) culverts and meets the 100-year level of service. It should be noted that the second and third culverts beneath the railroad were installed in 2015. The Memorial Drive crossing currently includes twin 8.5 ft by 5 ft elliptical culverts. However, one of the culverts is currently sealed closed, reportedly to manage flows without causing damage to the immediate downstream railroad crossing.

In order to meet the 50-year LOS, the closed 8.5 ft by 5 ft elliptical culvert should be opened and four 5 ft diameter RCPs should be installed. As an alternative to the additional RCPs, an arch spanned bridge could be utilized. A corresponding increase in capacity of the railroad crossing at this location is also required to achieve the 50-year LOS. Downstream flooding will not be significantly affected by the reduction in storage according to the modeling.

It is recommended that the closed 8.5 ft by 5 ft elliptical culvert be opened now, regardless of whether the other improvements are implemented concurrently. Memorial Drive is currently the bottleneck in the system and the additional culvert capacity will reduce upstream flood elevations, even for smaller storm events. This is important because the Greenfield Terrace neighborhood, which is upstream of Memorial Drive, experiences consistent flooding during small storm events, due in part to the Memorial Drive crossing.

Johnsons Mill Run Primary System

There were no primary or secondary system flooding issues identified through modeling or by citizens in JMR besides residential structures identified in the modeled floodplain associated with the existing conditions of 25-year and 100-year magnitude storm events. Due to the size and undeveloped status of the watershed, upstream improvements are not recommended to mitigate potential flood impacts.

Secondary Systems

Countryside/Oak Grove Estates – Drainage issues, including standing water in the road and ditches along residential yards, have been reported in this area. The Countryside subdivision drains to the west through a culvert under Fleming School Road and to the east beneath Oak Grove Avenue and Glenda Street. Neither the east or west culverts in conjunction with the respective downstream ditches are capable of conveying the 2-year design storm, let alone the 10-year designated LOS. However, the more immediate issues for the residents are associated with standing water occurring with smaller, more frequent rain events. At the end of Old Village Road, standing water is attributed to blockage of the downstream ditch in the County Drainage

District jurisdiction. On both the east and west sides of the area the downstream ditches are maintained by the County Drainage District. On the west side, flooding in District 12484 at the end of Old Village Road is attributed to blockage of the downstream ditch on private property. Low flows are not moving through the ditch and are backing up water all the way to Old Village Road. Removal of vegetation, trash, and sediment are required to maintain this ditch clear to allow drainage of Old Village Road.

Flooding of Oak Grove Avenue is expected during large storms as the system is only able to convey less than the 2-year storm without overtopping the roadway. However, the most frequent and visible issue is poor roadway drainage with standing water in the roadway caused by damaged, uneven, and uncrested pavement associated with original construction and installation of a sewer line beneath the road.

Modeling results of the Countryside- Oak Grove Avenue System indicate that meeting the 10-year LOS is feasible through extensive infrastructure improvements to the existing system. To address regular standing water, roadway improvements along Oak Grove Avenue are recommended to improve drainage along this roadway and direct runoff to the existing drainage system and avoid standing water. Due to the flatness of the area, elliptical pipes are required to attain capacity to convey the runoff from the neighborhood for the 10-year LOS storm with a minimum of 1 foot of ground cover over the pipes. Additionally, widening of the downstream channel is required to alleviate street overtopping flooding conditions for the 10-year LOS storm.

Greenfield Terrace – Issues associated with blockage of the drainage system along Greenfield Boulevard have made this area of greatest public concern in the PC watershed. Maintenance clearing of the blocked stormwater pipe outfalls in 2015 at the ditch to the north has alleviated the roadway flooding occurring on a regular basis. To achieve the designated 10-year LOS, modeled improvements include local pipe upsizing, storage, and the primary system culvert improvements at Memorial Drive. These improvements, once implemented are expected to eliminate flooding for up to the 10-year LOS event, however, surcharging will remain for the 10-year event. Surcharging where the drainage system is full above the top of the pipes and near the top of structures has the potential to cause damage by eroding the layer of soil above the pipes through the joints between the pipes.

- Local Pipe Upsizing: The existing pipe system requires larger diameter pipe to adequately convey runoff from the 10-year design storm from the streets to the downstream ditch.

- Storage: A 13-acre (566,300 cubic feet) detention pond at Greenfield Park was modeled to store the volume entering the system at the peak of the 10-year design storm. The pond will reduce the flood stage for the 10-year storm by nearly 0.5 feet. The pond will alleviate flooding by reducing the peak stage just enough to keep it below the surface of the drainage system on Greenfield Boulevard.

- Primary System Improvements at Memorial Drive: The proposed primary system improvements for Memorial Drive will attain the 50-year design storm LOS without

overtopping and almost entirely eliminate any backwater caused by this crossing for smaller design storms.

The above improvements will meet the desired LOS of the drainage system; however, it will not prevent surcharging of the system due to high backwater conditions. Even with the improvements at Memorial Drive, local pipe upsizing, and storage in Greenfield Terrace Park, the flood stage during the 10-year LOS storm will be at an estimated elevation of 22.6 feet—which is just below the surface of Greenfield Boulevard—with the rim of the catch basin at the intersection of Greenfield Boulevard and Beechwood Drive at 22.7 feet.

Haw Drive/E Catawba Road – The existing E Catawba Road drainage system does not meet a 2-year LOS according to the modeling and residents have reported roadway and yard flooding. Recurrent flooding was attributed to blockage of the local drainage system and this problem was fixed by a City roads maintenance crew. However, the system does not meet the desired 10-year LOS and has experienced frequent roadway flooding, also affecting multiple residential yards. A significant portion of the drainage system is currently located in backyards between E Catawba Road and Haw Drive. The system is limited by the downstream capacity of the ditch across the airport property and the local pipe drainage system for larger storms.

The proposed improvements to meet the designated LOS will include new pipes and inlets along E Catawba Road to direct runoff to a conveyance system within the City right-of-way which will more easily facilitate future maintenance of the system and improve the LOS. Proposed pipe improvements range in size from 18-inch RCP to 24-inch RCP. In some locations with limited cover, twin elliptical 24-inch RCPs are proposed. The addition of a connecting drainage feature on the airport property to allow drainage to the south is also required to achieve drainage for this system. Cooperation with the City-owned airport is needed to implement the downstream connection to ensure adequate drainage for larger, less frequent storm events.

Flood Control Prioritization

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

- Public health and safety
- Severity of street flooding
- Cost-effectiveness
- Effect of improvements
- Water quality best management practices (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 greatest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. While both alternatives are shown for some projects, it is acknowledged that only one of the two alternatives would need to be constructed. Once an alternative has been selected, the remaining alternative for the same project can be removed from the prioritization list. **Table ES-1** shows the proposed prioritizations and conceptual cost estimates for the Flood Control Improvements. The prioritization scoring for each project and a description of the aforementioned categories is included in Appendix M. The total cost for the recommended primary improvements and the secondary system improvements is approximately $3.2 million. Projects outside the City limits or on private property, as identified in the report, are not included in the City's prioritization for inclusion in the list of Capital Improvement Projects for implementation.

Table ES-1: Flood Control Prioritization

Prioritization	Project	Cost
1	Memorial Drive Crossing (Parkers Creek Lateral 2)	$1,170,000
2	Countryside/Oak Grove System (Parkers Creek Lateral 2)	$580,000
3	Greenfield Terrace System (Parkers Creek Lateral 2)*	$5,340,000
4	Haw Drive/Airport System (Parkers Creek Lateral 2)	$330,000
5	N. Greene Street Crossing (Parkers Creek Lateral 1)	$650,000
	Total	$3,180,000

Note: Staton Road and regional detention improvement projects are outside the City limits and are therefore not included in project prioritization for City Capital Improvement Projects.

* Greenfield Terrace System LOS improvements include drainage pipe replacements ($450,00) and detention storage ($4,890,000) in conjunction with Memorial Drive culvert replacement.

Stream Stabilization and Water Quality Project Prioritization

During the existing conditions analysis, the primary system streams were quantitatively assessed for stability. Based on this assessment, six stream stabilization/enhancement projects were identified, as shown in Figure ES-1, three of which are inside the City limits and included in the prioritized list. Components of the stabilization projects include flattening the slope of the channel banks, installing erosion control matting and plantings, and installing rock/log grade control structures. The stabilization projects will protect stream banks from further erosion, prevent wetlands from draining by channel degradation, and substantially decrease the instream sediment loads to downstream receiving waters.

In addition to the stream stability projects, water quality BMP retrofit projects were also identified. Potential project locations were initially identified using available GIS data by focusing on locations with contributing drainage areas that are highly impervious and on publically-owned land. Impervious areas typically generate the highest concentration of pollutants, therefore treating the runoff from these areas would provide more pollutant removal 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 inspected to determine if the site conditions were conducive to a BMP. This inspection typically included verifying that GIS data and aerial photography were accurate and to determine if there were project constraints present that may not be visible from GIS data, such as utility conflicts, private property conflicts, or limited access to the site. If possible, retrofit projects were located on public property to reduce land acquisition costs. Of the nine initial candidate BMP sites evaluated, five are included in the water quality prioritization. The other projects were not selected for further evaluation due to physical constraints or private ownership following discussion with City staff.

The stream stabilization projects and water quality retrofit projects were prioritized using similar categories as the flood control projects. Cost-effectiveness for stream stabilization projects was calculated based on a cost per linear foot of stabilized stream. Cost-effectiveness for water quality retrofit projects was calculated based on a cost per impervious acre treated. **Tables ES-2** and **ES-3** show the prioritization of the stream stabilization and water quality projects, along with preliminary cost estimates, respectively. Additionally, several recommended maintenance locations were identified throughout the watershed, as listed in Section 10. The maintenance items are based on the condition assessment completed during the stormwater inventory and stream assessment.

Table ES-2: Stream Stabilization Prioritization

Prioritization	Project	Cost
1	River Park North Channel Stabilization	$200,000
2	Parkers Creek Bubba Boulevard	$270,000
3	Greenfield Terrace Park Bank and Buffer Enhancement	$150,000
	Total	$620,000
Notes: Other projects identified outside the City limits are not included in project prioritization for City Capital Improvement Projects.		

Table ES-3: Water Quality Prioritization

Prioritization	Project	Cost
1	Welcome Middle School Wetland	$150,000
2	Greenfield Terrace Park Water Quality Wetland	$220,000
3	Staton Road Aquatics and Fitness Center Bioretention	$120,000
4	East Carolina Vocational Center Wet Pond	$140,000
5	Church Street Wetland	$200,000
	Total	$830,000