WK DICKSON
community infrastructure consultants

Town of Chapel Hill
Lower Booker Creek Subwatershed Study

Volume I : Report

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TOWN OF CHAPEL HILL

Lower Booker Creek Subwatershed Study Volume I: Report

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CLOMR	Conditional Letter of Map Revision
CMP	Corrugated Metal Pipe
DEMLR	Division of Energy, Mineral, and Land Resources
DEQ	Department of Environmental Quality
DIP	Ductile Iron Pipe
D/S	Downstream
DWQ	Division of Water Quality
EA	Environmental Assessment
EMC	Event Mean Concentrations
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning Systems
FEMA	Federal Emergency Management Agency
HEC-HMS	Hydrologic Engineering Centers Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HOA	Homeowners Association
IP	Individual Permit
LBC	Lower Booker Creek
LF	Linear Feet/Foot
LOMR	Letter of Map Revision
MDR	Medium Density Residential
NAD	North American Datum
NAVD	North American Vertical Datum
NCDEQ	North Carolina Department of Environmental Quality
NCDOT	North Carolina Department of Transportation
NCWRC	North Caroline Wildlife Resources Commission

NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSDQ	National Stormwater Quality Database
NWP	Nationwide Permit
O&M	Operations and Maintenance
OWASA	Orange Water and Sewer Authority
PCN	Pre-Construction Notification
RBP	Rapid Bioassessment Protocol
RCBC	Reinforced Concrete Box Culvert
RCD	Resource Conservation District
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
RSC	Regenerative Stormwater Conveyances
SCM	Stormwater Control Measure
SEPA	State Environmental Policy Act
SHPO	State Historic Preservation Office
SWMM	Storm Water Management Model
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UNC	University of North Carolina at Chapel Hill
U/S	Upstream
USA	Unified Stream Assessment
USACE	The United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WSEL	Water Surface Elevation
WTM	Watershed Treatment Model

EXECUTIVE SUMMARY

The Town of Chapel Hill retained WK Dickson to complete a Subwatershed Study and Plan for the Lower Booker Creek (LBC) subwatershed. As noted in the Town's Stormwater Master Plan adopted in September 2014, the development of subwatershed plans is a strategic initiative as part of the following goals of the Town's Stormwater Management Program:

- Address stormwater quantity (flooding) as an integral component within the program;
- Address stormwater quality as an integral function within the program;
- Protect and restore natural stream corridors.

The LBC subwatershed is approximately 1,130 acres (~1.8 square miles) and is located in the northern portion of the Chapel Hill. The subwatershed is the lower part of the overall Booker Creek watershed (~6.3 square miles), which includes the Booker Headwaters, Crow Branch, Eastwood Lake, and Cedar Fork subwatersheds in addition to Lower Booker Creek. While the overall watershed is generally residential in land use, the majority of Crow Branch includes a portion of the future Carolina North campus, and the central portion of LBC is highly commercialized including the Ephesus Fordham focus area.

The LBC Subwatershed Study includes a process to assess how stormwater is currently managed within the subwatershed, evaluate the impact of future development on the conveyance infrastructure, and to develop recommendations for improving the management of stormwater including the identification of capital projects. The process begins with assessing the existing conveyance infrastructure which included locating and attributing over 1,100 drainage structures and fourteen (14) miles of pipes within the LBC subwatershed. Additionally, the WK Dickson team evaluated 36,000 linear feet of open stream and channels in part to identify areas of erosion and buffer impacts.

Utilizing the drainage infrastructure inventory geodatabase as well as available Geographic Information System (GIS) data, WK Dickson completed several spatial analyses to identify infrastructure that may need maintenance or replacement based on the likelihood and consequence of the failure of any particular asset. Contributing factors for prioritizing maintenance needs included age of infrastructure, material, size, visual assessments, and location. The Town should consider additional investigation such as closed-circuit television (CCTV) inspection for high priority areas. The proactive maintenance of infrastructure even in areas that are not floodprone will reduce disruptions to roadways and other Town infrastructure, ensure the designed level of service is routinely met, and most efficiently manage the Town's limited resources. Infrastructure maintenance is one of the strategic initiatives of Goal 2 of the Town's Stormwater Master Plan.

While proactive maintenance will extend the life of the existing infrastructure, in many instances the existing infrastructure does not provide the desired level of service. Within the LBC subwatershed, there are several areas that have repetitive flooding during large storm events. As part of this study, the conveyance system within floodprone areas was evaluated to determine the existing level of service, the future level of service based on built-out land use in the watershed, and the potential capital improvements that would be required to reduce the risk of flooding. The existing 25-year and 100-year floodplains were mapped as part of this study (See Figures 3-1 and 3-2) based on the current land use and hydrologic parameters within the watershed. In some areas the floodplains were extended upstream of the effective Federal Emergency Management Agency (FEMA) floodplains to provide the Town a resource for managing floodplains within upland areas. In addition to modeling and mapping floodplains within the open portion of the conveyance system, WK Dickson evaluated the capacity needs for several closed or secondary systems identified as floodprone.

In part to help identify areas of concern within the watershed, the WK Dickson team conducted an expansive public outreach process. The public outreach allowed residents and business owners the opportunity to engage with team members, provide feedback on specific drainage issues, and learn about managing stormwater within Booker Creek. The community was able to give feedback through survey questionnaires, public forums, a project website, community events, and direct emails to the project team. Information collected during the outreach process, as well as information from Town staff, assisted the WK Dickson team in validating the hydraulic models against recent storm events and helped identify areas with repetitive flooding for further analysis. Engaging the community in stormwater management is critical for a successful program as many of the goals of the program are dependent on stewardship from the community.

Engagement from the community is even more critical when assessing Goals 3 and 4 of the Stormwater Master Plan with respect to water quality and protecting stream corridors. Many of the causes of water quality impairment from a runoff and riparian standpoint involve property outside of the Town's rights-of-way (ROW). Partnering with private residents and businesses will be an important component of the Town's Stormwater Program moving forward as it needs to comply with the Jordan Lake Rules and address impaired waters. Educating residents with regards to proper pet waste disposal, fertilizer applications, and buffer management will be critical for the success of any water quality program. The LBC Subwatershed study includes riparian assessments as well as a variety of GIS analyses that look for potential opportunities for retrofits to treat stormwater runoff and stabilize or restore eroding streams. Capital project recommendations that include Stormwater Control Measures (SCMs) and stream stabilization will likely require easements from landowners. Additionally, several neighborhoods have been identified for potential neighborhood green infrastructure retrofits. These can include modifications to the public ROW to promote the infiltration of stormwater runoff, as well as rain gardens and other practices on private property to treat rooftop drainage, prior to entering the conveyance system. These types of practices will require significant community buy-in prior to implementation. Individually these projects provide a small benefit, however as more property owners implement practices to reduce the volume of runoff and pollutant loads, the cumulative downstream impacts on water quality and quantity can be significant.

After completing all of the assessments and modeling noted above, WK Dickson developed conceptual solutions for a wide variety of capital projects to address the goals noted above with respect to water quantity, quality, and protecting natural stream corridors.

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

Project Recommendations

Significant flooding problems have been well documented in the LBC subwatershed. Developing retrofit solutions to these types of flooding problems in developed areas is difficult because of the limited land available, topographic constraints, and existing infrastructure including roads, utilities, and buildings. Due to these constraints, a combination of projects will be required to achieve significant reductions in the frequency, duration, and severity of flooding particularly in the areas most at risk.

The project recommendations are divided into five (5) geographic focus areas. The LBC subwatershed is divided into North, South, East, and West focus areas and the fifth area is for the portion of the Booker Creek watershed outside of the LBC subwatershed. While the focus of this study is to improve infrastructure within the LBC subwatershed, over 70% of the drainage area contributing to the overall watershed is outside of the LBC subwatershed. Therefore, potential projects were evaluated within the Booker Creek watershed to determine if strategically increasing flood storage in the upper portions of the watershed could potentially impact peak flows in the LBC subwatershed. It should be noted that all the proposed projects are based on the future land use conditions.

Overall Booker Creek Watershed

New Parkside Drive

The proposed 7.5-acre project includes excavating material in the Town-owned property behind the New Parkside Drive culvert in the Booker Creek Headwaters subwatershed. Stormwater could temporarily fill the floodplain storage area during a storm event and slowly discharge through the existing culvert, which could reduce the 25-year peak flow at that location by as much as 90%. In combination with the other proposed storage areas, the New Parkside Drive project can have significant benefits of reducing downstream flows in the LBC subwatershed. The Town could also consider providing connectivity between the proposed project and Homestead Park and implementing additional passive recreational facilities in the New Parkside Project.

Martin Luther King Jr. Boulevard

The proposed 2.5-acre project is located on private property along Martin Luther King Jr. Boulevard near the intersection with Homestead Road. The project includes acquisition of the property north of Orange United Methodist Church as well as obtaining an easement on the church property. The proposed project site contains regulatory floodplains, stream buffers, and a sanitary sewer outfall, making future development of the property challenging. The project consists of excavation to increase the floodplain storage along the upper portion of Booker Creek and provide a temporary ponded area. The project would lower the 25-year peak flow by approximately 2% immediately upstream of East Franklin Street and would result in greater flow reductions if constructed in combination with the other proposed storage areas.

Piney Mountain Road
The proposed 5.5-acre project is located on common property upstream of Piney Mountain Road approximately 0.5 miles east of Martin Luther King Jr. Boulevard. Significant excavation would be required to provide temporary storage upstream of Piney Mountain Road during storm events that would result in a 3% reduction in the 25-year peak flow upstream of East Franklin Street. Passive recreational amenities could be added to the project if desired to enhance pedestrian connectivity in the community. The drainage area to this location is over 2 square miles. Given the relatively low surface area to drainage area ratio, the proposed project has a greater impact with slowing the timing of the runoff downstream than actually providing significant peak reduction at the site.

The combined impact of the three storage areas listed above results in an 11% reduction in the 25-year peak flow downstream of Eastwood Lake and a corresponding 0.4-foot reduction in the 25-year peak water surface elevation at that location.

Lower Booker Creek North

The LBC North portion of the project consists of the area north of the confluence between Booker Creek (discharging from Eastwood Lake) and Sierra Branch. A variety of projects are proposed in this area including storage areas, roadway culvert improvements, secondary system improvements, stream stabilization, and neighborhood retrofits.

Red Bud Storage Area
The proposed 2-acre temporary storage area is the expansion of an existing storage area located on Town property upstream of Honeysuckle Road and between Red Bud Lane and Chesley Lane. While the existing facility provides some detention benefits, the facility can be expanded and optimized to provide an approximately 50% reduction in the 25-year peak flow. The detention would allow for less costly improvements immediately downstream at Honeysuckle Road and along Booker Road as well as provide some peak reduction for Booker Creek itself.

Honeysuckle Road
The existing culvert at Honeysuckle Road overtops during the 10-year event and can back water into the properties at 2411 and 2415 Honeysuckle Road causing significant property damage. Replacing the existing culvert with an 8′ by 4′ reinforced concrete box culvert (RCBC) would provide a 25-year level of service based on built-out conditions assuming the Red Bud Storage Area is constructed as well. If the Red Bud Storage Area is not implemented, then an 11′ by 4′ RCBC would be required to provide a similar level of service.

Booker Creek Road Upstream

Less than 200 feet downstream of Honeysuckle Road, a culvert crossing conveys water across Booker Creek Road to the east side and draining south. The conveyance system transitions to an open channel with six driveway culverts before crossing back to the west side of Booker Creek Road near the Booker Creek Apartments. Flooding has been reported along Booker Creek Road and erosion was identified in the open channel portion. The proposed solution includes replacing all of the culverts with 8′ by 4′ RCBCs provided the Red Bud Storage Area is implemented as well as spot stream stabilization as needed. The proposed culverts should be buried to promote habitat and fish passage as the existing culverts are perched. Improvements for the downstream Booker Creek culvert located near the LBC Trail were designed and constructed concurrently with this Study. The existing corrugated metal pipe (CMP) arch culverts were replaced with twin 5′ x 6′ RCBCs.

Daley Road Storage Area

The proposed 11-acre temporary storage area is located downstream of Booker Creek Road in an area predominantly owned by the Town. To maximize the size of the project private property impacts would be required. Excavation at this location would reduce the 25-year peak flow by 27% for the northern portion of the subwatershed and provide flow reduction benefits downstream of the confluence with Booker Creek. Immediately downstream of the confluence with Booker Creek the proposed Daley Road Storage Area would reduce the peak 25-year water surface elevation by approximately 0.4 feet. The proposed project would provide an opportunity for the Town to implement additional recreational features if desired along with the existing LBC Trail. Any recreational features should be able to withstand periodic inundation during storm events. Water quality treatment practices could also be incorporated at this location to provide additional benefits of the proposed project.

Secondary Drainage Improvements

In addition to the primary system improvements summarized above, secondary drainage system improvements are recommended at Chesley Lane, the Booker Creek Road and Lakeshore Lane intersection, and the Old Oxford Road and Booker Creek Road intersection. Proposed improvements include replacing existing pipes with larger capacity pipes, rerouting drainage to the ROW as applicable and adding inlet capacity. Utility conflicts will need to be resolved during design and implementation of these projects.

Water Quality Projects

Multiple opportunities exist in the northern portion of the subwatershed to improve the water quality, which will aid the Town in complying with the Jordan Lake Rules. Stream stabilization projects are recommended upstream of Honeysuckle Road, along Booker Creek Road, and along the backyard channel between Sedgefield Drive and Honeysuckle Road. The Honeysuckle Road and Booker Creek Road stabilization projects should be combined with the proposed flood control projects listed above to the extent practicable, if funding is available.

As noted above opportunities exist to provide water quality treatment at the proposed storage areas, particularly at Daley Road where several closed piped systems convey untreated runoff from impervious areas and lawns. The outfall from the Booker Creek Apartments system discharges to a concrete channel that could be replaced with a natural channel or a linear water quality treatment practice such as regenerative stormwater conveyance.

Portions of the Lake Forest and Booker Creek neighborhoods ranked high for the potential of green infrastructure retrofits. Possible components of retrofits in these areas could include green street features such as grass swales, grass medians, bioretention bump outs, inlet treatment, residential rain gardens, and disconnection of downspouts. The Town should consider engaging the Homeowners' Associations (HOAs) for high ranking neighborhoods to determine if interest exists for pilot green infrastructure retrofits.

Lower Booker Creek South

The LBC South portion of the project consists of the area from Franklin Street to the confluence with Little Creek including the Ephesus Fordham Focus Area. The southern portion of the subwatershed is subject to some of the more severe flooding in the project area for multiple reasons. Firstly, while a large portion of the overall Booker Creek watershed is steep in topography, the lower portion of Booker Creek is relatively flat. In the upper portion of the watershed, runoff flows quickly with high velocities until reaching the flatter floodplain in LBC where the velocities slow down. Additionally, Little Creek is relatively flat with lower velocities and can back up water into LBC. Secondly, significant development occurred within the floodplain in this area prior to FEMA's flood insurance program which results in commercial and residential structures being located in the natural floodplain. While measures can be taken to reduce the risk of flooding at these locations, the risk cannot be eliminated without removing structures from the floodplain. The proposed projects in the southern portion of the subwatershed coupled with the recommended storage areas summarized above will reduce the severity, frequency, and duration of flooding in the Eastgate shopping area as well as downstream residential areas in the Ridgefield subdivision. To achieve the maximum reductions in water surface elevations all of the recommended projects would need to be implemented, however individual projects will still have their own utility. All proposed projects incorporate the recent lining of the South Elliott Road culverts.

Elliott Storage Area/Passive Green Space

One of the significant factors impacting the culvert through Eastgate and thereby water surface elevations is the backwater or tailwater effects limiting the ability of water to flow efficiently through the Eastgate culvert. By lowering water surface elevations downstream of Eastgate, the culvert can convey more flow and lower water surface elevations throughout the Eastgate property. The open green space between the Eastgate culvert and South Elliott Road could be excavated above the ordinary high-water mark to provide additional floodplain storage that would lower the tailwater at the Eastgate culvert outlet. The proposed 5.5-acre project is predominantly within the floodplain and a portion of the area is within the floodway, so limited development can take place at this location. The Town could consider adding additional amenities in this area and enhancing the pedestrian walkways in the Ephesus Fordham area. Any recreational facilities should be able to withstand temporary inundation and should be coordinated with the Town's Multi-Modal Transportation Plans. Significant coordination with private property owners, Orange Water and Sewer Authority (OWASA), FEMA, the United States Army Corps of Engineers (USACE), North Carolina Department of Environmental Quality (NCDEQ), and Town staff will be required to implement this project. Without upstream detention, this project can decrease the 25-year water surface elevation by approximately one (1) foot upstream of the Eastgate Shopping Center depending on the final design constraints. The Elliott storage project will have minimal water surface reductions downstream of South Elliott Road.

Willow Drive

The areas south of Willow Drive and between Willow Drive and Fordham Boulevard can also be utilized to expand the available floodplain storage by excavating material above the ordinary high-water mark. The majority of the 15-acre proposed project is located within the FEMA floodplain and wetlands are likely present in the project area as well. The proposed project is located predominantly on public property. The primary benefit of the Willow Drive project is to lower water surface elevations for properties along Hickory Drive, Walnut Street, Ridgefield Road, Willow Drive, Longleaf Drive, and Fordham Boulevard. The proposed project would remove three (3) structures from the 25-year floodplain and an additional two (2) structures from the 100-year floodplain and reduce the severity, duration, and frequency of flooding. The project will also reduce the tailwater at Fordham Boulevard which will slightly reduce water surface elevations upstream of the bypass. The Town could consider incorporating recreational features with this project as well. The Town's Greenway Plan does include proposed greenways through this section of the creek to connect to the existing Booker Creek Trail.

Secondary Drainage Improvements

In addition to the primary system improvements summarized above, the secondary drainage system starting at Clover Drive and draining under Ephesus Church Road to Fordham Boulevard is undersized causing flooding in the vicinity of Ephesus Church Road. While the required pipe sizes and lengths are provided in this report to estimate the project costs, the final alignment of this system will likely change from the current alignment based on the roadway extensions of Elliott Road and Legion Road. Town staff should work closely with the roadway engineers to ensure the proper conveyance system is installed to meet the desired level of service.

Water Quality Projects

Multiple opportunities exist in the southern portion of the subwatershed to improve the water quality and will aid the Town in complying with the Jordan Lake Rules.

Opportunities exist to provide water quality treatment at the proposed storage areas where several closed piped systems convey untreated runoff from impervious areas and lawns both in the Eastgate shopping area and downstream of Willow Drive. Treatment of runoff at the piped outfalls before the runoff enters the stream can provide a significant benefit to the overall water quality and help comply with the Jordan Lake Rules. Outfall treatment can potentially be provided downstream of Willow Drive, adjacent to Squids, downstream of Eastgate, southeast of the Ephesus Church Road/Fordham Boulevard intersection and near the Franklin Street/Fordham Boulevard intersection. Green infrastructure should be required and/or highly incentivized for redevelopment projects within the watershed.

Portions of the Ridgefield neighborhood ranked high for the potential of green infrastructure retrofits. Possible components of retrofits in these areas could include green street features such as grass swales, grass medians, bioretention bump outs, inlet treatment, residential rain gardens, and disconnection of downspouts. The Town should consider engaging the HOAs for high ranking neighborhoods to determine if interest exists for pilot green infrastructure retrofits.

Lower Booker Creek West

The LBC West portion of the project consists predominantly of residential areas in Coker Hills, Oxford Hills, and a portion of Lake Forest. The infrastructure in the area consists of open and closed systems that drain to Booker Creek. There are no proposed primary system or flood storage improvements in this portion of the subwatershed.

Secondary Drainage Improvements
Secondary drainage improvements are recommended at the following locations:

- Old Oxford Road between Oxford Hills Drive and Markham Drive
- Old Oxford Road between N. Elliott Road and Oxford Hills Drive
- Wood Circle/Velma Road

Each of the recommended projects was based on feedback from residents and Town staff that flooding has repetitively occurred in these locations. This area of the watershed is characterized by steep slopes which can cause high velocity runoff to impact homes below the road elevation or downhill of adjacent properties.

Water Quality Projects
Stream stabilization projects are recommended downstream of Velma Road and downstream of Old Oxford Road. In both instances the Town should consider coupling the recommended stabilization projects with the infrastructure projects above. The project downstream of Old Oxford Road is characterized by a limited buffer and little to no vegetation stabilizing the banks. The project downstream of Velma Road is relatively steep and will require some hardened grade control. In both instances, easements will be required to complete the work.

Opportunities are available to treat stormwater runoff at four (4) outfalls located east of Oxford Hills Drive. Based on the screening tools utilized to prioritize outfalls for treatment, three of the four outfalls were recommended for projects. Potential treatment practices at these locations include regenerative stormwater conveyance and bioretention.

Lower Booker Creek East

The LBC East portion of the project drains Summerfield Crossing, Foxcroft Apartments, and the portion of Fordham Boulevard northeast of the intersection with Franklin Street. A primary system stream originating near Erwin Road drains to the west to the confluence with Booker Creek. The downstream portion of the tributary is located within the Booker Creek floodplain. Several office buildings along Dobbins Drive are floodprone, however flood reductions in this location are dependent on the Lower Booker Creek South projects.

Dobbins Drive

The existing 72″ CMP culvert at Dobbins Drive currently provides a 2-year level of service. The proposed twin 54″ reinforced concrete pipe (RCP) culverts will provide the 25-year level of service with minimal freeboard. Water surface reductions will be approximately 0.8 feet for the 25-year storm.

Foxcroft Drive

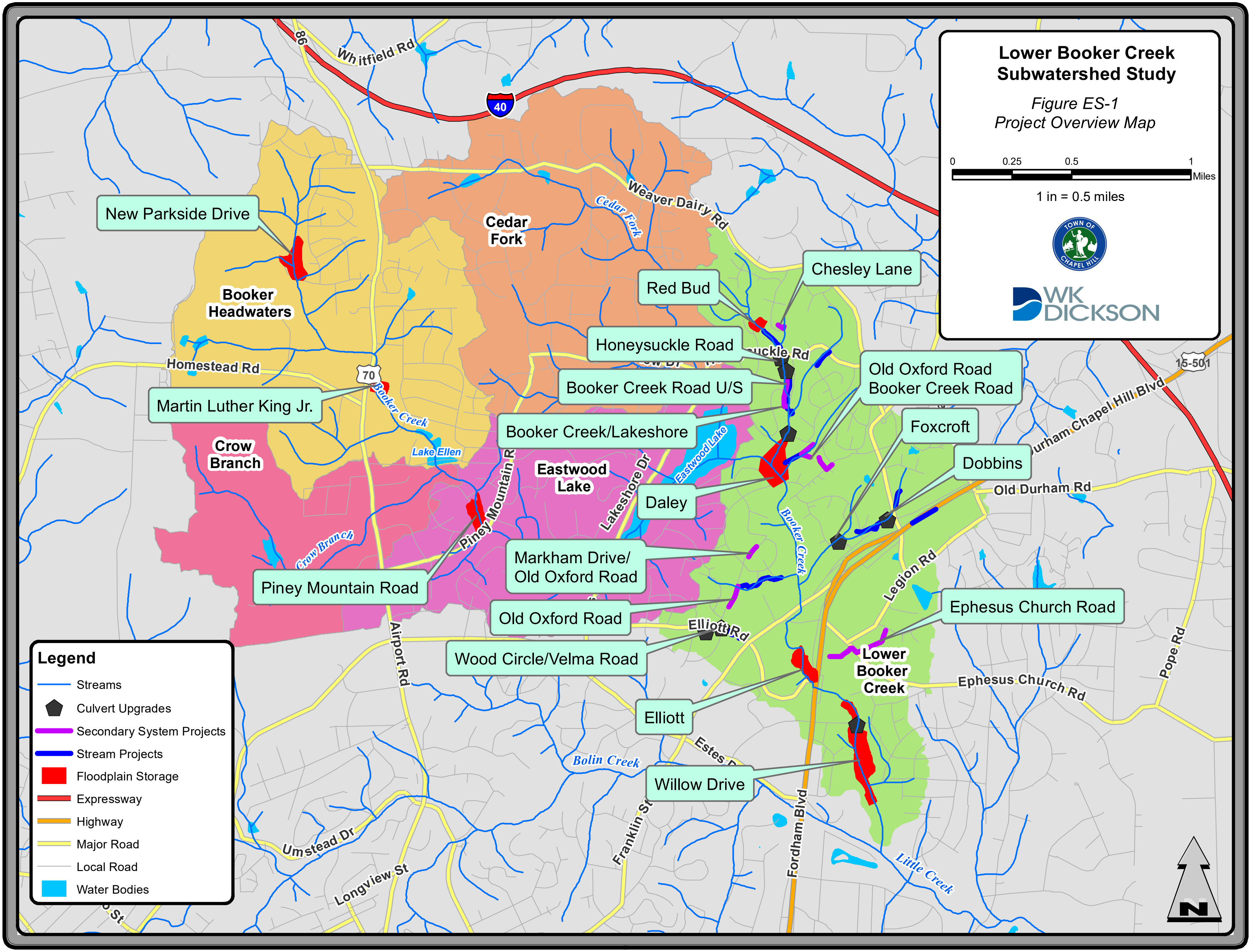
The existing culvert crossing meets the desired level of service however water backs up behind the Foxcroft Drive culverts and could potentially cause flooding of property at the Foxcroft Apartments. The proposed 12′ x 4′ RCBC would reduce water surface elevations by 1.4 feet upstream of Foxcroft Drive during the 25-year storm. Prior to implementing this project, the Town should survey finished floor elevations and lowest adjacent grade elevations at the apartments to better quantify the benefits of the culvert upgrade.

Secondary Drainage Improvements

Secondary drainage improvements are necessary for the pond outfall at the potential Oxford Reserve development. If the Oxford Reserve development proceeds, the Town should work with the developer to implement an engineered outfall from the existing or modified pond. Currently when the pond overtops, water drains in an uncontrolled manner in multiple directions causing flooding along Berry Patch Lane. If the Oxford Reserve development does not proceed, the Town should consider installing an engineered outfall for the existing pond.

Water Quality Projects

Stream stabilization projects are recommended downstream of Dobbins Drive, along Fordham Boulevard, and on the Duke Energy property along Erwin Road. The Dobbins Drive stabilization project should be implemented with the culvert improvements if possible, however temporary stabilization may be required for a portion of the stream in the near future due to active erosion directly adjacent to Dobbins Drive. The proposed stabilization along Fordham Boulevard could also incorporate outfall treatments at multiple locations as shown in Section 6.



Lower Booker Creek Subwatershed Study
Figure ES-1
Project Overview Map
0
0.25
0.5
1
Miles
1 in = 0.5 miles
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Culvert Upgrades
Secondary System Projects
Stream Projects
Floodplain Storage
Expressway
Highway
Major Road
Local Road
Water Bodies
New Parkside Drive
Booker Headwaters
Cedar Fork
Crow Branch
Eastwood Lake
Lower Booker Creek
Red Bud
Chesley Lane
Honeysuckle Road
Booker Creek Road U/S
Old Oxford Road Booker Creek Road
Martin Luther King Jr.
Booker Creek/Lakeshore
Foxcroft
Dobbins
Daley
Markham Drive/ Old Oxford Road
Piney Mountain Road
Old Oxford Road
Wood Circle/Velma Road
Ephesus Church Road
Elliott
Willow Drive
Whitfield Rd
Weaver Dairy Rd
Homestead Rd
Piney Mountain Rd
Lakeshore Dr
Old Durham Rd
Durham Chapel Hill Blvd
Legion Rd
Elliott Rd
Ephesus Church Rd
Estes Dr
Airport Rd
Umstead Dr
Longview St
Franklin St
Fordham Blvd
Pope Rd
Cedar Fork
Booker Creek
Lake Ellen
Eastwood Lake
Crow Branch
Bolin Creek
Little Creek
40
70
15-501
86
N

Prioritization and Recommendations

To appropriately allocate Town 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
- Project dependency
- Water quality – SCM
- Open channel – erosion control
- Implementation constraints
- Grant funding
- Constructability

In some instances, project prioritization will be impacted by the required sequencing to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts for the proposed projects. For example, the Booker Creek Road U/S project needs to be completed before the Honeysuckle Road project is implemented. Table ES-1 shows the proposed prioritizations for the Primary Flood Control Improvements. The total cost for all of the recommended primary and secondary system capital improvements in the Lower Booker Creek subwatershed is approximately $23,267,000.

In addition to the proposed capital projects, Section 5 and Appendix I discuss the maintenance requirements for the aging infrastructure. The Town should consider proactively maintaining the infrastructure before failure which will provide long term savings. Additional more detailed condition assessment can be completed in the future to better prioritize and plan maintenance needs.

Based on the existing flooding in the watershed, it is highly recommended the Town strongly review any rezoning requests that will increase the impervious area and determine if additional stormwater measures are required. It is also highly recommended that the Town require green infrastructure and low impact development to the extent possible for both new development and redevelopment to promote infiltration and minimize increases to peak flow and volumes.

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

Prioritization	Project	Cost
1	Elliott Storage	$1,140,000
2	Red Bud Storage	$914,000
3	Piney Mountain Road	$1,906,000
4	Booker Creek Road U/S	$1,285,000
5	Honeysuckle Road	$336,000
6	Dobbins	$200,000
7	Willow Drive	$4,010,000
8	New Parkside Drive	$2,786,000
9	Daley Storage	$3,140,000
10	Martin Luther King Jr. Storage	$3,789,000
11	Foxcroft Drive	$660,000
	Total	$20,166,000

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

Prioritization	Project	Cost
1	Old Oxford Road/Booker Creek Road System	$634,000
2	Markham Drive/Old Oxford Road System	$451,000
3	Chesley Lane System	$146,000
4	Booker Creek Road/Lakeshore Lane System	$263,000
5	Old Oxford Road System	$295,000
6	Wood Circle/Velma Road System	$170,000
7	Ephesus Church Road System	$1,045,000
8	Summerfield Crossing System	$97,000
	Total	$3,101,000

Stream Stabilization and Water Quality Projects

Stream stabilization projects, neighborhood retrofits, and outfall retrofits are not separately prioritized, however those projects that can be incorporated into flood control projects should be scheduled with the flood control projects. The anticipated cost range for stream stabilization projects is $2 million to $3.5 million depending on the required measures and design specifics. The anticipated total cost for outfall retrofits is $2.4 million based on literature values for similar projects. The stream stabilization and water quality projects will add approximately $6 million to the total costs ($23,267,000) for the recommended primary and secondary system capital improvements.

Neighborhood retrofits and stream stabilization projects on private property will be heavily dependent on community acceptance and willingness to participate. It is recommended that the Town consider a pilot neighborhood retrofit project to encourage green infrastructure both in public rights-of-way and on private property. Neighborhood retrofits can improve the aesthetics, provide traffic calming, improve water quality and help meet requirements of the Jordan Lake rules, and reduce the quantity of stormwater runoff. While individual retrofits will not have a significant impact on flooding, the cumulative impact of these practices throughout a community and watershed can be significant. Outfall retrofit priorities will likely adjust with project opportunities such as grant funding or availability of property.

INTRODUCTION

1.1 PROJECT DESCRIPTION

The Town of Chapel Hill retained WK Dickson to complete a Subwatershed Study and Plan for the Lower Booker Creek (LBC) subwatershed. As shown in Figure 1-1, the LBC subwatershed is located in the northeastern portion of Chapel Hill and generally drains north to south discharging to Little Creek. The 1.8 square mile LBC subwatershed is the most downstream subwatershed within the 6.3 square mile Booker Creek watershed. As noted in the Executive Summary, the continued development of Subwatershed Studies is a strategic initiative as part of the Town's Stormwater Program and Master Plan Goals 2, 3, and 4 which include: (2) addressing stormwater quantity, (3) addressing stormwater quality, and (4) protecting and restoring natural stream corridors. To assist in achieving the goals listed above, WK Dickson completed a stormwater inventory of both infrastructure and natural features within the LBC subwatershed.

The Subwatershed Study includes an evaluation of the segment of Booker Creek from Eastwood Lake at the upstream end to its confluence with Little Creek at the downstream end. The following unnamed tributaries were evaluated as part of this study:

- Dobbins Reach from approximately 75 feet upstream of the Dobbins Drove crossing at the upstream end to its confluence with Booker Creek at the downstream end; and
- Sierra Reach from approximately 500 feet upstream of the Honeysuckle Road crossing at the upstream end to its confluence with Booker Creek at the downstream end.

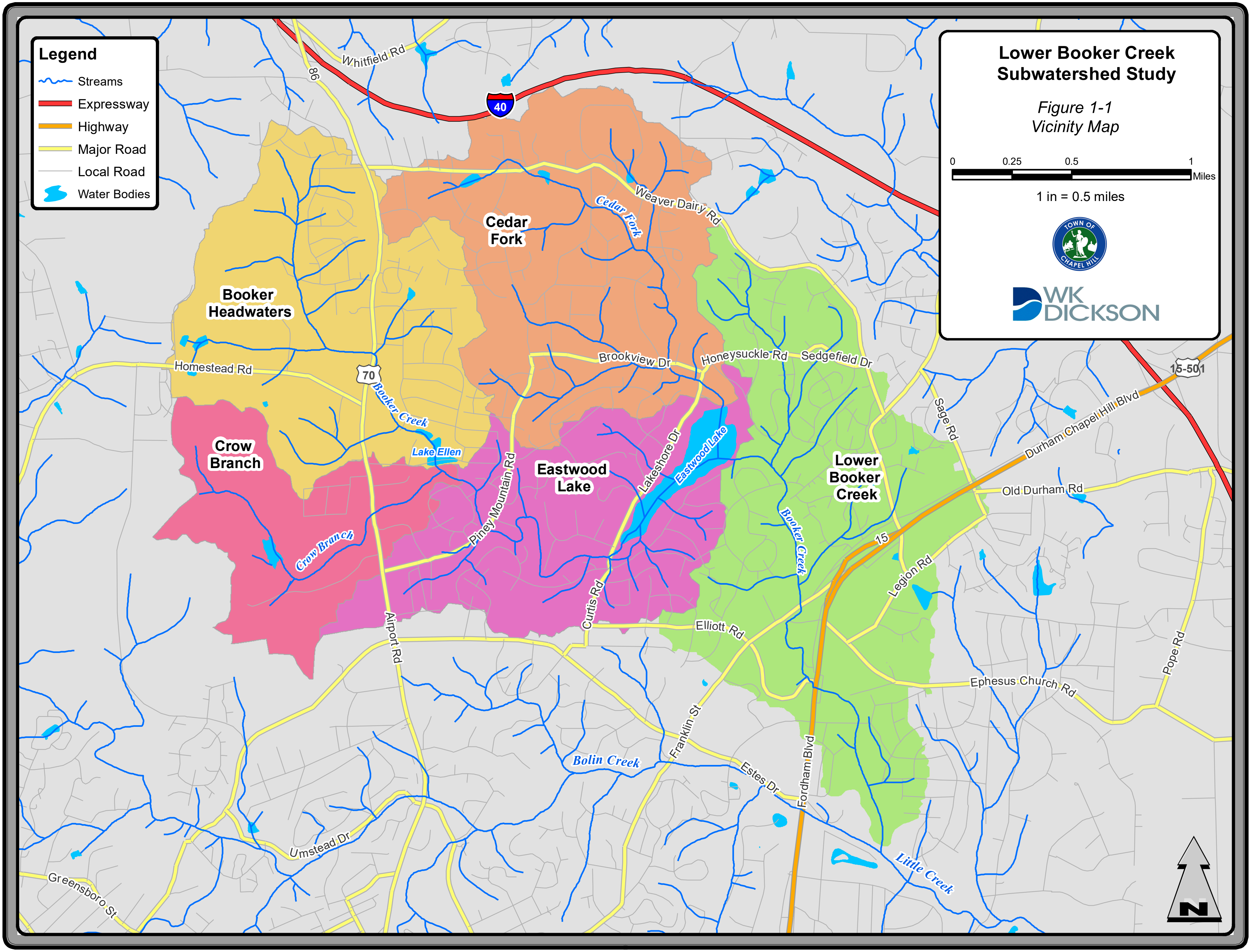
Additionally, eight (8) conveyance systems that drain to the main creeks were evaluated. For the purposes of this report, Booker Creek, Dobbins Reach, and Sierra Reach will be noted as primary systems and the conveyance systems will be noted as secondary systems. A project area map showing the LBC subwatershed and the conveyance systems evaluated as part of this study is included as Figure 1-2. Detailed hydraulic analysis included the following:

- Primary System – Booker Creek
    - East Franklin Street Culvert
    - Eastgate Crossing Culvert
    - South Elliott Road Culvert
    - Highway 15-501/Fordham Boulevard Culvert
    - Willow Drive Bridge

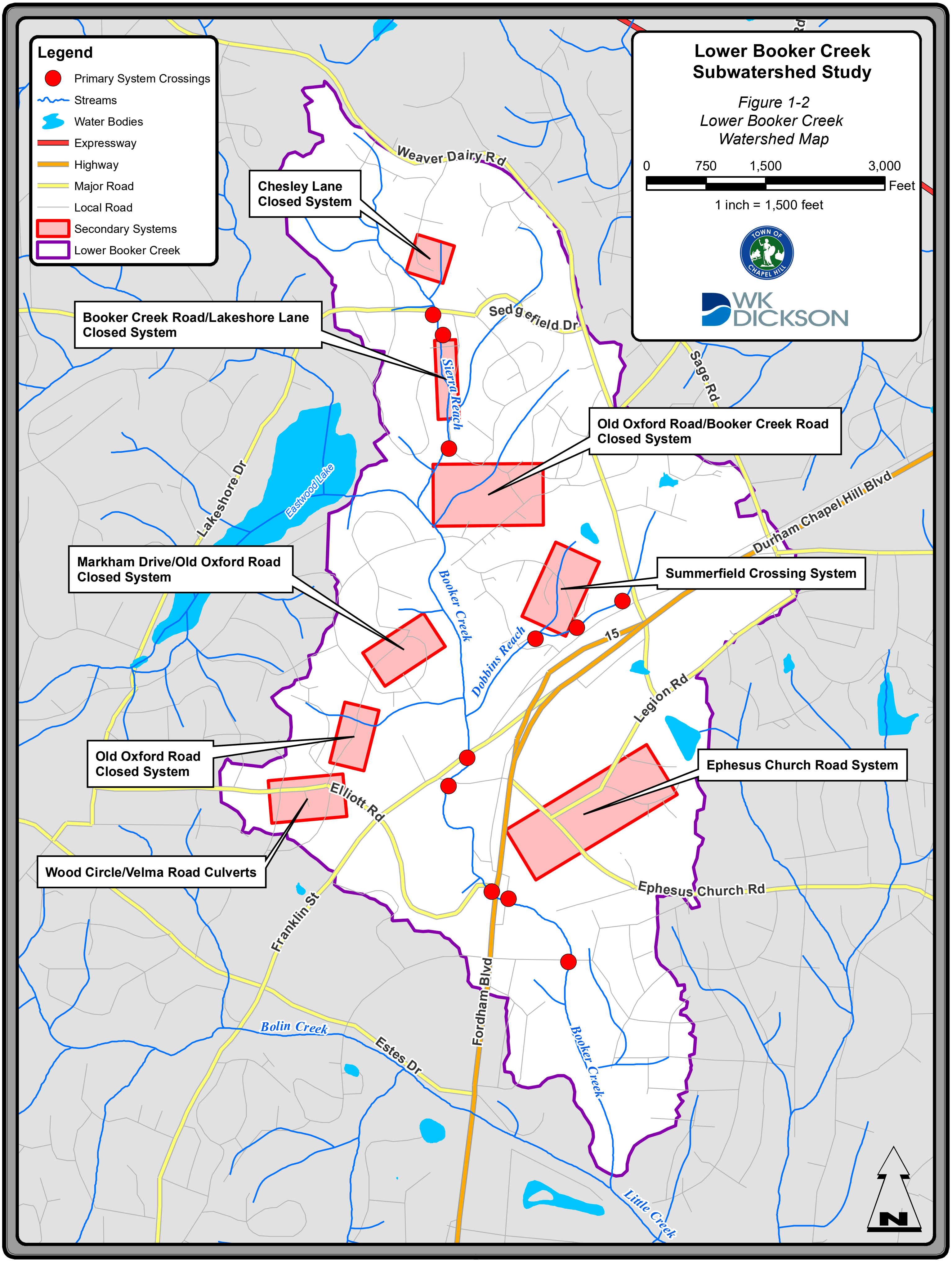
- Primary System – Dobbins Reach
    - Dobbins Drive Culvert
    - Summerfield Crossing Culvert
    - Foxcroft Drive Culvert

- Primary System – Sierra Reach
  - Honeysuckle Road Culvert
  - Booker Creek Road - Upstream Culvert
  - Booker Creek Road - Downstream Culvert

- Secondary Systems
  - Chesley Lane Closed System
  - Old Oxford Road/Booker Creek Road Closed System
  - Booker Creek Road/Lakeshore Lane Closed System
  - Markham Drive/Old Oxford Road Closed System
  - Old Oxford Road Closed System
  - Wood Circle/Velma Road Culverts
  - Ephesus Church Road System
  - Summerfield Crossing System



Lower Booker Creek Subwatershed Study
Figure 1-1
Vicinity Map
0
0.25
0.5
1
Miles
1 in = 0.5 miles
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
Booker Headwaters
Cedar Fork
Crow Branch
Eastwood Lake
Lower Booker Creek
Whitfield Rd
86
40
Weaver Dairy Rd
Cedar Fork
Homestead Rd
70
Booker Creek
Lake Ellen
Brookview Dr
Honeysuckle Rd
Sedgefield Dr
15-501
Sage Rd
Durham Chapel Hill Blvd
Old Durham Rd
Lakeshore Dr
Eastwood Lake
Piney Mountain Rd
Crow Branch
Curtis Rd
Airport Rd
Elliott Rd
15
Legion Rd
Booker Creek
Ephesus Church Rd
Pope Rd
Franklin St
Bolin Creek
Estes Dr
Fordham Blvd
Umstead Dr
Greensboro St
Little Creek
N



Legend
Primary System Crossings
Streams
Water Bodies
Expressway
Highway
Major Road
Local Road
Secondary Systems
Lower Booker Creek
Lower Booker Creek Subwatershed Study
Figure 1-2
Lower Booker Creek Watershed Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
WK DICKSON
Chesley Lane Closed System
Booker Creek Road/Lakeshore Lane Closed System
Old Oxford Road/Booker Creek Road Closed System
Markham Drive/Old Oxford Road Closed System
Summerfield Crossing System
Old Oxford Road Closed System
Ephesus Church Road System
Wood Circle/Velma Road Culverts
Weaver Dairy Rd
Sedgefield Dr
Sage Rd
Sierra Reach
Lakeshore Dr
Eastwood Lake
Durham Chapel Hill Blvd
Booker Creek
Dobbins Reach
15
Legion Rd
Elliott Rd
Franklin St
Ephesus Church Rd
Fordham Blvd
Bolin Creek
Estes Dr
Booker Creek
Little Creek
N

1.2 DESIGN STANDARDS AND CRITERIA

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

- 10-year storm event – piped collection systems and local roadway bridges and culverts;
- 25-year storm event – minor thoroughfare (collector and arterial roadways) bridges and culverts;
- 50-year storm event – bridges, box culverts, and stream crossings;
- 100-year storm event – regulatory floodway; and
- 100-year storm event – structural flooding of homes.

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

Table 1-1: Project Area Design Standards and Criteria

Drainage Type	Design Storm (years)	Project Area
Piped Collection Systems Local Roadway Crossings	10	• Dobbins Drive (Dobbins Reach) • Summerfield Crossing (Dobbins Reach) • Foxcroft Drive (Dobbins Reach) • Booker Creek Road - Upstream (Sierra Reach) • Booker Creek Road - Downstream (Sierra Reach)
Minor Thoroughfare (Collector and Arterial Roadway) Crossings	25	• Honeysuckle Road (Sierra Reach)
Regulatory Floodway	100	• East Franklin Street (Booker Creek) • Eastgate Crossing Road (Booker Creek) • South Elliott Road (Booker Creek) • Highway 15-501/Fordham Boulevard (Booker Creek) • Willow Drive (Booker Creek)

It should be noted that Dobbins Drive, East Franklin Street, and Highway 15-501/Fordham Boulevard are all State maintained roadways.

EXISTING WATERSHED CONDITIONS

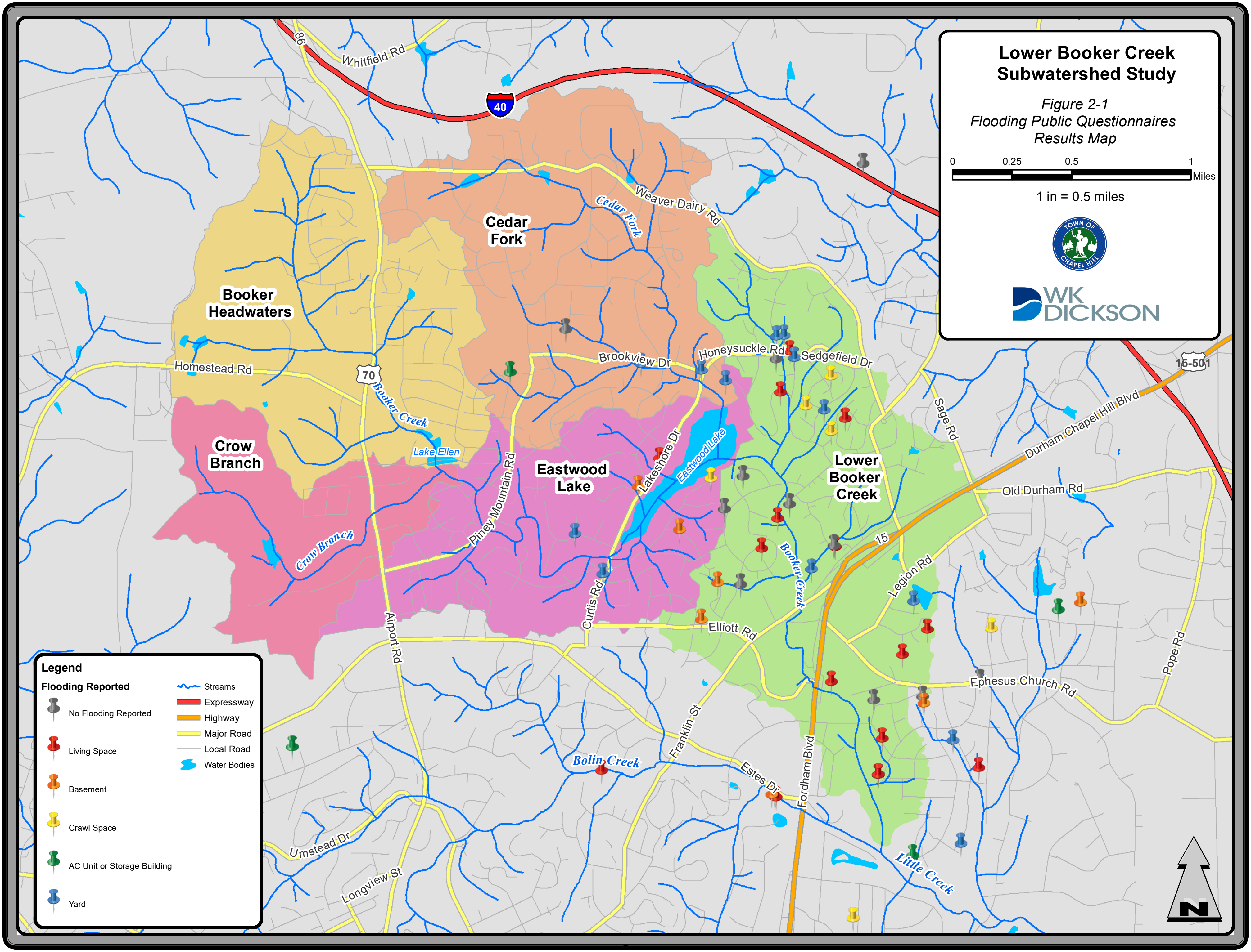
2.1 CITIZEN INPUT

The Subwatershed Study included a citizen input component to solicit feedback and information regarding stormwater impacts and future stormwater management in the Town. Important steps in public outreach were taken by WK Dickson within the Booker Creek watershed through the use of direct mail questionnaires, web-based applications, and public meetings. In October 2015, the WK Dickson began distribution of questionnaires to property owners in the entire Booker Creek watershed requesting feedback on erosion and flooding.

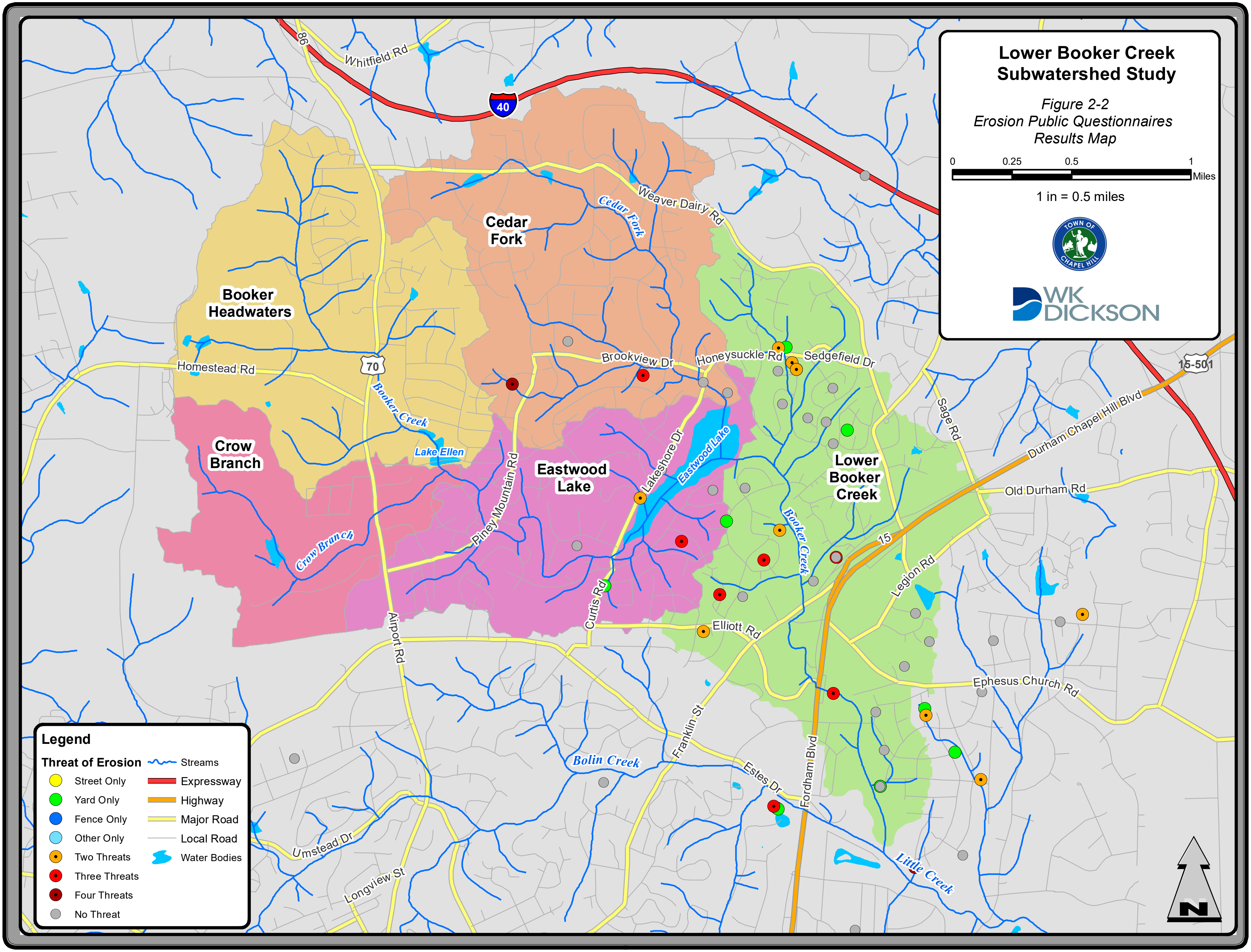
Seventy-five (75) questionnaires were completed and returned to WK Dickson for consideration from Booker Creek watershed property owners. The questionnaire results were georeferenced according to the address of the questionnaire respondent (See Figures 2-1 and 2-2). Out of the seventy-five (75) respondents, thirty-three (33) respondents were located in the Lower Booker Creek subwatershed. Twenty-three (23) of the respondents indicated some level of property flooding, with one (1) property owner experiencing basement flooding at least once a year. Eighteen (18) respondents identified locations where street flooding occurs while twenty-five (25) residents reported yard flooding. A total of fourteen (14) residents reported erosion threatening streets, yards, garages, or fences. See Figure 2-2 for locations of reported erosion. A sample questionnaire and the tabulated results are provided in Appendix D.

Other opportunities for obtaining citizen input included setting up an online website specifically for this project, outreach to local groups and events, stakeholder interviews, and public meetings. The first public meeting was held on January 7, 2016, to introduce the project and facilitate further feedback from the public. The initial public feedback was critical to identifying flood-prone areas and validating model results. A follow-up meeting was held on June 23, 2016 to share results of the Subwatershed Study with the public. Each meeting provided opportunities for residents to speak with Town staff or representatives from WK Dickson. The results and comments from the citizens' input contributed significantly to the identification and prioritization of problem areas, and validation of model results. Minutes from these meetings are included in Appendix D.

As selected projects proceed into design and construction, continuous citizen input will be critical to the success of the projects. Additional public meetings and individual property owner meetings will help educate property owners on the benefits of the proposed projects as well as the temporary and permanent impacts from construction.



Lower Booker Creek Subwatershed Study
Figure 2-1
Flooding Public Questionnaires Results Map
0
0.25
0.5
1
Miles
1 in = 0.5 miles
WK DICKSON
Legend
Flooding Reported
No Flooding Reported
Living Space
Basement
Crawl Space
AC Unit or Storage Building
Yard
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
Booker Headwaters
Cedar Fork
Crow Branch
Eastwood Lake
Lower Booker Creek
Whitfield Rd
Weaver Dairy Rd
Cedar Fork
Homestead Rd
Booker Creek
Lake Ellen
Brookview Dr
Honeysuckle Rd
Sedgefield Dr
Lakeshore Dr
Eastwood Lake
Piney Mountain Rd
Crow Branch
Airport Rd
Curtis Rd
Elliott Rd
Sage Rd
Durham Chapel Hill Blvd
Old Durham Rd
Legion Rd
Ephesus Church Rd
Pope Rd
Franklin St
Bolin Creek
Estes Dr
Fordham Blvd
Umstead Dr
Longview St
Little Creek
40
70
86
15
15-501
N


Lower Booker Creek Subwatershed Study
Figure 2-2
Erosion Public Questionnaires Results Map
0 0.25 0.5 1 Miles
1 in = 0.5 miles
TOWN OF CHAPEL HILL
WK DICKSON
Booker Headwaters
Cedar Fork
Crow Branch
Eastwood Lake
Lower Booker Creek
Whitfield Rd
Weaver Dairy Rd
Cedar Fork
Homestead Rd
Brookview Dr
Honeysuckle Rd
Sedgefield Dr
Booker Creek
Lake Ellen
Piney Mountain Rd
Lakeshore Dr
Eastwood Lake
Sage Rd
Durham Chapel Hill Blvd
Old Durham Rd
Crow Branch
Curtis Rd
Airport Rd
Elliott Rd
Legion Rd
Ephesus Church Rd
Franklin St
Bolin Creek
Estes Dr
Fordham Blvd
Umstead Dr
Longview St
Little Creek
86
40
70
15
15-501
Legend
Threat of Erosion
Street Only
Yard Only
Fence Only
Other Only
Two Threats
Three Threats
Four Threats
No Threat
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
N

2.2 WATERSHED CHARACTERISTICS

The entire Booker Creek watershed is approximately 4,000 acres (~6.3 square miles). It is divided into five (5) separate subwatersheds: Booker Headwaters, Crow Branch, Cedar Fork, Eastwood Lake, and Lower Booker Creek. The LBC subwatershed is approximately 1,130 acres (~1.8 square miles) between its downstream boundary east of Fordham Boulevard and its upstream boundary along Weaver Dairy Road. Land use in the Lower Booker Creek subwatershed is predominately built-out as shown on the Existing Conditions Land Use Map (Appendix C-2). Likewise, the overall Booker Creek watershed is mostly built-out with portions of the Crow Branch and Booker Headwaters subwatersheds not currently being developed to their zoned uses. The existing land use in the overall Booker Creek watershed, as well as the LBC subwatershed, is mostly residential with a small percentage of commercial, office, and institutional (See Tables 2-1 through 2-4). As described in detail in Appendix A, the existing land use is based off of actual impervious coverages provided by the Town and ground-truthed by the WK Dickson team. The percentage of directly connected impervious was estimated based on EPA guidance for the 2010 NPDES MS4 permits in Massachusetts (www3.epa.gov/region1/npdes/stormwater/ma/MADCIA.pdf).

Future conditions land use was adjusted based on Town zoning, feedback from Town planning staff, review of upcoming development projects (http://www.townofchapelhill.org/town-hall/departments-services/planning-and-sustainability/development), analysis of Town focus areas, and assumptions related to redevelopment. There is approximately 7% of the Booker Creek watershed that is classified as a development opportunity area including the Ephesus-Fordham area and Northern Area Task Force focus areas. It should be noted that the existing land use for the Ephesus-Fordham area is commercial and rights-of way, while the Northern Area Task Force has open space, office, and mixed use. The Carolina North plan was also incorporated into the future development plan. The proposed development for Carolina North is required to provide detention for up to the 50-year storm event, so that peak flows should not exceed pre-development conditions for storms equal to or less than the 50-year event. Finally, it is acknowledged that single lot redevelopment can have impacts on the future hydrology as well. It is difficult to know the extent of this redevelopment and if the redevelopment will significantly increase the percent impervious, however assumptions were included in the future conditions land use to account for some redevelopment of small houses particularly on larger lots unless the lots were within a protected community, such as Coker Hills. See Appendix A for details.

Table 2-1: Overall Booker Creek Watershed Existing Land Use

Land Use Category	Area (acres)
Commercial	20
Office/Institutional/Mixed Used	239
High Density Residential	167
Medium Density Residential	453
Low Density Residential	2,175
Parks/Open Space	543
Right-of-Way	133
Development Opportunity Area*	292

*Includes Northern Area Task Force and Ephesus-Fordham areas

Table 2-2: Overall Booker Creek Watershed Future Land Use

Land Use Category	Area (acres)
Commercial	142
Office/Institutional/Mixed Used	239
High Density Residential	209
Medium Density Residential	486
Low Density Residential	2,229
Parks/Open Space	278
Right-of-Way	133
University	306

Table 2-3: Lower Booker Creek Subwatershed Existing Land Use

Land Use Category	Area (acres)
Commercial	12
Office/Institutional/Mixed Used	85
High Density Residential	66
Medium Density Residential	103
Low Density Residential	565
Parks/Open Space	114
Right-of-Way	65
Development Opportunity Area*	122

*Includes Ephesus-Fordham area

Table 2-4: Lower Booker Creek Subwatershed Future Land Use

Land Use Category	Area (acres)
Commercial	134
Office/Institutional/Mixed Used	85
High Density Residential	66
Medium Density Residential	103
Low Density Residential	565
Parks/Open Space	114
Right-of-Way	65

The soils within the Booker Creek watershed are predominately Natural Resource Conservation Service (NRCS) hydrologic groups B (52%) and D (27%) while in the LBC subwatershed approximately 60% of the soils are NRCS hydrologic group D. See Appendix C-4 for a soils map of the Booker Creek watershed.

2.3 EXISTING CONDITIONS SURVEY AND FIELD DATA COLLECTION

For the LBC Subwatershed Study, stormwater utility infrastructure throughout the watershed in Town limits was collected by WK Dickson personnel to compile a GIS stormwater inventory database for the Town. This was accomplished by using survey grade Global Positioning Systems (GPS) as the primary means of data capture to locate the x, y, and z coordinates of each visible stormwater system structure. Conventional surveying techniques were used to obtain attributes including but not limited to size, material, slope, and length. The data were collected using horizontal datum North American Datum (NAD) 1983 and vertical datum North American Vertical Datum (NAVD) 1988. A total of 1,185 closed system structures and 75,504 linear feet of pipe was collected as part of the inventory. Tables 2-5 and 2-6 summarize the inventory collected in the LBC subwatershed.

Table 2-5: Inventory Summary – Closed System Structures

Structure Type	Number Surveyed
Yard Inlet	31
Drop Inlet	127
Junction Box	51
Pipe End	297
Pond Structure	4
Slab Top Inlet	33
Catch Basin	529
Underground Pipe Junction	28
Difficult Access	85

Table 2-6: Inventory Summary – Pipes*

Size	Length (Linear Feet)
12″ Diameter	571
15″ Diameter	26,284
18″ Diameter	14,663
24″ Diameter	6,513
30″ Diameter	2,431
36″ Diameter	3,309
42″ Diameter	1,574
48″ Diameter	2,145
54″ Diameter	658
60″ Diameter	705
72″ Diameter	60
'Other' Diameter	1,444

*Lengths provided do not include 'mismatched' pipe ends (12,342 linear feet) or diameters from underground pipe junctions (2,805 linear feet).

Data were obtained for those open channels required to complete connectivity for modeling purposed. Attributes such as shape, lining type, bed type, flow, bottom width, top width, and bank heights were collected for 145 open channel sections totaling approximately eight (8) miles in length. For those sections of open channel where more detailed information was required for model input, cross sections were surveyed. Data including elevations for the top of the back, bottom of bank, and channel centerline were obtained at twenty-eight (28) cross sections throughout the LBC subwatershed to supplement the existing FEMA cross section data.

EXISTING WATERSHED ANALYSIS

3.1 PRIMARY SYSTEM HYDROLOGIC AND HYDRAULIC ANALYSES

3.1.1 HYDROLOGY

The purpose of the hydrologic analysis is to estimate the magnitude of selected frequency floods for the LBC subwatershed. However, to estimate floods in LBC, the entire Booker Creek watershed must be hydrologically evaluated. The USACE HEC-HMS program was selected to model the primary systems. HEC-HMS simulates the surface runoff response to precipitation for an interconnected system of surfaces, channels, and ponds. Input data for the HEC-HMS model were developed using topographic, land use, and soils maps in GIS to delineate and calculate the basin areas and NRCS hydrologic parameters. For each delineated sub-basin in the Booker Creek watershed the percent of impervious cover was calculated. Detailed descriptions of the model parameters can be found in Appendices A and B.

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

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

- Booker Headwaters
  - Martin Luther King Jr. Boulevard
  - Lake Ellen
- Crow Branch
  - Horace Williams Airport Pond
- Cedar Fork
  - Kenmore Road
  - Brookview Drive

- Eastwood Lake
  - Piney Mountain Road
  - Eastwood Lake

- Lower Booker Creek
  - East Franklin Street (Booker Creek)
  - Highway 15-501/Fordham Boulevard (Booker Creek)
  - Foxcroft Drive (Dobbins Reach)
  - Summerfield Crossing (Dobbins Reach)
  - Weir East of Red Bud Lane (Sierra Reach)

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

Table 3-1: Existing Conditions Flows from HEC-HMS for Lower Booker Creek Subwatershed

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
BOOKER CREEK							
ADD-LBC-40-50	Confluence of Sierra Reach and Booker Creek	10024	780	1,902	2,578	3,067	3,326
ADD-LBC-70-130	Confluence of Dobbins Reach and Booker Creek	7024	807	1,961	2,671	3,205	3,502
East Franklin Street	East Franklin Street	6733	856	2,155	2,951	3,531	3,904
Fordham Blvd-Downstream	South Elliott Road/Fordham Blvd – Downstream	4696	832	1,964	2,686	3,225	3,597
Willow Drive	Willow Drive	3185	849	1,990	2,732	3,281	3,665
DOBBINS REACH							
Dobbins Drive	Dobbins Drive	2697	120	208	261	302	343
Summerfield Crossing	Summerfield Crossing	1890	138	239	300	347	394
Foxcroft Drive	Foxcroft Drive	1485	162	282	359	415	467
SIERRA REACH							
Honeysuckle Road	Honeysuckle Road	2867	89	177	232	277	320
Booker Creek Road	Booker Creek Road	955	141	275	357	423	484

3.1.2 HYDRAULICS

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

- Cross-section geometry of the channel and floodplain;
- Roughness coefficients to describe characteristics of the channel and floodplain;
- Size, shape, and characteristics of culverts and roadways along the stream reach; and

- Energy loss coefficients for flow in the channel and at roadway crossings.

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

The starting water surface elevations for the HEC-RAS model were set based on values calculated in the Little Creek FEMA HEC-RAS models.

Hydraulic Performance

Eleven (11) roadway crossings were analyzed for flooding potential of the primary system. Five (5) were located along Booker Creek, three (3) along Dobbins Reach, and the remaining three (3) were located along Sierra Reach. Descriptions of the existing primary system crossings analyzed are summarized in Table 3-2. Pictures 3-1 through 3-8 of this report provide visual images of several primary system crossings.

Table 3-2: Existing Condition of Primary System Crossings

Location	Size/Material	Condition
East Franklin Street (Booker Creek)	Triple 11′ x 11′ RCBCs	Good
Eastgate Crossing Road (Booker Creek)	35′ x 10.5′ RCBC	Good
South Elliott Road (Booker Creek)	Triple 16′ x 9′ Elliptical CMPs	Fair to Poor – Heavy Corrosion*
Highway 15-501/ Fordham Boulevard (Booker Creek)	Triple 11.5′ x 11.5′ RCBCs	Good
Willow Drive (Booker Creek)	Bridge	Good
Dobbins Drive (Dobbins Reach)	72″ CMP	Good
Summerfield Crossing (Dobbins Reach)	Twin 66″ RCPs	Fair
Foxcroft Drive (Dobbins Reach)	Triple 48″ RCPs	Good
Honeysuckle Road (Sierra Reach)	54″ CMP	Good
Booker Creek Road - Upstream (Sierra Reach)	54″ RCP	Good
Booker Creek Road - Downstream (Sierra Reach)**	Twin 5′ x 3.4′ Elliptical CMPs	Poor

* South Elliott Road culverts were slip lined in the Fall of 2016.

**Booker Creek Road culverts were replaced with twin 5′ x 6′ RCBCs in 2017.

Picture 3-1: East Franklin Street Culvert (Booker Creek) – Downstream Face

Picture 3-2: Fordham Boulevard Culvert (Booker Creek) – Upstream Face

Picture 3-3: Dobbins Drive Culvert (Dobbins Reach) – Downstream Face

Picture 3-4: Summerfield Crossing Culvert (Dobbins Reach) – Upstream Face

Picture 3-5: Foxcroft Drive Culvert (Dobbins Reach) – Upstream Face

Picture 3-6: Honeysuckle Road Culvert (Sierra Reach) – Downstream Face

Picture 3-7: Booker Creek Road -U/S Culvert (Sierra Reach) – Upstream Face

Picture 3-8: Booker Creek Road -D/S Culvert (Sierra Reach) – Downstream Face

The 2-, 10-, 25-, 50- and 100-year existing conditions flood elevations for the primary system crossings are identified in Table 3-3. The minimum elevations at the top of the road for each crossing are also listed in Table 3-3. Along Booker Creek, three (3) of the five (5) crossings are not meeting the desired 100-year level of service. The crossings at Highway 15-501/Fordham Boulevard and Willow Drive are performing at their desired level of service while South Elliott Road is overtopping by 0.61 feet in the 100-year storm. East Franklin Street is operating at a 10-year level of service and the Eastgate Crossing Road overtops during the 10-year storm event.

Along the Dobbins Reach, two (2) of the three (3) crossings are meeting their desired level of service. The desired level of service for Dobbins Drive, Summerfield Crossing, and Foxcroft Drive is the 10-year storm. As shown in Table 3-3, Dobbins Drive is only providing a 2-year level of service while Summerfield Crossing and Foxcroft Drive are exceeding the desired 10-year level of service.

Along the Sierra Reach, none of the three (3) crossings is meeting its desired level of service. As shown in Table 3-3, Booker Creek Road - Downstream, Honeysuckle Road, and Booker Creek Road – Upstream are performing at only a 2-year level of service. The desired level of service for Honeysuckle Road is the 25-year event and for Booker Creek Road – Upstream and Downstream, it is the 10-year event.

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

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service (Year)	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
BOOKER CREEK							
East Franklin Street	263.48	100	258.37	262.50	**264.39**	**265.13**	**265.56**
Eastgate Crossing Road	260.81	100	258.10	**261.67**	**263.10**	**264.26**	**265.03**
South Elliott Road	262.95	100	256.87	259.09	260.68	262.30	**263.56**
Highway 15-501/Fordham Boulevard	264.21	100	255.40	257.58	258.83	259.81	260.67
Willow Drive	259.11	100	252.87	254.63	255.40	256.19	257.66
DOBBINS REACH							
Dobbins Drive	282.01	10	281.17	**282.54**	**282.85**	**283.00**	**283.09**
Summerfield Crossing	275.86	10	271.08	272.62	273.32	273.89	274.65
Foxcroft Drive	272.49	10	268.01	269.32	270.54	271.48	272.33
SIERRA REACH							
Honeysuckle Road	294.58	25	293.97	**295.39**	**295.61**	**295.76**	**295.84**
Booker Creek Road – Upstream	291.01	10	289.94	**291.24**	**291.39**	**291.48**	**291.57**
Booker Creek Road – Downstream	274.01	10	272.02	**274.26**	**275.02**	**275.36**	**275.63**

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

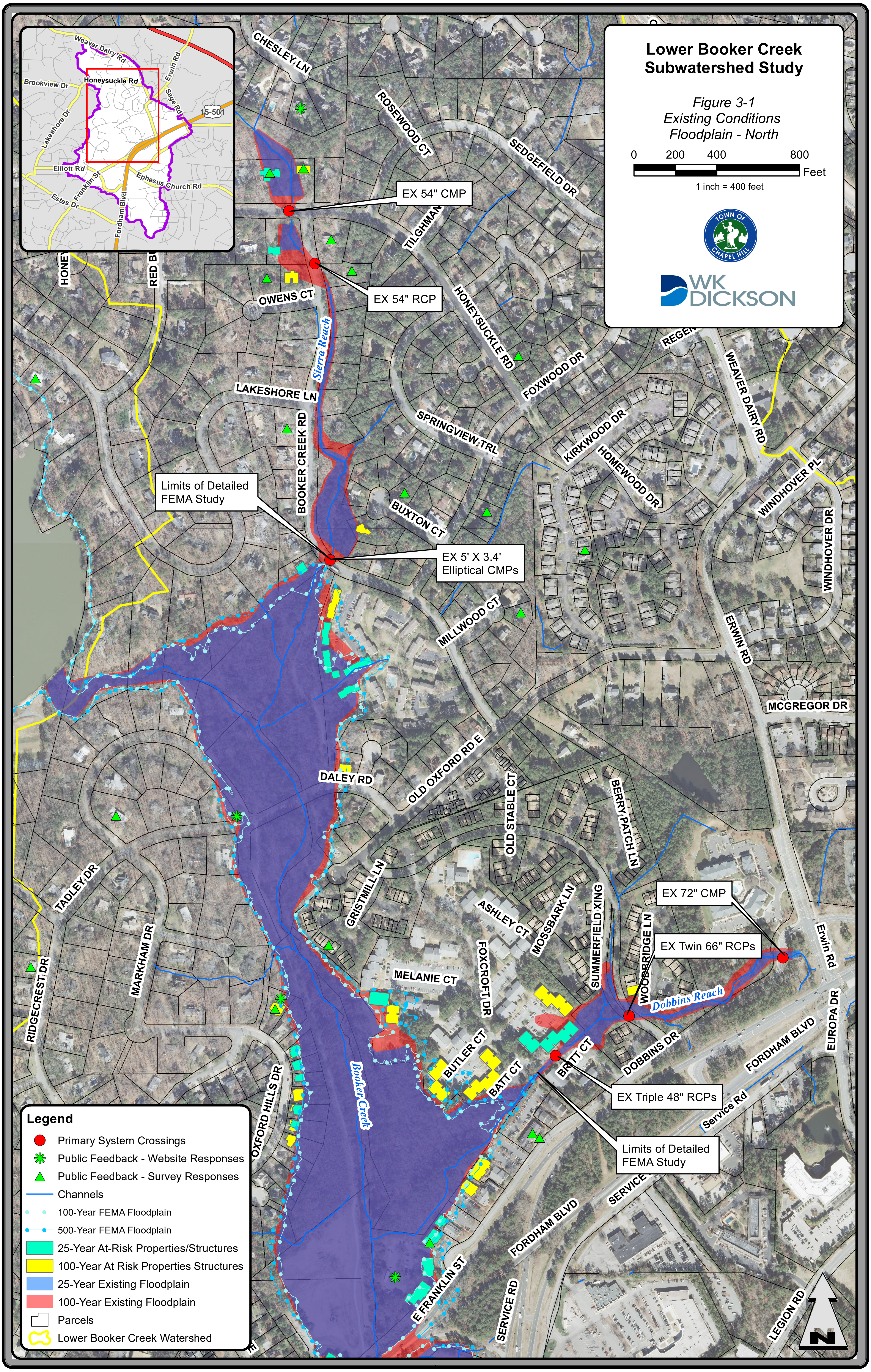
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

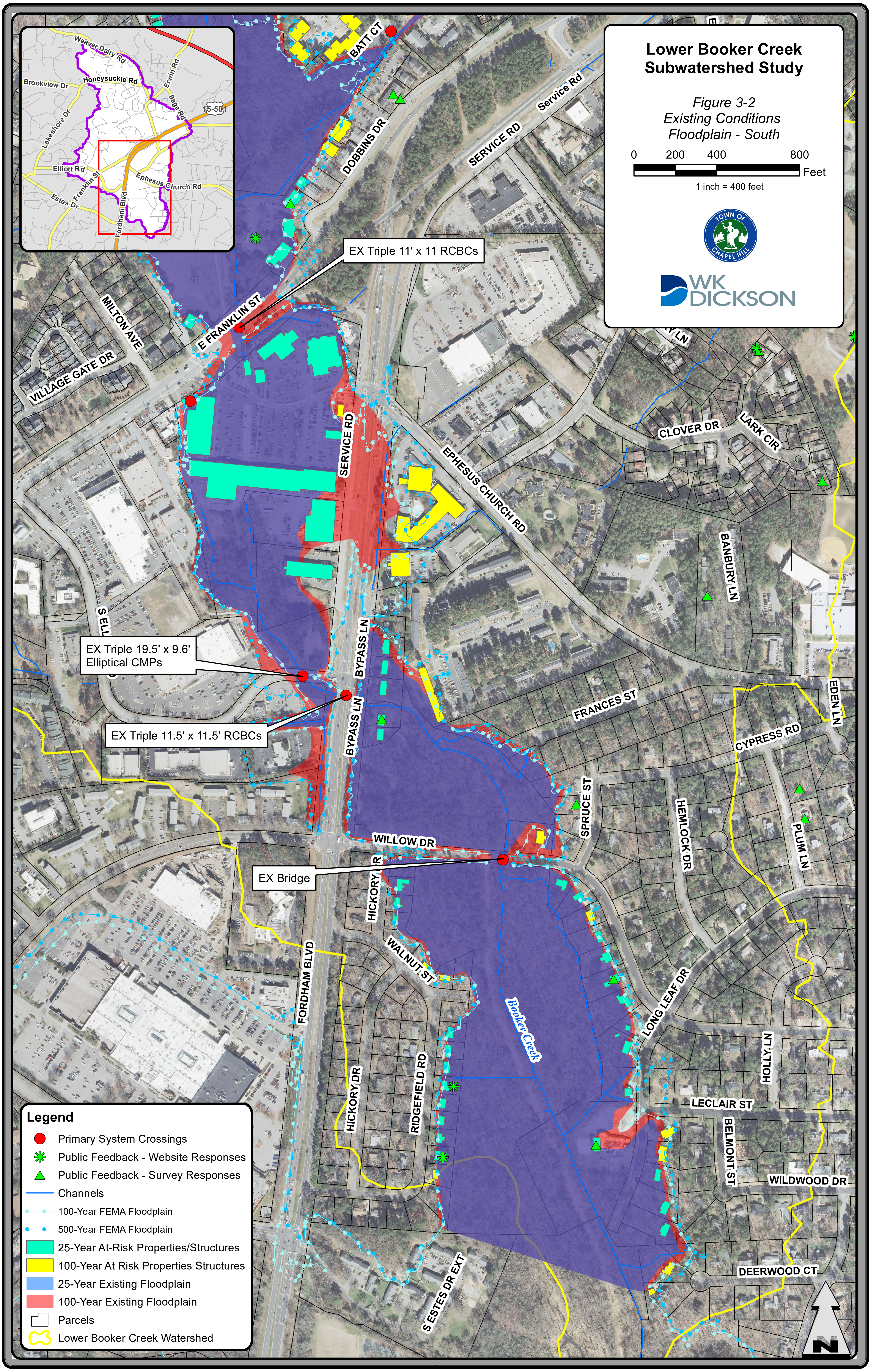
In addition to evaluating the roadway crossings, an evaluation was performed to determine the residences along the primary system streams that are at risk of flooding during the 25- and 100-year storm event. The existing 25- and 100-year floodplains for these streams are shown in Figures 3-1 and 3-2. The mapped floodplains are based on model results developed as part of this subwatershed plan and may differ from the published FEMA floodplains. For flood insurance purposes, the effective FEMA floodplain should be referenced. For structures outside of the 100-year effective FEMA floodplain, property owners must determine if purchasing flood insurance is necessary. The Town is not responsible for determining if flood insurance is required or for notifying property owners of the potential risk of flooding.

As shown in Tables B-14 and B-15 of Appendix B, fifty-one (51) structures along Booker Creek were identified for being at risk of flooding in the 25-year storm event and an additional sixteen (16) were identified for the 100-year event. Existing conditions model results were validated with the feedback received during the outreach process. Model parameters were adjusted as appropriate to more closely match the results from the models to observed conditions. See Appendix B for more details on the validation process.

Several offices in Franklin Square and apartment buildings in Foxcroft Apartments are at risk for being flooded in the 25- and 100-year storm events along the Dobbins Reach (See Tables B-14 and B-15 of Appendix B). Three (3) questionnaires were submitted indicating that the Franklin Square Offices parking lot experiences flooding two (2) to three (3) times per year.

As shown in Tables B-14 and B-15 of Appendix B, eight (8) structures along the Sierra Reach were identified for being at risk of flooding in the 25-year storm event and an additional two (2) were identified for the 100-year event. There were several accounts of yard and street flooding reported along this reach particularly upstream of Honeysuckle Road and along Booker Creek Road.


Lower Booker Creek
Subwatershed Study
Figure 3-1
Existing Conditions
Floodplain - North
0 200 400 800
Feet
1 inch = 400 feet
TOWN OF CHAPEL HILL
WK DICKSON
EX 54" CMP
EX 54" RCP
Limits of Detailed FEMA Study
EX 5' X 3.4' Elliptical CMPs
EX 72" CMP
EX Twin 66" RCPs
EX Triple 48" RCPs
Limits of Detailed FEMA Study
Sierra Reach
Booker Creek
Dobbins Reach
Weaver Dairy Rd
Honeysuckle Rd
Brookview Dr
Erwin Rd
Sage Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
CHESLEY LN
ROSEWOOD CT
SEDGEFIELD DR
TILGHMAN
OWENS CT
HONEYSUCKLE RD
FOXWOOD DR
REGENT
WEAVER DAIRY RD
LAKESHORE LN
BOOKER CREEK RD
SPRINGVIEW TRL
KIRKWOOD DR
HOMEWOOD DR
WINDHOVER PL
WINDHOVER DR
BUXTON CT
MILLWOOD CT
ERWIN RD
MCGREGOR DR
DALEY RD
OLD OXFORD RD E
OLD STABLE CT
BERRY PATCH LN
TADLEY DR
GRISTMILL LN
ASHLEY CT
MOSSBARK LN
SUMMERFIELD XING
WOODBRIDGE LN
Erwin Rd
RIDGECREST DR
MARKHAM DR
MELANIE CT
FOXCROFT DR
BUTLER CT
BATT CT
BRITT CT
DOBBINS DR
FORDHAM BLVD
EUROPA DR
OXFORD HILLS DR
Service Rd
SERVICE
FORDHAM BLVD
E FRANKLIN ST
SERVICE RD
LEGION RD
HONEY
RED B
Legend
Primary System Crossings
Public Feedback - Website Responses
Public Feedback - Survey Responses
Channels
100-Year FEMA Floodplain
500-Year FEMA Floodplain
25-Year At-Risk Properties/Structures
100-Year At Risk Properties Structures
25-Year Existing Floodplain
100-Year Existing Floodplain
Parcels
Lower Booker Creek Watershed
N



Lower Booker Creek Subwatershed Study
Figure 3-2
Existing Conditions
Floodplain - South
0 200 400 800
Feet
1 inch = 400 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Erwin Rd
Brookview Dr
Sage Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
BATT CT
DOBBINS DR
SERVICE RD
Service Rd
EX Triple 11' x 11 RCBCs
MILTON AVE
E FRANKLIN ST
VILLAGE GATE DR
SERVICE RD
EPHESUS CHURCH RD
CLOVER DR
LARK CIR
BANBURY LN
S ELLIOTT RD
EX Triple 19.5' x 9.6' Elliptical CMPs
BYPASS LN
BYPASS LN
EX Triple 11.5' x 11.5' RCBCs
FRANCES ST
EDEN LN
CYPRESS RD
SPRUCE ST
HEMLOCK DR
PLUM LN
WILLOW DR
EX Bridge
HICKORY DR
WALNUT ST
FORDHAM BLVD
Booker Creek
LONG LEAF DR
HOLLY LN
HICKORY DR
RIDGEFIELD RD
LECLAIR ST
BELMONT ST
WILDWOOD DR
S ESTES DR EXT
DEERWOOD CT
Legend
Primary System Crossings
Public Feedback - Website Responses
Public Feedback - Survey Responses
Channels
100-Year FEMA Floodplain
500-Year FEMA Floodplain
25-Year At-Risk Properties/Structures
100-Year At Risk Properties Structures
25-Year Existing Floodplain
100-Year Existing Floodplain
Parcels
Lower Booker Creek Watershed
N

3.2 SECONDARY SYSTEM HYDROLOGIC AND HYDRAULIC ANALYSES

While Booker Creek, Dobbins Reach, and Sierra Reach are the primary sources of flooding within the watershed, undersized systems can also lead to structural and roadway flooding. Based on the questionnaire responses, public meetings, and feedback from City staff, eight (8) secondary systems were identified for further evaluation. The secondary systems evaluated are:

- Chesley Lane Closed System;
- Booker Creek Road/Lakeshore Lane Closed System;
- Old Oxford Road/Booker Creek Road System;
- Old Oxford Road System;
- Markham Drive/Old Oxford Road Closed System;
- Wood Circle/Velma Road System;
- Summerfield Crossing System; and
- Ephesus Church Road System.

3.2.1 HYDROLOGY

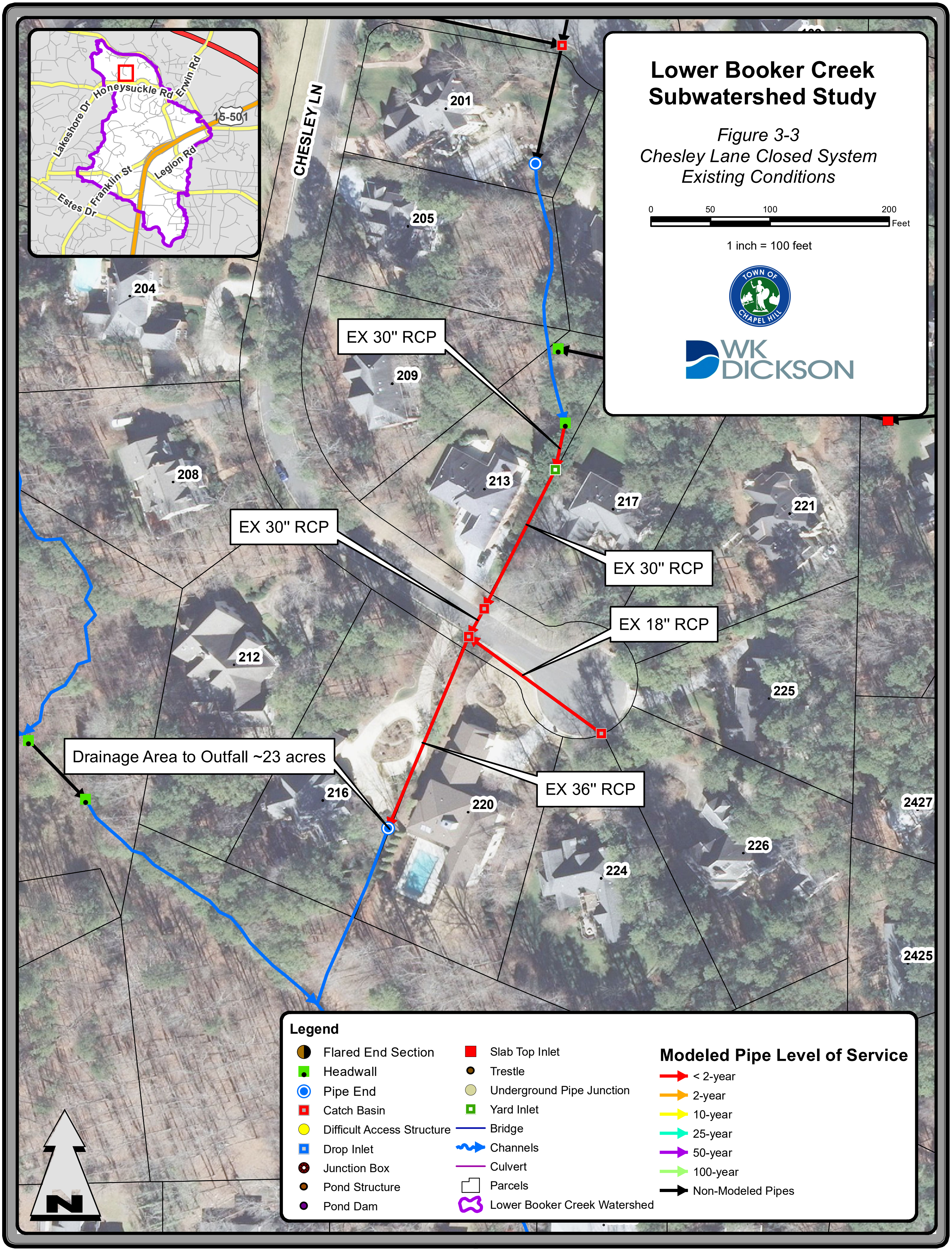
Three (3) models were used in the hydrologic evaluation of the secondary systems: HEC-HMS, EPA Storm Water Management Model (SWMM), and Hydraflow Storm Sewers. For the larger more complex secondary systems (Old Oxford Road/Booker Creek Road, Summerfield Crossing, and Ephesus Church Road Systems), SWMM was selected as the hydrologic and hydraulic model. Smaller systems that were completely closed systems including Chesley Lane, Booker Creek Road/Lakeshore Lane, and Markham Drive/Old Oxford Road were modeled using Rational flow calculations within Hydraflow Storm Sewers. HEC-HMS was used to model the Old Oxford Road and Wood Circle/Velma Road Systems. A detailed description about the hydrologic modeling methodology used for the systems analyzed as part of this report is included in Appendix A.

3.2.2 HYDRAULICS

Chesley Lane Closed System

The Chesley Lane Closed System collects drainage from approximately 22 acres in the Chesley subdivision. It discharges to a channel section that outlets to an unnamed tributary of Booker Creek (Sierra Reach). The conveyance system is comprised of RCPs ranging in size from 18 to 36 inches in diameter that is in good condition based on data collected during the inventory.

Figure 3-3 shows the level of service being provided by the existing closed system. The model results show that the existing system is operating below the desired 10-year level of service. As reported by the resident at 226 Chesley Lane and shown by the existing conditions model, the water is not being captured due to a limited number of inlets. There is only one (1) inlet in the



Lower Booker Creek Subwatershed Study
Figure 3-3
Chesley Lane Closed System
Existing Conditions
0 50 100 200 Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
CHESLEY LN
EX 30" RCP
EX 30" RCP
EX 30" RCP
EX 18" RCP
EX 36" RCP
Drainage Area to Outfall ~23 acres
201
205
204
209
208
213
217
221
212
225
216
220
2427
226
224
2425
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

cul-de-sac at the sag point and it is inadequate to capture the design flow. It exceeds the allowable stormwater spread limits outlined in the Town's Design Manual.

Booker Creek Road/Lakeshore Lane System

The Booker Creek Road/Lakeshore Lane System collects drainage from approximately 10 acres in the Lake Forest subdivision. It discharges to a trapezoidal channel section that outlets to an unnamed tributary of Booker Creek (Sierra Reach). The conveyance system is comprised of 15" and 18" RCPs. Based on data collected during the inventory, the pipes are in good condition. The closed system which crosses Lakeshore Lane and Booker Creek Road is connected by an open channel section with a 4-foot high bank, a 3-foot bottom width, and a 12-foot top width. There is one (1) report of flooding adjacent to this system. The resident at 397 Lakeshore Lane has reported experiencing yard flooding at least once a year and first floor water damage during the summer of 2013. There are also reports of the channel being filled with sediment.

Figure 3-4 shows the level of service being provided by the existing closed system. The model results show that the existing system is operating below the desired 10-year level of service. The majority of the system is operating at a 2-year level of service while the lower portion of the system is operating below a 2-year level of service. This can be attributed to the existing pipes being undersized and unable to accommodate the amount of flow it is currently receiving from the drainage area. Backwater from Booker Creek also contributes to the capacity of the existing system and should be accounted for in the development of a proposed solution.

Old Oxford Road/Booker Creek Road System

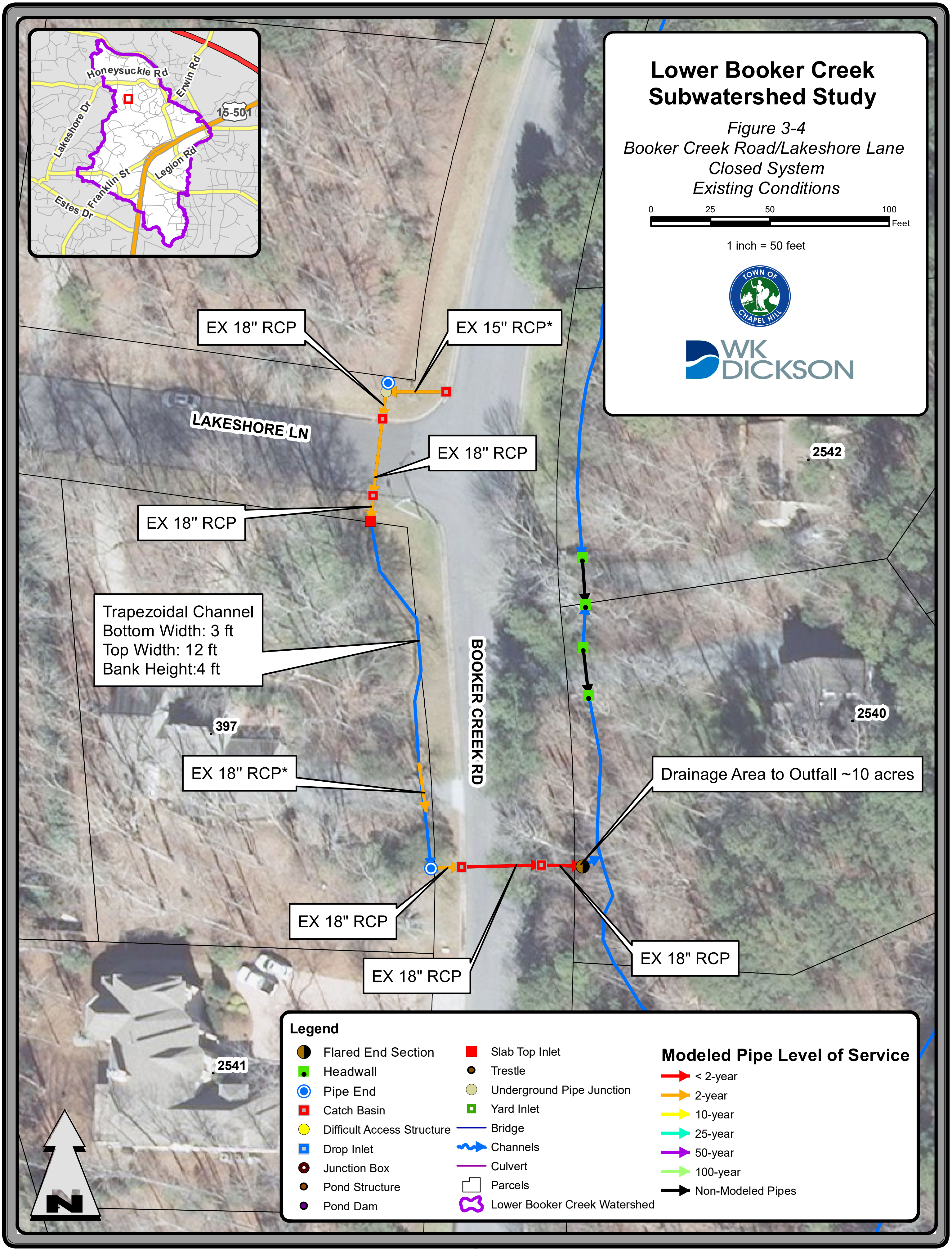
The Old Oxford Road/Booker Creek Road System collects drainage from approximately 75 acres from sections of the Booker Creek Townhouse Apartments, Kirkwood Condominiums, and adjacent residential parcels. It discharges to a channel section that outlets to Booker Creek. The conveyance system is comprised of RCPs ranging in size from 15 to 42 inches, as well as 42" CMP. The upper portion of the system carries drainage from Old Oxford Road through a series of yards before conveying drainage across Booker Creek Road. Based on data collected during the inventory, the pipes are in good condition.

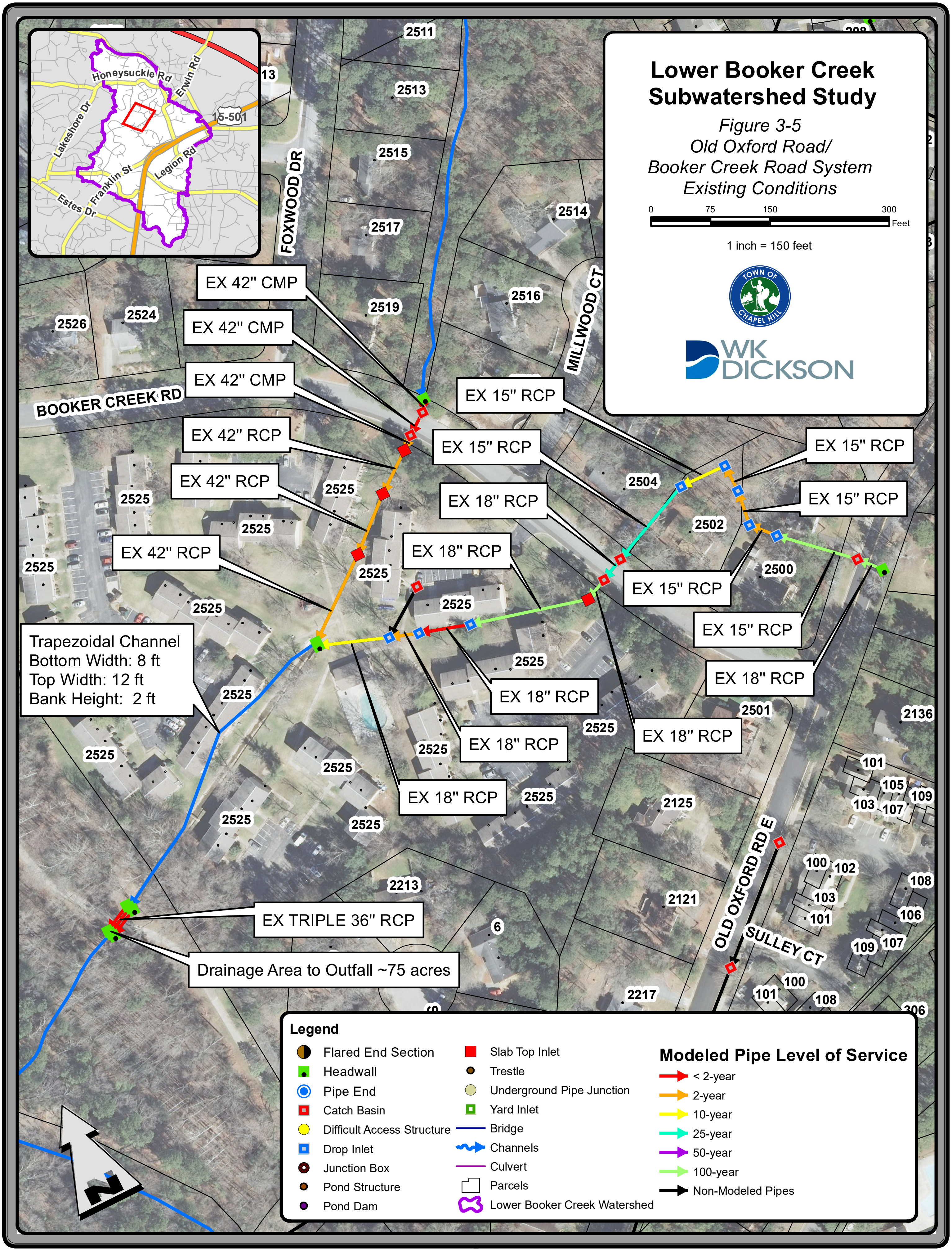
Figure 3-5 shows the level of service being provided by the existing closed system. The model results show that the majority of the existing system is operating below the desired 10-year level of service. The existing 42" RCP and CMP segments are operating at or below a 2-year level of service. The underperformance of these segments is caused by the large contributing drainage area. The majority of the upstream Kirkwood Condos drain to a channel that outlets to the 48" CMP at Booker Creek Road. There are several reports of yard flooding in this upstream area. At the downstream end of the system, the triple 36" RCPs under the Booker Creek greenway are performing below a 2-year level of service. This can be attributed to the backwater from the Booker Creek primary system.

It should be noted that there are several segments of the existing closed system that are performing at or above a 10-year level of service.

Lower Booker Creek Subwatershed Study

Figure 3-4
Booker Creek Road/Lakeshore Lane
Closed System
Existing Conditions





Lower Booker Creek Subwatershed Study
Figure 3-5
Old Oxford Road/
Booker Creek Road System
Existing Conditions
0
75
150
300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
FOXWOOD DR
BOOKER CREEK RD
MILLWOOD CT
OLD OXFORD RD E
SULLEY CT
EX 42" CMP
EX 42" CMP
EX 42" CMP
EX 42" RCP
EX 42" RCP
EX 42" RCP
EX 15" RCP
EX 15" RCP
EX 18" RCP
EX 18" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
Trapezoidal Channel
Bottom Width: 8 ft
Top Width: 12 ft
Bank Height: 2 ft
EX TRIPLE 36" RCP
Drainage Area to Outfall ~75 acres
2511
2513
2515
2517
2519
2514
2516
2524
2526
2525
2504
2502
2500
2501
2136
2125
2121
2213
2217
6
101
105
109
103
107
100
102
108
106
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

Old Oxford Road System

The Old Oxford Road System collects drainage from approximately 24 acres in the Lake Forest subdivision. It discharges to an unnamed tributary of Booker Creek. The conveyance system is comprised of 24" and 36" RCPs. The 24" RCP crosses Old Oxford Road and outlets to a 36" RCP along with a non-modeled lateral system. There is a report of street flooding from the resident at 1612 Old Oxford Road.

Figure 3-6 shows the level of service being provided by the existing closed system. The model results show that the existing system is operating at a 50-year level of service which exceeds the desired 10-year level of service. The primary flooding issue for this area appears to be the lack of infrastructure along Old Oxford Road between Eastwood Lake Road and the culvert crossing adjacent to 1700 Old Oxford Road.

Markham Drive/Old Oxford Road Closed System

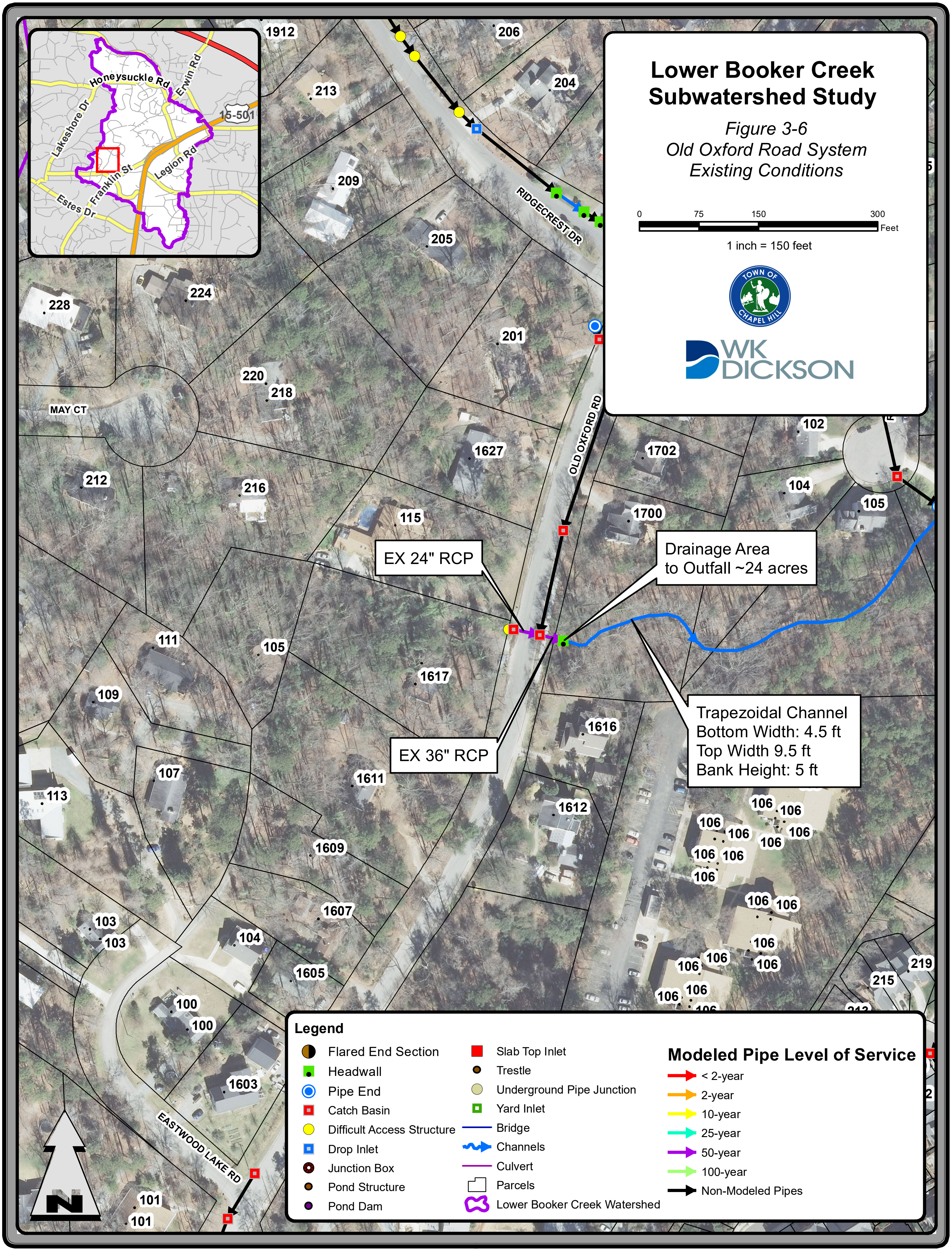
The Markham Drive/Old Oxford Road Closed System collects drainage from approximately 7 acres from sections of the Lake Forest, Oxford Hills, and Clark Hills subdivisions. It discharges adjacent to the property located at 224 Oxford Hill Drive. The conveyance system is comprised of RCPs ranging in size from 15 to 24 inches and is in good condition based on data collected during inventory. There is one (1) report of flooding adjacent to this system. It is a report of street and yard flooding from the resident at 226 Oxford Hill Drive.

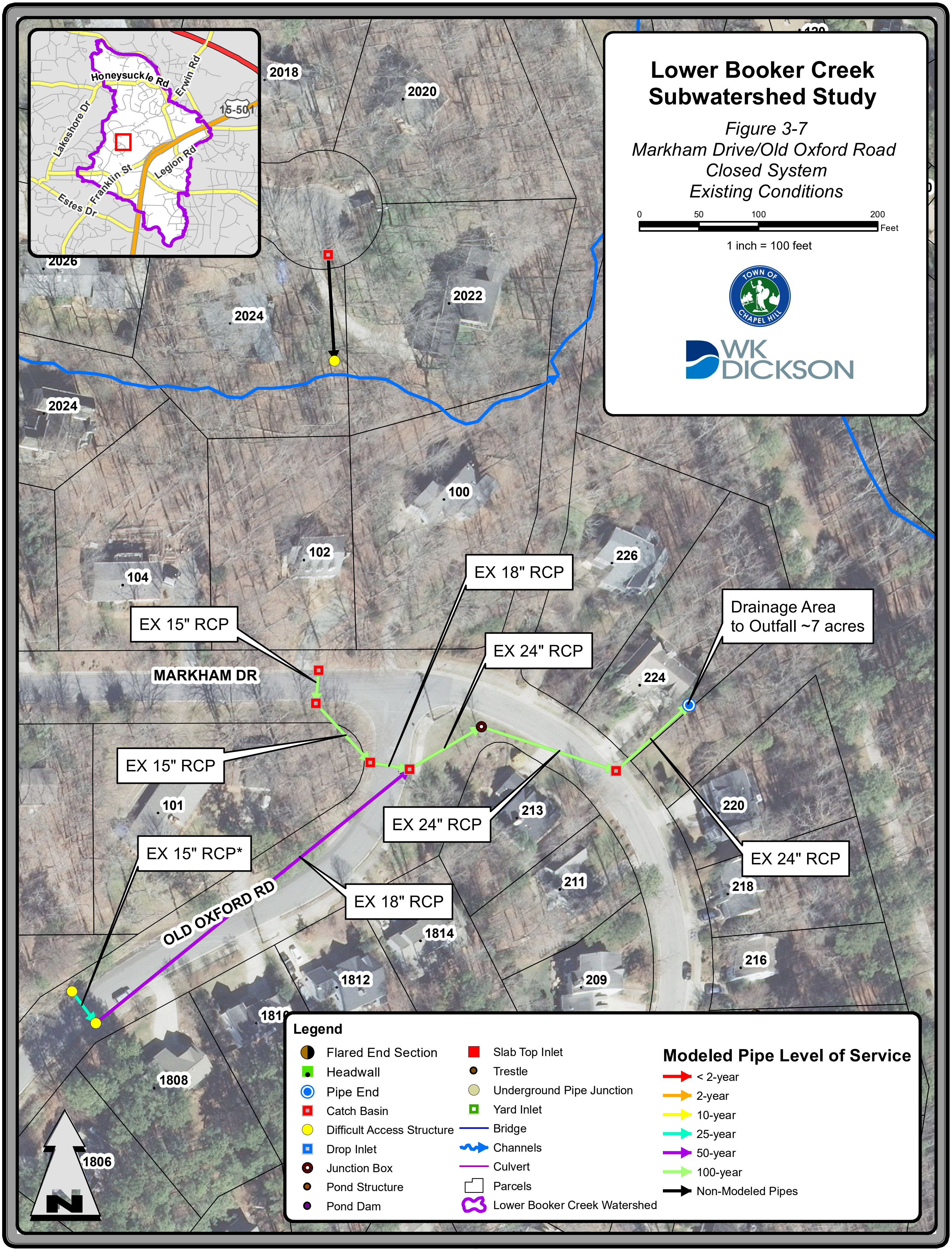
Figure 3-7 shows the level of service being provided by the existing closed system. The model results show that the existing system is operating above the desired 10-year level of service. However, there are segments of the system where the hydraulic grade line surcharges the pipe. One of the main drainage issues for this system is there are no drainage structures along Old Oxford Road between Oxford Hills Drive and 1808 Old Oxford Road. Water generally drains from high terrain west of Old Oxford Road onto the properties east of Old Oxford Road that are below the roadway elevation. Flows that exceed the gutter capacity can cause flooding issues on the properties that are lower in elevation.

Wood Circle/Velma Road System

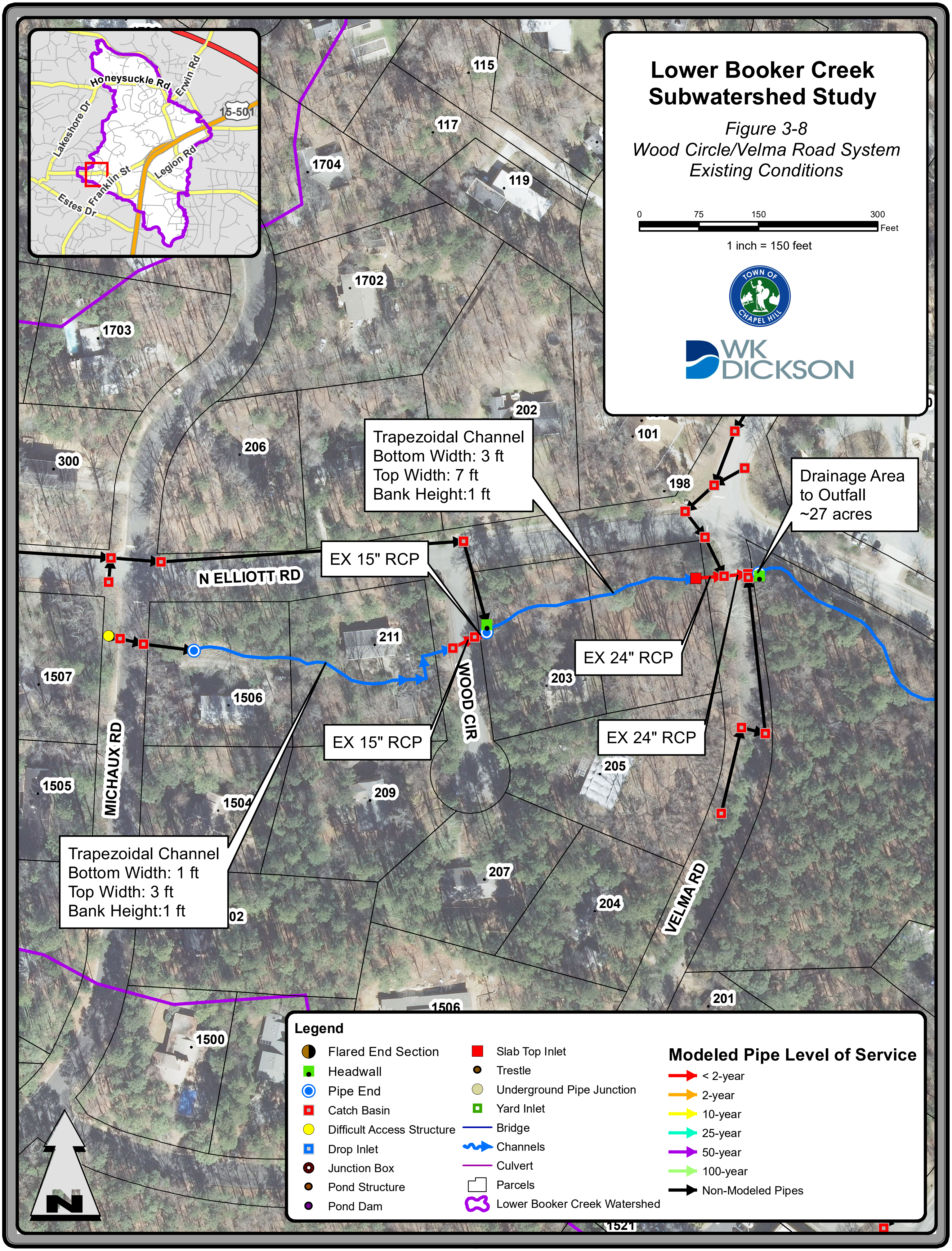
The Wood Circle/Velma Road System collects drainage from approximately 27 acres in the Coker Hills and Vernon Hills subdivisions. It discharges to a trapezoidal channel section paralleling North Elliott Road. The conveyance system is comprised of 15" RCPs that cross Wood Circle and 24" RCPs that cross Velma Road. These culverts are connected by open channel sections that have a 1-foot high bank with bottom widths ranging from 1 to 3 feet and top widths ranging from 3 to 9 feet. Based on data collected during the inventory, the pipes are in good condition.

Figure 3-8 shows the level of service being provided by the existing closed system. The model results show that the existing system is operating below a 2-year level of service. There is one (1) report of flooding adjacent to this system. The resident at 211 North Elliott Road has reported experiencing yard flooding at two (2) to three (3) times per year and street flooding at least once a year.


Lower Booker Creek Subwatershed Study
Figure 3-6
Old Oxford Road System
Existing Conditions
0
75
150
300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
RIDGECREST DR
OLD OXFORD RD
MAY CT
EASTWOOD LAKE RD
EX 24" RCP
EX 36" RCP
Drainage Area
to Outfall ~24 acres
Trapezoidal Channel
Bottom Width: 4.5 ft
Top Width 9.5 ft
Bank Height: 5 ft
1912
206
204
213
209
205
224
228
201
220
218
1627
1702
102
212
216
115
1700
104
105
111
105
1617
109
1616
107
1611
113
1612
1609
1607
103
103
104
1605
100
100
1603
101
101
219
215
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N



Lower Booker Creek Subwatershed Study
Figure 3-7
Markham Drive/Old Oxford Road
Closed System
Existing Conditions
0 50 100 200 Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
2018
2020
2022
2024
2026
2024
100
102
104
226
224
220
218
216
213
211
209
101
1814
1812
1810
1808
1806
MARKHAM DR
OLD OXFORD RD
EX 18" RCP
EX 15" RCP
EX 24" RCP
Drainage Area to Outfall ~7 acres
EX 15" RCP
EX 24" RCP
EX 24" RCP
EX 15" RCP*
EX 18" RCP
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N



Lower Booker Creek Subwatershed Study
Figure 3-8
Wood Circle/Velma Road System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 7 ft
Bank Height:1 ft
Drainage Area
to Outfall
~27 acres
EX 15" RCP
EX 24" RCP
EX 15" RCP
EX 24" RCP
Trapezoidal Channel
Bottom Width: 1 ft
Top Width: 3 ft
Bank Height:1 ft
N ELLIOTT RD
MICHAUX RD
WOOD CIR
VELMA RD
115
117
119
1704
1702
1703
202
101
206
300
198
211
1507
1506
203
205
1505
1504
209
207
204
201
1500
1521
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

Summerfield Crossing System

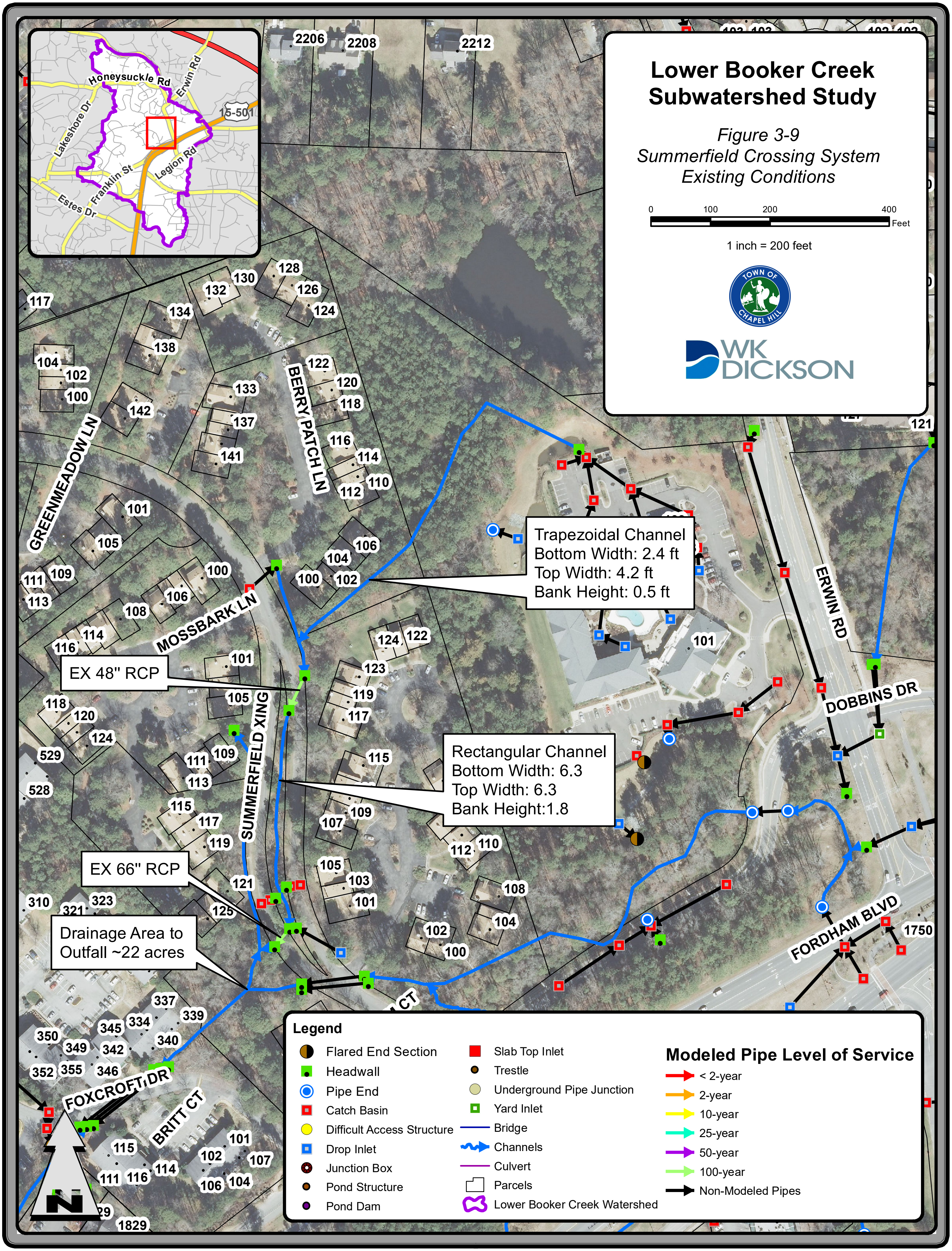
The Summerfield Crossing System collects drainage from approximately 22 acres from sections of the Summerfield Crossing Condominiums, Old Oxford Green subdivision and the adjacent hotel property. It discharges to an unnamed tributary of Booker Creek (Dobbins Reach) before it outlets to Booker Creek. The conveyance system is comprised of 48″ and 66″ RCP culverts crossing Summerfield. Based on data collected during the inventory, the pipes are in good condition. These culverts are connected by open channel sections that have bank heights ranging from 0.5 to 1.8 feet with bottom widths ranging from 2.4 to 6.3 feet and top widths ranging from 4.2 to 6.3 feet.

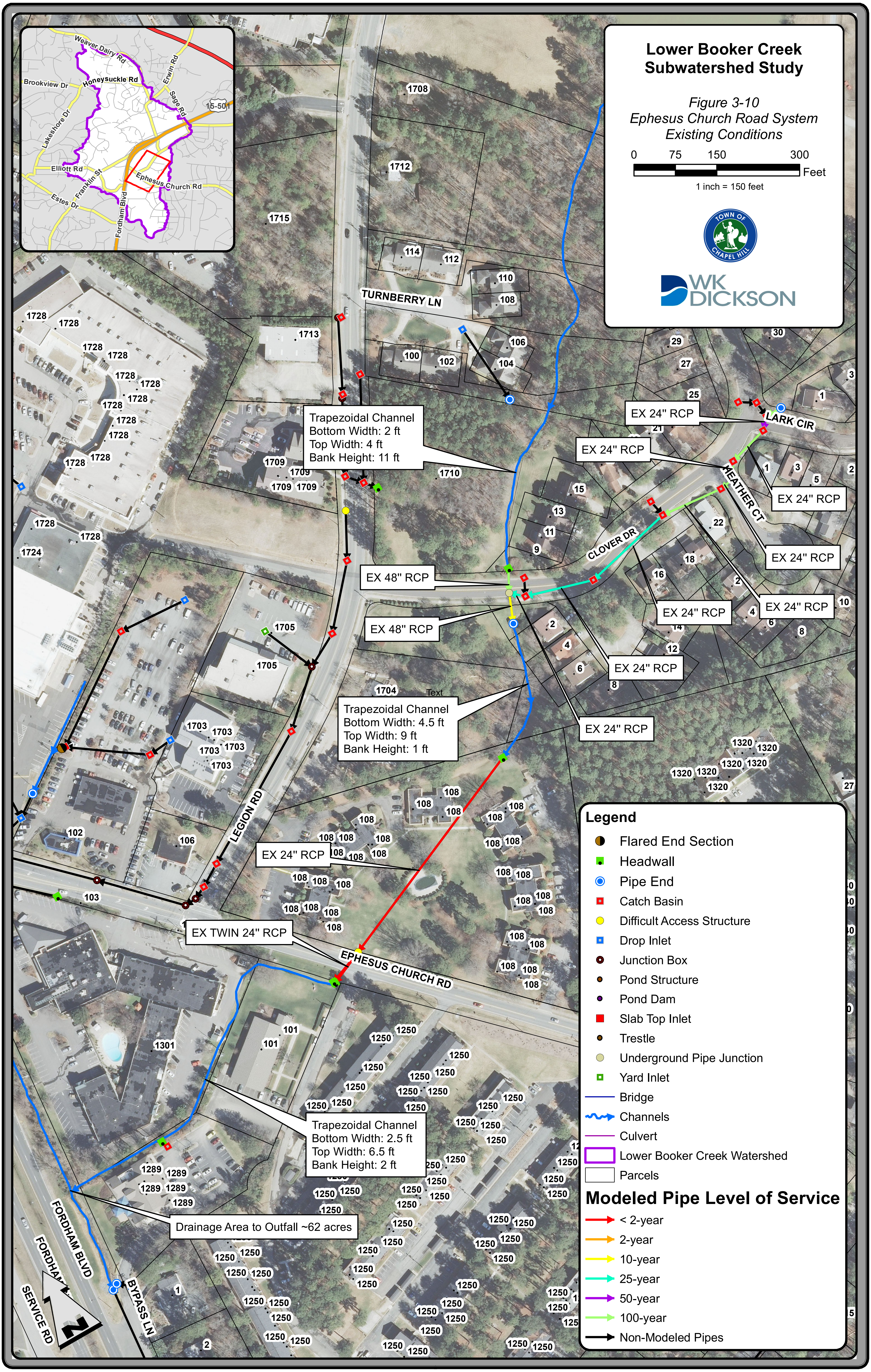
Figure 3-9 shows the level of service being provided by the existing system. The model results show that the existing system is operating above the desired 10-year level of service. However, the upstream trapezoidal channel frequently overtops and private drainage structures are oftentimes overwhelmed causing flooding along Berry Patch Lane. The existing pond located to the northeast of Berry Patch Lane appears to have no engineered outlet. As water flows out of the pond it is conveyed in an uncontrolled manner towards the units along Berry Patch Lane. The pond may potentially be reconfigured as part of the proposed Oxford Reserve development which is currently under review by the Town.

Ephesus Church Road System

The Ephesus Church Road System collects drainage from approximately 62 acres from sections of several high density residential areas including Colony and King's Arms Apartments, Oxford Condominiums, and Hamlin Park. It discharges to a roadside ditch along Fordham Boulevard that outlets to Booker Creek. The conveyance system is comprised of RCPs ranging in size from 15 to 48 inches. Based on data collected during the inventory, the pipes are in good condition.

Figure 3-10 shows the level of service being provided by the existing closed system. The model results show that there are segments of existing system operating below the desired 10-year level of service. The portion of the system downstream of Clover Drive including the 24″ RCP that travels through Hamlin Park, and the twin 24″ RCPs that cross Ephesus Church Road are all operating at or below a 2-year level of service. The 24″ RCP segments along Clover Road are meeting the desired level of service. The configuration of the drainage system will likely be impacted by the proposed road extensions of Legion Road and South Elliott Road.


Lower Booker Creek Subwatershed Study
Figure 3-9
Summerfield Crossing System
Existing Conditions
0
100
200
400
Feet
1 inch = 200 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
Trapezoidal Channel
Bottom Width: 2.4 ft
Top Width: 4.2 ft
Bank Height: 0.5 ft
EX 48" RCP
Rectangular Channel
Bottom Width: 6.3
Top Width: 6.3
Bank Height:1.8
EX 66" RCP
Drainage Area to
Outfall ~22 acres
GREENMEADOW LN
BERRY PATCH LN
MOSSBARK LN
SUMMERFIELD XING
ERWIN RD
DOBBINS DR
FORDHAM BLVD
FOXCROFT DR
BRITT CT
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes


Lower Booker Creek Subwatershed Study
Figure 3-10
Ephesus Church Road System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Brookview Dr
Erwin Rd
Sage Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
TURNBERRY LN
LARK CIR
HEATHER CT
CLOVER DR
LEGION RD
EPHESUS CHURCH RD
FORDHAM BLVD
BYPASS LN
SERVICE RD
Trapezoidal Channel
Bottom Width: 2 ft
Top Width: 4 ft
Bank Height: 11 ft
Trapezoidal Channel
Bottom Width: 4.5 ft
Top Width: 9 ft
Bank Height: 1 ft
Trapezoidal Channel
Bottom Width: 2.5 ft
Top Width: 6.5 ft
Bank Height: 2 ft
EX 24" RCP
EX 48" RCP
EX TWIN 24" RCP
Drainage Area to Outfall ~62 acres
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Lower Booker Creek Watershed
Parcels
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes

3.3 STREAM STABILITY FIELD ASSESSMENTS

The following overview and description of the Little Creek watershed, where the LBC sub-basin is located, are excerpted in part from a report by the North Carolina Department of Environment and Natural Resources, *Assessment Report - Biological Impairment in the Little Creek Watershed* (June 2003).

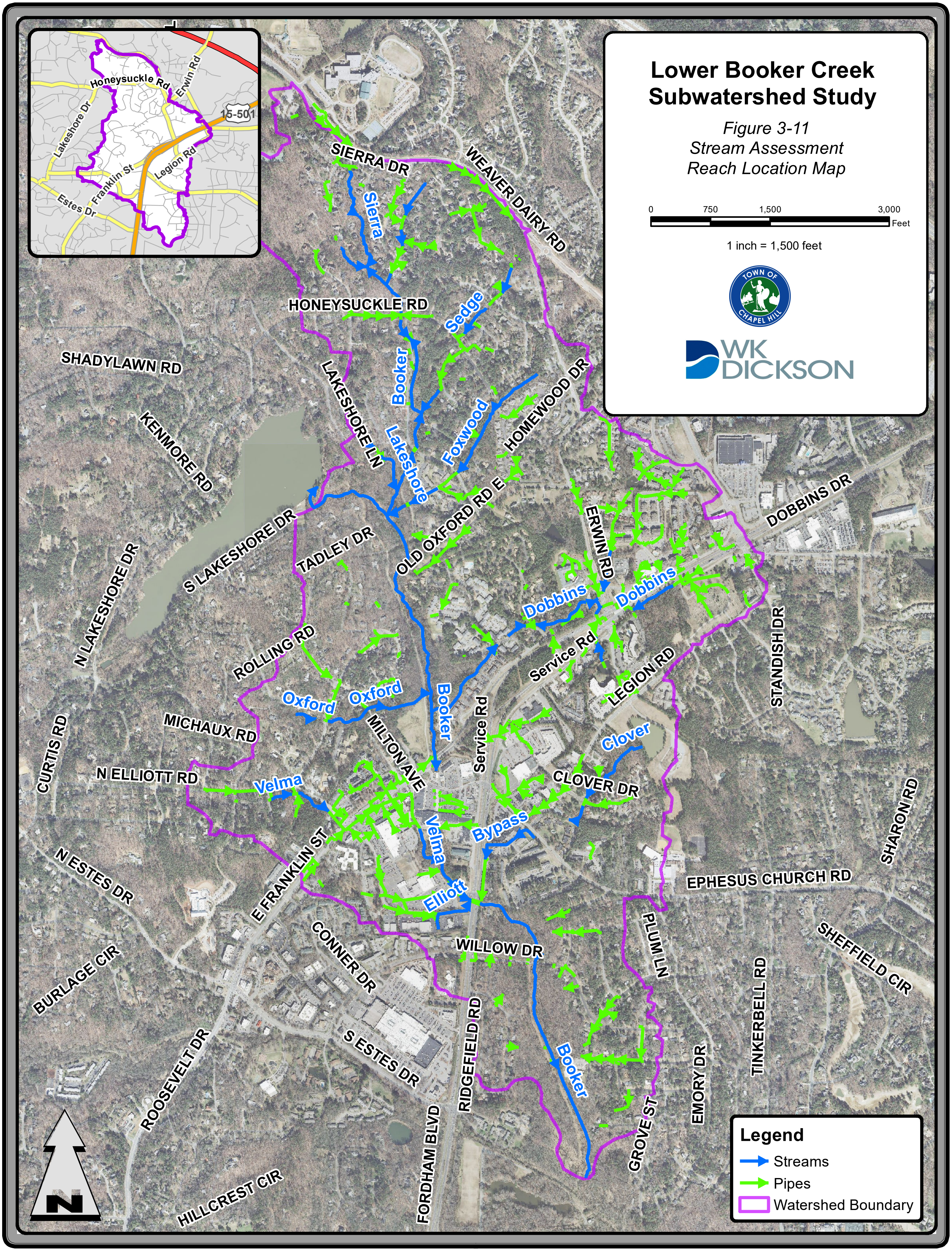
Located in Orange and Durham Counties, Little Creek flows into the New Hope arm of B. Everett Jordan Lake, draining a 24.6-square mile area in sub-basin 03-06-06 of the Cape Fear River basin. Two major tributaries, Booker Creek and Bolin Creek, drain the majority of the Little Creek catchment. The watershed includes extensive areas of residential and commercial development, as well as a portion of the campus of the University of North Carolina at Chapel Hill (UNC). The upper three quarters of this area lies in the Carolina Slate Belt, and streams here exhibit the narrow valleys and rocky substrates associated with this geologic zone. Little Creek and the downstream reaches of Booker and Bolin Creek are located in a Triassic Basin and exhibit its characteristic broad floodplains and sandy substrates. Visual assessment suggests that most streams downstream of East Franklin Street were channelized (straightened and dredged) in the past. An OWASA sewer easement follows Booker, Bolin and Little Creeks for much of their lengths.

3.3.1 BOOKER CREEK

The headwaters of Booker Creek rise southwest of the intersection of Martin Luther King Jr. Boulevard (NC 86) and Weaver Dairy Road in Chapel Hill. Booker Creek is joined by two named tributaries: Cedar Fork and Crow Branch. The mainstem of Booker Creek has been dammed to create Lake Ellen (surface area of seven acres, built in 1961) and, further downstream, Eastwood Lake. Unlike Bolin Creek, which drains progressively more developed areas as it flows downstream, most of the Booker Creek watershed is heavily developed.

3.3.2 METHODS

Intermittent and perennial streams were estimated in the LBC subwatershed using U.S. Geological Survey and Town of Chapel Hill GIS data. The identified reaches were assessed by physically walking the channels and making on-site observations. The goal of the stream walk was to identify points or reaches of streams within the LBC subwatershed that may be contributing to the degradation of water quality, aquatic habitat, or stream stability. Stream assessment protocols utilized during the stream walk facilitated the categorization of the types of degradation encountered (e.g., eroding stream banks, eroding stream crossings or outfalls, channel head-cutting, impacted riparian buffers, poor instream habitat, etc.). The total length of stream channel assessed was in excess of 36,000 linear feet, or approximately seven (7) miles (See Figure 3-11).


Lower Booker Creek
Subwatershed Study
Figure 3-11
Stream Assessment
Reach Location Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Pipes
Watershed Boundary
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
SIERRA DR
WEAVER DAIRY RD
Sierra
HONEYSUCKLE RD
Sedge
SHADYLAWN RD
LAKESHORE LN
Booker
KENMORE RD
Foxwood
HOMEWOOD DR
LakeShore
OLD OXFORD RD E
S LAKESHORE DR
TADLEY DR
DOBBINS DR
ERWIN RD
N LAKESHORE DR
Dobbins
Dobbins
Service Rd
ROLLING RD
LEGION RD
STANDISH DR
Oxford
Oxford
Booker
MICHAUX RD
MILTON AVE
Service Rd
CURTIS RD
Clover
N ELLIOTT RD
Velma
CLOVER DR
SHARON RD
Velma
Bypass
E FRANKLIN ST
N ESTES DR
EPHESUS CHURCH RD
Elliott
CONNER DR
WILLOW DR
PLUM LN
SHEFFIELD CIR
BURLAGE CIR
TINKERBELL RD
S ESTES DR
RIDGEFIELD RD
Booker
ROOSEVELT DR
EMORY DR
GROVE ST
FORDHAM BLVD
HILLCREST CIR
N

Two (2) assessment protocols were used to evaluate stream stability and stream and riparian corridor habitat. The first, focusing mainly on stream stability, was drawn from the *Unified Stream Assessment (USA) protocol, Manual 10*, a rapid assessment technique developed by the Center for Watershed Protection, to locate and evaluate problems and restoration opportunities within an urban stream corridor. The other protocol used was taken from the *EPA's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (1999). Specifically, the Habitat Assessment and Physicochemical Parameters methodology described in this protocol was used. It focuses on stream and riparian buffer habitat quality, and utilizes visual observations recorded in the field. The paper forms from both these protocols were converted into electronic forms, and descriptive data, assessment scores, photographs and GPS locations were recorded in the field using data pads.

3.3.3 UNIFIED STREAM ASSESSMENT PROTOCOL DESCRIPTION

Two (2) general types of data were collected for the USA assessment – reach (or stream segment) data and point data.

A separate form was used to document details of each of the following stream/watershed attributes for the USA assessments.

Form No.	Attribute Type	Attribute
1	Point	Stormwater outfalls - 12" and greater, unless smaller outfalls were encountered that were degrading water quality and needed to be documented
2	Point	Severe erosion - using visual estimates
3	Point	Impacted buffers
4	Point	Utilities in the stream corridor
5	Point	Stream crossings, including roadways and pedestrian paths
6	Reach	Reach level assessment

Reach data were generated for sections of stream that exhibited similar channel geomorphology, stability, or erosion characteristics. Consequently, stream segments of varying lengths were delineated in the field and existing conditions were recorded (Form 6). The data recorded on the actual forms included descriptive data, such as surroundings land use, size of dominant channel substrate, stream shading, and approximate bank heights. It also included numerical rating scores, ranging from 0-10 points, and 0-20 points for overall stream conditions characteristics such as:

- Reach accessibility
- In-stream habitat
- Vegetative protection
- Bank erosion
- Floodplain connection
- Vegetated buffer width

- Floodplain vegetation
- Floodplain encroachment

Within each delineated reach, point data were recorded on a separate form (Forms 1 – 5) for each occurrence that one of the following attributes was observed:

- Stormwater outfalls greater than 12” in diameter, or smaller diameter outfalls that appeared to be impacting water quality
- Severe bank erosion
- Impacted buffers
- Utility impacts, such as sewer line crossings
- Stream crossings, such as roads

Point data forms included both descriptive data and numerical data. For stormwater outfalls (Form 1), descriptive data included on which side of the stream the outfall was located, the type of pipe and its material, its shape, condition, and descriptive characteristics of the flow such as odor, the presence of deposits or stains, and if benthic growth was present. The form also included a numeric evaluation of outfall severity, from 0-5 points, that described the outfall discharge, color and smell.

In addition to descriptive and numerical data recorded for the USA assessment, GPS coordinates and a photo log of data collection locations were included also.

3.3.4 EPA RAPID BIOASSESSMENT PROTOCOL (RBP) DESCRIPTION

The Lower Booker Creek subwatershed assessment also applied the Habitat Assessment and Physicochemical Parameters data collection methodology from the EPA Rapid Bioassessment Protocol (RBP). The form for high gradient streams (mountain or piedmont regions) was used. Habitat attribute data collected, based on the RBP, included:

1. Epifaunal substrate/available cover
2. Embeddedness
3. Velocity/depth regime
4. Sediment deposition
5. Channel flow status
6. Channel alteration
7. Frequency of riffles/bends
8. Bank stability
9. Bank vegetative protection
10. Buffer width/condition

Each of the first seven (7) attributes were scored employing a point range of zero (0) to twenty (20) that the assessor could use to estimate the quality of that attribute observed, from poor (0) to optimal (20). The remaining three (3) attributes were assessed using point ranges from one (1) to ten (10) (poor [1] -optimal [10]). For each reach, a habitat assessment score was generated, based on the points scored for each of the attributes.

Using both of the assessment protocols during the stream walks facilitated:

1. The documentation of observable stream channel and riparian buffer conditions along the targeted reaches.
2. Identification of stream channel and riparian buffer problem areas, such as high erosion areas or degraded outfalls, a description of the severity of the problem, and information that will help inform recommendations for correcting problems.
3. Compilation of sufficient data so that problems and potential solutions can be prioritized.

3.3.5 RESULTS AND DISCUSSION

The Booker Creek subwatershed was divided into forty-four (44) individual reaches, based on observations made in the field during stream assessment data collection and relatively similar channel characteristics. The scores for each reach were tabulated in the field for the USA stream stability and EPA habitat assessments.

EPA Habitat Assessment Scores

There are four "Condition" categories for each parameter assessed in the EPA Habitat Assessment and Physiochemical Parameters methodology: they are the same as those used in the USA Stream Stability protocol - Optimal, Suboptimal, Marginal, and Poor. The total maximum score for the EPA protocol is 200 points. The point ranges for the respective categories is as follows:

Category	Point Range
Optimal	166-200
Suboptimal	103-165
Marginal	60-102
Poor	0-59

The EPA protocol does not require comparison of scores to a reference reach score range. The stability scores recorded in the field in the Lower Booker Creek subwatershed ranged from 45 to 170 points, with a mean of 101 points. A summary of stream stability score statistics is included in Table 3-4.

Table 3-4: Statistical Summary of EPA Habitat Assessment Scores

Mean	101
Standard Error	3.8
Median	96.5
Standard Deviation	25.3
Range	125
Minimum	45
Maximum	170

The average score of 101 points falls in the upper range of the marginal category. In a highly developed watershed, this score is not unexpected. The wide range of scores, 45 to 170, indicates that there are streams in poor condition, but that there are also reaches that are stable and in good condition, as were documented with the reach stability scores.

The next step in the analysis process was to group the stream segments into low, medium and high score groups based on their respective score within the range of scores recorded in the field. The Jenks-Natural Breaks algorithm or method, a component of the ESRI GIS software, was used to determine the ranges.

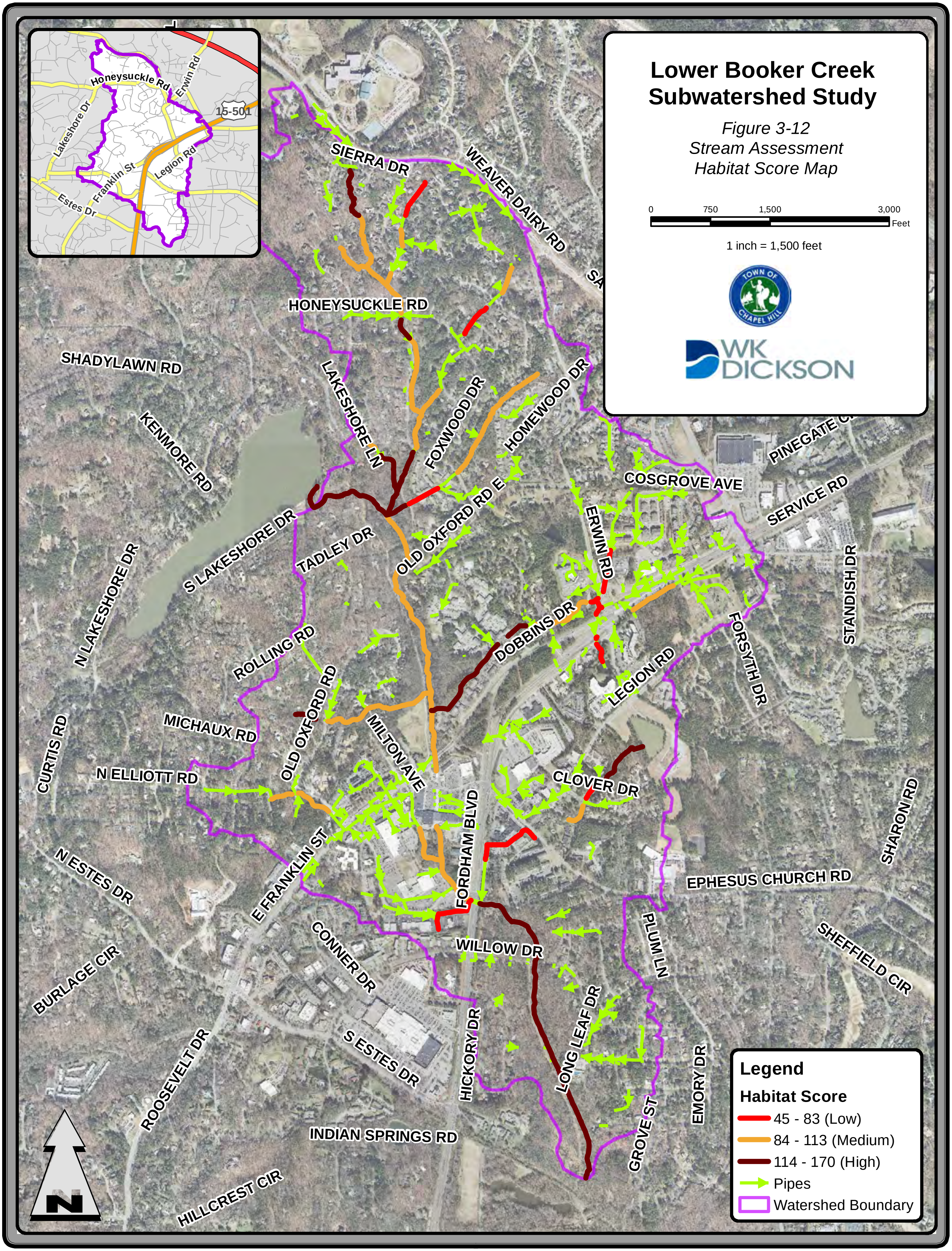
From the ESRI ArcView website, the description of how the Jenks-Natural Breaks algorithm works is as follows. "Classes [or low, medium and high score groups for the stream stability scores] are based on natural groupings inherent in the data. ArcMap identifies break points by picking the class breaks that best group similar values and maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values." And from the ESRI GIS Dictionary, the Jenks-Natural Breaks algorithm is described as follows. "A method of statistical data classification that partitions data into classes using an algorithm that calculates groupings of data values based on the data distribution. Jenks' optimization seeks to reduce variance within groups and maximize variance between groups."

The ranges for habitat scores generated by the Jenks-Natural Breaks algorithm were:

Group	Range	Number of Reaches in Range	Total Length (ft)
Low	45 - 83	10 reaches	4,336
Medium	84 – 113	22 reaches	15,621
High	114 – 170	12 reaches	10,833
			Total: 30,850

The reaches, color-coded by group, are illustrated in Figure 3-12.

From Figure 3-12, the distribution of low, medium and high scoring reaches is spread relatively evenly across the sub-watershed, with no apparent pattern for any of the groups. There are high quality reaches in the upper watershed, on first order streams, and at the downstream end of the watershed too. A substantial portion of the Booker Creek main channel downstream of Fordham Boulevard, in the southern end of the watershed, is in the high range. It is incised with eroding



Lower Booker Creek Subwatershed Study
Figure 3-12
Stream Assessment
Habitat Score Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
SIERRA DR
WEAVER DAIRY RD
HONEYSUCKLE RD
SHADYLAWN RD
LAKESHORE LN
FOXWOOD DR
HOMEWOOD DR
KENMORE RD
PINEGATE CI
COSGROVE AVE
SERVICE RD
ERWIN RD
S LAKESHORE DR
TADLEY DR
OLD OXFORD RD E
N LAKESHORE DR
STANDISH DR
DOBBINS DR
FORSYTH DR
ROLLING RD
LEGION RD
MICHAUX RD
OLD OXFORD RD
MILTON AVE
CURTIS RD
N ELLIOTT RD
CLOVER DR
FORDHAM BLVD
SHARON RD
N ESTES DR
E FRANKLIN ST
EPHESUS CHURCH RD
CONNER DR
WILLOW DR
PLUM LN
SHEFFIELD CIR
BURLAGE CIR
LONG LEAF DR
HICKORY DR
S ESTES DR
ROOSEVELT DR
EMORY DR
GROVE ST
INDIAN SPRINGS RD
HILLCREST CIR
N
Legend
Habitat Score
45 - 83 (Low)
84 - 113 (Medium)
114 - 170 (High)
Pipes
Watershed Boundary

banks in places, but the presence of more defined riffle pool sequences, instream aquatic habitat, intact stream buffers, and substantial buffer widths increased the habitat score into the high range.

USA Stream Stability Scores

There are four "Overall Stream Condition" categories for each parameter assessed in the USA Stream Stability protocol - Optimal, Suboptimal, Marginal, and Poor. The total maximum score for the USA stream stability protocol is 160 points. The point ranges for the respective categories are as follows:

Category	Point Range
Optimal	134-160
Suboptimal	91-133
Marginal	48-90
Poor	0-47

The protocol instructs users to compare the score of their project reaches to a "reference" stream or stable, high quality stream. A reasonable range for stream stability scores for a stable reference stream is 126 to 148 points, which encompasses the upper scores in the Suboptimal category, through the Optimal range.

The stability scores recorded in the field in the Lower Booker Creek subwatershed ranged from 46 to 135 points, with a mean of 86 points. A summary of stream stability score statistics is included in Table 3-5.

Table 3-5: Statistical Summary of USA Stream Stability Scores

Mean	86
Standard Error	3.6
Median	82
Standard Deviation	23.6
Range	89
Minimum	46
Maximum	135

The average score of 86 points falls in the upper range of the marginal category, which in a highly developed watershed, is not unexpected. The wide range of scores, 46 to 135, indicates that there are streams in poor condition, but that there are also reaches that are stable and in good condition.

The ranges for stream stability scores generated by the Jenks-Natural Breaks algorithm were:

Group	Range	Number of Reaches in Range	Total Length (ft)
Low	46-76	20 reaches	9,668
Medium	77-98	11 reaches	7,482
High	99-135	13 reaches	13,730
			Total: 30,850

The reaches, color-coded by group, are illustrated in Figure 3-13.

From Figure 3-13, the distribution of low, medium and high scoring reaches is spread relatively evenly across the sub-watershed, with no apparent pattern for any of the groups. There are high quality reaches in the upper watershed, on first order streams, and at the downstream end of the watershed.

The length of stream reach within each group is listed in Table 3-6.

Table 3-6: Length of Reach in Each Stability Score Group

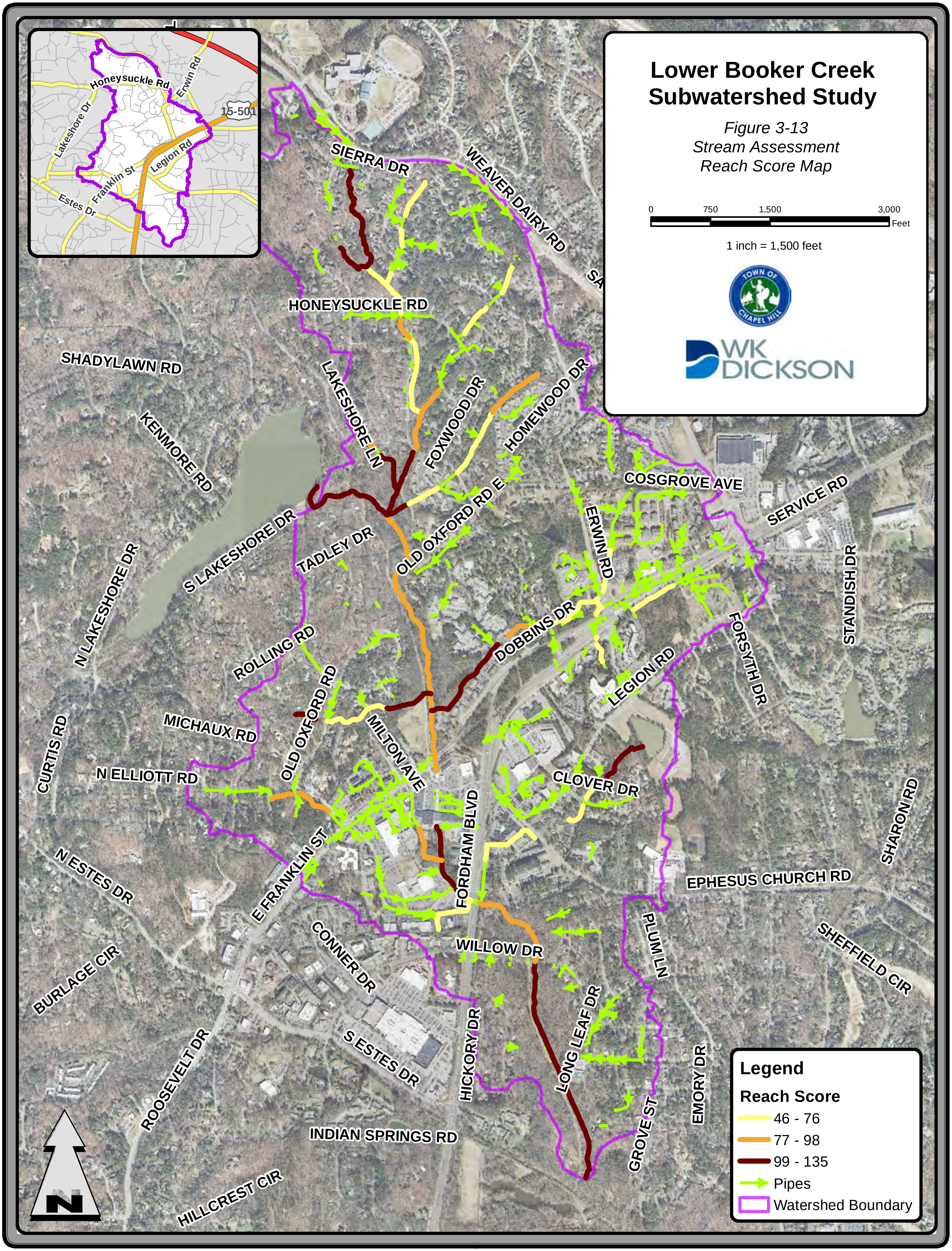
Group	Reach Length (ft)
Low	9,668
Medium	7,482
High	13,730
Total	30,850

Approximately 31% of the total subwatershed stream length is in the Low group, approximately 24% is in the Medium group, and approximately 45% is in the High group.

Not surprisingly, a comparison of the habitat and stability scores by reach confirms that in general, better habitat exists where there is higher stream stability. The absence of good habitat in less stable reaches provides an opportunity to improve habitat, and potentially improve water quality assessment scores that could move surface water in the watershed towards meeting compliance standards.

During the field survey, eleven (11) reaches or sections of stream in the Lower Booker Creek subwatershed were identified as candidates for stabilization, restoration, buffer improvements or a combination of all of these, based on further future analysis. An additional reach was added by the Town of Chapel Hill that was not surveyed in the field, but presents an opportunity to implement a riser device to direct storm flows emanating from a pond into an existing channel more efficiently and safely. This reach was not surveyed in the field by the team because it was not designated as an intermittent or perennial stream by the data available at the time of the survey, but it was added later. It is located downstream of the pond at the Summerfield Crossing development, near Berry Patch Lane. Although not part of this analysis, the low stability reach locations may be cross-referenced with parcel data to determine where low stability reaches intersect with homeowners' association property, to identify possible riparian buffer restoration projects.

The reaches identified as candidates for improvements are described in more detail in Section 6.1.


Lower Booker Creek Subwatershed Study
Figure 3-13
Stream Assessment Reach Score Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Reach Score
46 - 76
77 - 98
99 - 135
Pipes
Watershed Boundary
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
SIERRA DR
WEAVER DAIRY RD
HONEYSUCKLE RD
SHADYLAWN RD
LAKESHORE LN
FOXWOOD DR
HOMEWOOD DR
KENMORE RD
COSGROVE AVE
SERVICE RD
S LAKESHORE DR
TADLEY DR
OLD OXFORD RD E
ERWIN RD
N LAKESHORE DR
STANDISH DR
DOBBINS DR
FORSYTH DR
ROLLING RD
LEGION RD
OLD OXFORD RD
MICHAUX RD
MILTON AVE
CURTIS RD
N ELLIOTT RD
CLOVER DR
SHARON RD
FORDHAM BLVD
E FRANKLIN ST
N ESTES DR
EPHESUS CHURCH RD
CONNER DR
WILLOW DR
PLUM LN
BURLAGE CIR
SHEFFIELD CIR
LONG LEAF DR
HICKORY DR
S ESTES DR
ROOSEVELT DR
EMORY DR
GROVE ST
INDIAN SPRINGS RD
HILLCREST CIR
N

3.4 OUTFALL ANALYSIS

A desktop assessment was conducted for the Lower Booker Creek subwatershed to evaluate stormwater outfalls for retrofit potential. The assessment involved automated processes performed with GIS, as well as application of engineering judgement to screen and prioritize outfalls with the highest potential for retrofitting. The results of the analysis are intended to guide future field evaluation efforts by directing attention to outfalls for which retrofitting is likely feasible, complexity, costs and impacts are minimized and benefits are maximized. The analysis evaluated factors including hydraulics, access, earthwork requirements, property ownership, impacts to utilities, traffic, and existing forested areas, as well as the benefits of impervious area treated and subwatershed treatability. Additional validation was provided through comparison of information gathered on specific outfalls from the physical stream assessment that took place in the watershed. Retrofitting existing outfalls is one of several strategies often implemented as part of a comprehensive watershed restoration plan. Providing detention and/or treatment for stormwater at an outfall can reduce pollutant loads and improve downstream hydrology.

3.4.1 PROCESS

The desktop assessment followed a four-step process. The first step established the dataset of outfalls to consider for analysis. The second step analyzed each outfall for a set of evaluation factors. The third step involved scoring the outfalls based on a system of points assigned to each evaluation factor and creating a prioritized list. The final step was to produce summary profiles for the top ten (10) outfalls.

A preliminary test set of six (6) outfalls was analyzed and scored to ensure the evaluation factors and points system were functional. As a result of the test, the evaluation factors were adjusted slightly and points system calibrated such that the process was best able to identify outfalls with the highest potential for retrofitting.

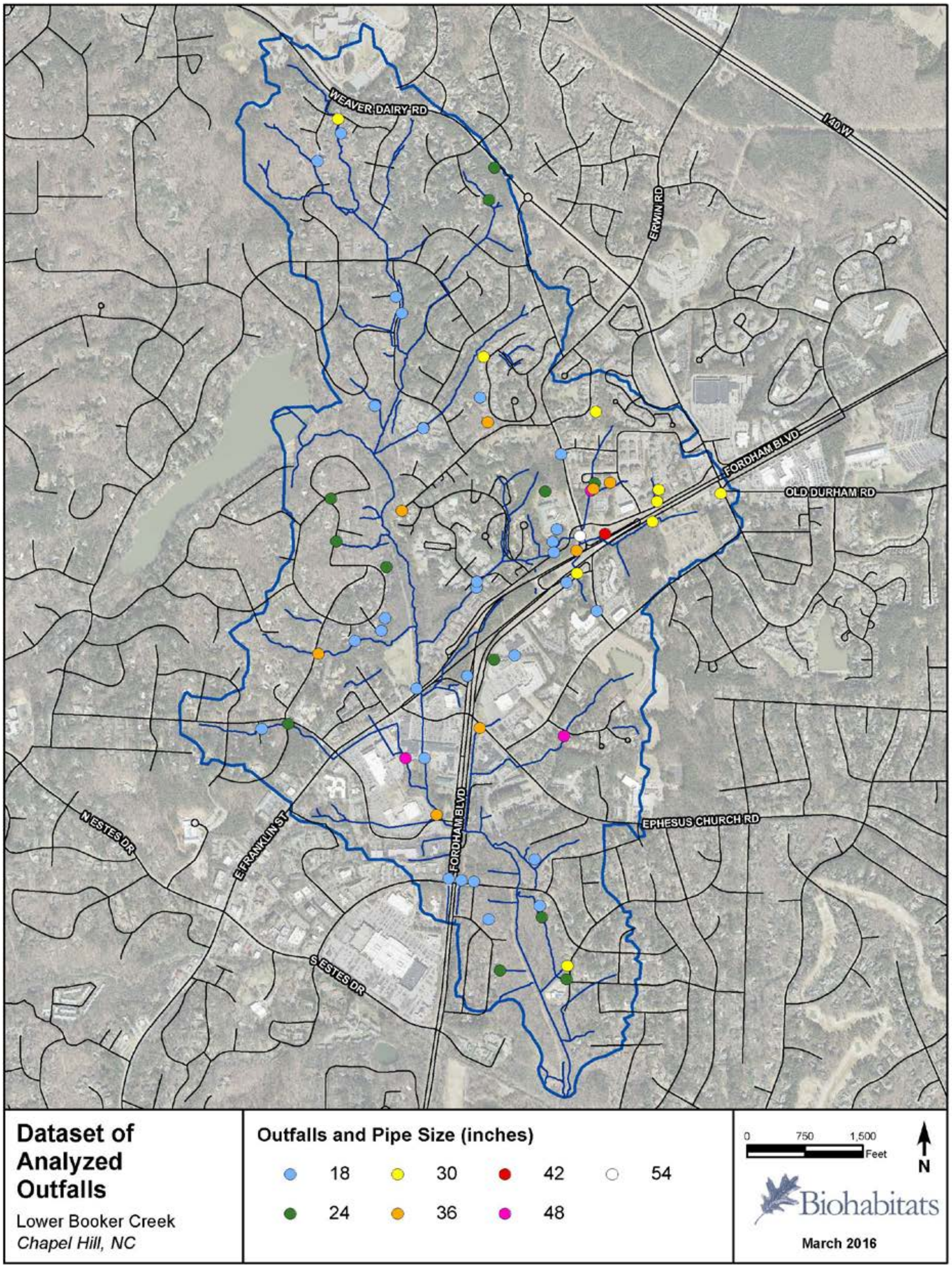
The following sections describe the first three steps of the process. The results section, Section 3.4.2, provides the full list of prioritized outfalls as well as the summary profiles for the top ten (10) outfalls.

<u>Dataset of Outfalls for Analysis</u>
GIS data documenting the location of storm sewer system pipes and outfalls were collected as part of the stormwater inventory. The initial dataset containing 269 pipe ends was sorted to include only pipe ends designated as “outgoing” and having a diameter greater than 18-inches. The resulting 110 outfalls were then visually evaluated to exclude those serving as the downstream end of a single segment culvert.

Additionally, certain outfalls serving as a pass-through for perennial stream flows were excluded. This was determined by outfall location along a stream line, the presence of an upstream “incoming” pipe end also along the same stream line, and stream order combined with pipe diameter. For pass-through outfalls along first order streams, the outfall was excluded if it was larger than 36” in diameter. All pass-through outfalls along second order streams were excluded.

The final dataset analyzed included sixty-eight (68) outfalls. The locations are shown in Figure 3-14 with the outfalls color coded by pipe diameter.

Figure 3-14: Dataset of Analyzed Outfalls



Evaluation Factors and Outfall Analysis

A set of evaluation factors was developed in order to score and prioritize the outfalls. The factors were selected to consider feasibility, complexity, costs, impacts, and benefits of each potential outfall retrofit and include:

- Hydraulics Feasibility
- Need for Additional Infrastructure
- Accessibility
- Property Ownership
- Earthwork
- Utility Conflicts
- Traffic Impacts
- Tree Impacts
- Impervious Cover Treated
- Practice Area to Drainage Area Ratio

The first screening evaluation factor, Hydraulic Feasibility, is a fatal flaw test. If an outfall fails this factor, it is excluded from further analysis. A description of each factor is provided along with details of how the factor was evaluated in Table 3-7.

Table 3-7: Factor Description and Evaluation

Hydraulic Feasibility Hydraulic feasibility looks at whether diversion for an outfall retrofit is possible/practical. Hydraulic feasibility is evaluated by engineering judgement based on outfall invert elevation and surrounding elevations, constraints on the SCM footprint placement, and any other aspects of the outfall hydraulics which may make retrofitting the outfall infeasible. This factor is assigned a result of either feasible or infeasible. Analysis continues for feasible outfalls. Outfalls determined to be infeasible for retrofitting are excluded from further analysis and a note is made documenting the reason for infeasibility.
Additional Infrastructure Additional infrastructure looks at the how flow will be diverted from the outfall to the SCM. This factor relates to complexity and cost with retrofits requiring additional infrastructure to be more complex and likely more costly. This factor is evaluated by approximating the distance from the outfall to the practice footprint into three categories: 0 ft, <100ft, and >100ft.

Accessibility

Accessibility looks at the relative ease of accessing the site for retrofit construction and maintenance. This factor is related to complexity, costs, and impacts. Accessibility is evaluated by engineering judgment and divided into three categories: Easy, Medium, and Hard. Looking at the most likely access route to the practice footprint the following aspects are considered:

1. Is distance to the SCM over 100-ft from access point?
2. Is access over steep terrain?
3. Will access result in additional tree impacts?
4. Will access require a property agreement separate from the SCM footprint agreement?

If the answer to all the above questions is no, then access is rated as easy. A positive answer to one of the questions results in a rank of medium. A positive answer to two or more questions results in a rank of hard. If access is through an existing cleared easement, questions 3 and 4 are not considered.

Property Ownership

Property ownership looks at the type of entity that owns the land where the SCM footprint would be located. This factor is related to complexity and cost with retrofits on private lands likely requiring additional efforts and costs to develop agreements with the landowner(s) compared with public lands. This factor is evaluated by identifying the parcel(s) that contain the SCM footprint and the associated owner. Property ownership is assigned into one of six categories: Public, Rights-of-Way (ROW), Commercial, Homeowners Association (HOA), Mixed (any combination of the other categories), Private Residential. While commercial, HOA and mixed are recorded as different categories, they are scored the same as described in the following section.

Earthwork

Earthwork looks at the amount of excavation that will be required to implement an outfall retrofit SCM. This factor relates to feasibility and cost with greater excavation resulting in higher costs. It is evaluated using ArcGIS to calculate the average elevation of the SCM footprint. The diversion elevation is then subtracted from the calculated average and the difference recorded as the result. The larger the number, the more excavation is required, driving cost higher, and lowering the category score.

Utilities

Utilities look at the possibility of impacts to existing utilities including water, sewer, telecom, optic fiber and overhead electrical. This factor relates to impacts, complexity, and cost with outfall retrofits impacting utilities likely to be more complex and more costly to implement. Utility impacts are evaluated by engineering judgement and divided into three categories: None, Possible, and Expected. An outfall is designated as having Expected utility impacts when the practice footprint or additional infrastructure overlays a utility. Impacts are classified as Possible if the SCM footprint is within 5-ft of a utility or the access path crosses overhead electrical. Otherwise, impacts are classified as None.

Traffic Traffic looks at the possibility of impacts to traffic patterns during outfall retrofit construction. This factor relates to impacts, complexity, and cost with outfall retrofits impacting traffic likely to be more complex and more costly to implement. Traffic impacts are evaluated by engineering judgement and divided into three categories: Low, Medium, and High. An outfall is designated as having High traffic impacts if access to the SCM footprint would require altering existing traffic patterns on a public, non-residential street. Impacts are classified as Medium when access to the SCM footprint would require altering existing traffic patterns on a private or residential street. Otherwise, impacts are classified as Low.
Tree Impacts Tree impacts looks at the loss of trees that would result from clearing and grubbing to implement the outfall retrofit. This factor relates to feasibility, impacts, and complexity with more opposition anticipated for outfall retrofits impacting more trees. Tree impacts are evaluated by engineering judgement to estimate the percent of tree cover within the SCM footprint and divided into three categories: Minimal, Moderate, and Significant. Impacts of less than or equal to 30% of the tree cover are classified as Minimal. Impacts between 30% and 70% are classified as Moderate, and impacts greater than or equal to 70% are classified as Significant.
Impervious Cover Treated Impervious cover treated looks at the area of impervious surface within the drainage area to the outfall. This factor relates to benefits with outfall retrofits treating more impervious cover being more desirable. This factor is evaluated using ArcGIS to delineate the drainage area and then calculate the impervious cover within the drainage area. The area in acres is recorded as the result.
SCM Area to Drainage Area Ratio The SCM area to drainage area ratio looks at treatability. The ratio approximates the extent to which the outfall retrofit can receive and treat the water quality volume from the watershed. This factor relates to feasibility and benefits of the outfall with a higher ratio being more desirable. This factor is evaluated using ArcGIS to delineate and calculate the drainage area in acres and as well as the area of the SCM footprint in acres. The ratio is recorded as the result.

Outfalls were analyzed in a systematic way to gather the information required to make a determination for each evaluation factor. For each outfall, a map was developed showing relevant information such as outfall invert, upstream pipe network, elevation contours, property ownership of surrounding properties (within a 100-foot radius of each outfall), utilities, upstream pipe slope, and aerial imagery. This map was then used to carry out an initial desktop engineering evaluation.

The engineering evaluation first screened for hydraulic feasibility. For all outfalls deemed feasible, a stormwater control measure retrofit footprint was then sketched and a likely access path drawn. The following principles guided the siting of proposed practice footprint.

1. Steep areas should be avoided in favor of flatter areas. Generally, the proposed retrofit footprint should span only 1-2 of the 2-foot contours.
2. While a proposed retrofit may be placed in a floodplain, a 20-30 foot offset from the stream bank should be maintained.

3. Proposed retrofit should avoid utilities as much as possible.
4. No proposed retrofit should average more than 15 feet higher than the invert of the stormwater pipe at the diversion point (i.e., the elevation and location where flow is split and the design volume is diverted to the treatment practice).
5. The retrofit footprint area should be limited to a maximum of 4-5% of the contributing drainage area.

Once the footprint and access were drawn, the following information was assessed and recorded:

- Proposed diversion invert
- Distance from diversion point to retrofit footprint
- Access: distance, steepness, tree cover, property ownership
- Property ownership
- Location of utilities in relationship to footprint and access
- Potential traffic impacts at access point
- Percent tree coverage in practice footprint
- 7Pipe slope of the immediately upstream pipe segment
- Other notes including if the outfall is located near an existing SCM, and any other significant aspects relating to the outfall not otherwise recorded.

Following the engineering evaluation, the footprint was digitized in ArcGIS. Geoprocessing was used to calculate the area of the retrofit footprint, average elevation of the retrofit footprint, drainage area to the outfall, and impervious cover within the drainage area.

Together the desktop engineering evaluation and ArcGIS geoprocessing provided all necessary information to make a determination for each factor.

Outfall Scoring Points System

To develop the system for scoring the outfalls, factors were first assigned to a tier. Tier assignment was based on evaluating the relative importance of the factor in determining the potential for retrofitting. Tier 1 factors were most important and each allotted a possible fifteen (15) points. Next, Tier 2 factors were allotted a possible twelve (12) points each, and finally Tier 3 factor point ranges varied from ten (10) to four (4) points maximum. The total points possible is 100. Factors and the point system are shown in Table 3-8 along with how the points are divided among categories. For two Tier 1 factors and a Tier 2 factor for which specific numeric values were calculated rather than using pre-established thresholds, categories are based on the distribution of values within the dataset (Top third, Middle third, Bottom third) to allow for more direct comparison between outfall retrofit opportunities. Also, hydraulic feasibility is not assigned to a tier or allotted points as it is the initial screening factor.

Table 3-8: Factors and Scoring

Factor	Points Possible	Scoring Division	Points by Category
Hydraulic Feasibility	**NA**	Feasible	Continue
		Infeasible	Stop
Tier 1			
Earthwork	**15**	Top third	15
		Middle third	10
		Bottom third	5
Accessibility	**15**	Easy	15
		Medium	10
		Hard	5
SCM Area to Drainage Area Ratio	**15**	Top third	15
		Middle third	10
		Bottom third	5
Tier 2			
Property Ownership	**12**	Public	12
		ROW	10
		HOA or Commercial or Mixed	8
		Private Residential	4
Impervious Cover Treated	**12**	Top third	12
		Middle third	8
		Bottom third	2
Utilities	**12**	None	12
		Possible	8
		Expected	4
Tier 3			
Tree Impacts	**10**	Minimal, <=30% forested	10
		Moderate, >30%, <=70%	5
		Significant >70%	2
Additional Infrastructure	**5**	No	5
		Yes, <100ft	3
		Yes, >100ft	2
Traffic	**4**	Low	4
		Medium	2
		High	0
Total Points Possible	**100**		

3.4.2 RESULTS

The above process was applied to a preliminary test set of six (6) outfalls. All outfalls were considered feasible for retrofitting and the scores by factor as well as total are shown in Table 3-9 with the outfalls listed by highest total points.

The priority order that the desktop analysis process produced with the test set generally agrees with how the outfalls would be prioritized for retrofit based on engineering judgement only.

Table 3-9: Results of Outfall Retrofitting Desktop Analysis

	Earthwork	Accessibility	Practice area to drainage area ratio	Property Ownership	Impervious Cover Treated	Utilities	Tree Impacts	Additional Infrastructure	Traffic	Total Score
LBC0625	5	15	10	10	12	12	2	5	4	75
LBC0170	15	15	10	8	12	12	5	3	2	82
LBC0528	15	5	15	12	8	8	2	2	4	71
LBC0008	10	5	5	8	12	12	2	2	4	60
LBC0878	5	15	10	8	8	8	2	2	4	62
LBC0079	10	10	5	4	8	8	2	5	4	56

Subsequent to the testing of a preliminary subset of outfalls, the analysis protocol was applied to the full set of sixty-eight (68) targeted outfalls in Lower Booker Creek. Of the sixty-eight (68) outfalls, twenty-one (21) were deemed to be infeasible due to hydraulic feasibility or redevelopment conflicts and thus dropped from further consideration. The remaining forty-seven (47) outfalls were analyzed and ranked. Scores ranged from fifty-five (55) to ninety (90) and were statistically broken into quartiles (See Table 3-10 and Figure 3-15). It should be noted that outfalls assessed during the preliminary screening scored differently in the full screening based on a larger data set and the fact that three of the factors are based on relative scoring compared to the rest of the sample population.

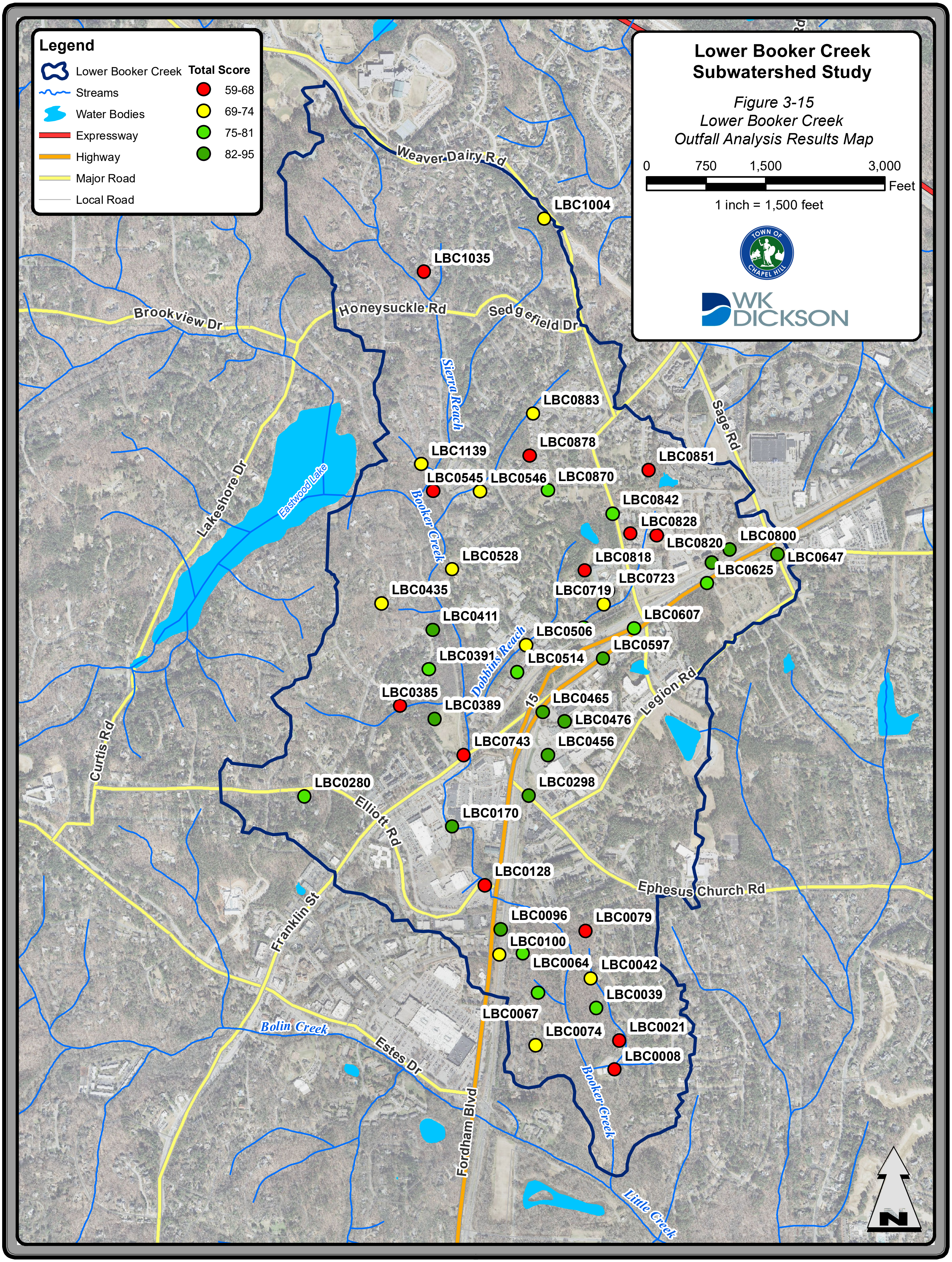

Legend
Lower Booker Creek
Streams
Water Bodies
Expressway
Highway
Major Road
Local Road
Total Score
59-68
69-74
75-81
82-95
Lower Booker Creek
Subwatershed Study
Figure 3-15
Lower Booker Creek
Outfall Analysis Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Sedgefield Dr
Brookview Dr
Lakeshore Dr
Eastwood Lake
Sierra Reach
Booker Creek
Dobbins Reach
Sage Rd
Legion Rd
Curtis Rd
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Bolin Creek
Fordham Blvd
Little Creek
15
LBC1004
LBC1035
LBC0883
LBC0878
LBC1139
LBC0851
LBC0545
LBC0546
LBC0870
LBC0842
LBC0828
LBC0820
LBC0800
LBC0647
LBC0625
LBC0528
LBC0818
LBC0723
LBC0435
LBC0719
LBC0411
LBC0607
LBC0506
LBC0597
LBC0391
LBC0514
LBC0385
LBC0389
LBC0465
LBC0476
LBC0743
LBC0456
LBC0280
LBC0298
LBC0170
LBC0128
LBC0096
LBC0079
LBC0100
LBC0064
LBC0042
LBC0039
LBC0067
LBC0074
LBC0021
LBC0008
N

Table 3-10: Summary Ranking of Outfalls for Lower Booker Creek

	Earthwork	Practice Area to Drainage Area Ratio	Accessibility	Property Ownership	Impervious Cover Treated	Utilities	Tree Impacts	Additional Infrastructure	Traffic	Total Score
LBC0456	15	15	15	10	12	12	2	5	4	**90**
LBC0597	15	10	15	10	8	12	10	5	4	**89**
LBC0800	15	10	15	10	8	12	10	5	4	**89**
LBC0669	15	5	15	10	12	12	10	5	4	**88**
LBC0411	15	15	15	12	4	12	2	5	4	**84**
LBC0298	10	5	15	10	12	12	10	5	4	**83**
LBC0170	15	10	15	8	12	12	5	3	2	**82**
LBC0476	5	15	15	8	8	12	10	5	4	**82**
LBC0096	10	10	15	10	12	12	2	5	4	**80**
LBC0389	15	15	15	12	4	8	2	5	4	**80**
LBC0514	15	15	15	8	4	12	2	5	4	**80**
LBC0607	10	15	15	10	4	12	10	2	2	**80**
LBC0647	15	10	15	10	8	8	5	5	2	**78**
LBC0280	15	5	15	4	8	12	10	3	4	**76**
LBC0870	10	10	15	12	8	12	2	3	4	**76**
LBC0625	5	10	15	10	12	12	2	5	4	**75**
LBC0435	15	5	15	4	4	12	10	5	4	**74**
LBC0064	10	10	15	8	4	12	5	5	4	**73**
LBC0067	5	15	10	12	8	12	2	5	4	**73**
LBC0723	15	15	10	8	4	12	2	3	4	**73**
LBC0039	10	15	10	12	4	12	2	3	4	**72**
LBC0842	10	10	15	10	4	12	2	5	4	**72**
LBC0528	15	15	5	12	8	8	2	2	4	**71**
LBC0577	5	5	15	8	12	12	5	5	4	**71**
LBC0391	15	10	10	4	8	12	2	5	4	**70**
LBC0100	10	15	15	8	4	8	2	3	4	**69**
LBC0818	10	5	15	8	12	8	2	5	4	**69**
LBC0820	10	5	15	8	12	8	2	5	4	**69**
LBC0828	10	5	15	8	12	8	2	5	4	**69**
LBC0883	5	5	15	12	12	12	2	2	4	**69**
LBC0743	15	10	10	10	4	2	10	5	2	**68**
LBC0042	5	15	10	12	4	12	2	3	4	**67**
LBC0506	10	10	15	8	8	8	2	2	4	**67**
LBC1004	5	15	10	8	8	12	2	3	4	**67**
LBC1139	5	15	10	12	4	12	2	3	4	**67**
LBC0074	5	15	5	12	8	12	2	3	4	**66**
LBC0546	5	5	15	8	12	12	2	2	4	**65**
LBC0719	5	15	10	8	4	12	2	5	4	**65**
LBC0128	5	5	10	8	12	12	2	5	4	**63**
LBC0878	5	10	15	8	8	8	2	2	4	**62**
LBC0545	5	5	15	8	12	8	2	2	4	**61**
LBC0008	10	5	5	8	12	12	2	2	4	**60**
LBC0851	15	5	15	4	4	8	2	3	4	**60**
LBC0385	10	10	15	4	4	8	2	2	2	**57**
LBC0079	10	5	10	4	8	8	2	5	4	**56**
LBC0021	5	5	5	8	12	12	2	2	4	**55**
LBC1035	5	10	10	12	8	2	2	2	4	**55**

Individual maps for the highest-ranking outfalls, after further individual analysis and refinement, are in Section 6.2.1.

3.5 IMPERVIOUS ANALYSIS

A desktop assessment was conducted in the Lower Booker Creek subwatershed to evaluate and identify impervious areas meeting a minimum acre threshold that could provide potential retrofit opportunities. Using the GIS data provided by the Town of Chapel Hill and other sources, contiguous impervious surfaces were clipped to the Lower Booker Creek subwatershed boundary and analyzed to find expanses of parking lots, roads and rooftops that exceeded one (1) acre and were contained within an individual parcel. Some of the impervious areas were subdivided if contained within a single parcel based on road crossings or impervious types. This impervious acre threshold was chosen to identify areas that provided the greatest potential for retrofits. Parking lots are typically retrofitted using a mixture of underground and surface stormwater control measures such as permeable pavement, stormwater tree pits, vegetated swales (bioswales), and bioretention basins. These stormwater control measures allow for pollutant removal and can provide peak flow attenuation for small frequently occurring storm events. Underground storage can be used in conjunction with these stormwater control measures to increase storage and further attenuate peak flows with larger storms.

3.5.1 PROCESS

A GIS impervious layer was received from the Town of Chapel Hill and appended to the Lower Booker Creek subwatershed boundary. Using the newly created layer, contiguous impervious areas (in acres) were calculated using GIS spatial analysis tools. The impervious layer was then queried using a minimum threshold of one (1) acre resulting in twenty-two (22) impervious areas ranging from 1.04 to 4.11 acres.

3.5.2 RESULTS

The queried impervious areas were organized based on impervious type, ownership and spatial location which resulted in a final number of fifteen (15) impervious groupings (See Figure 3-16). This part of the analysis was done using the parcels layer, cross checking through aerial imagery and Google maps. Exhibit 3-1 below shows the sum of total acreage by type and ownership. Exhibit 3-2 shows the number of acres of impervious area by grouping.

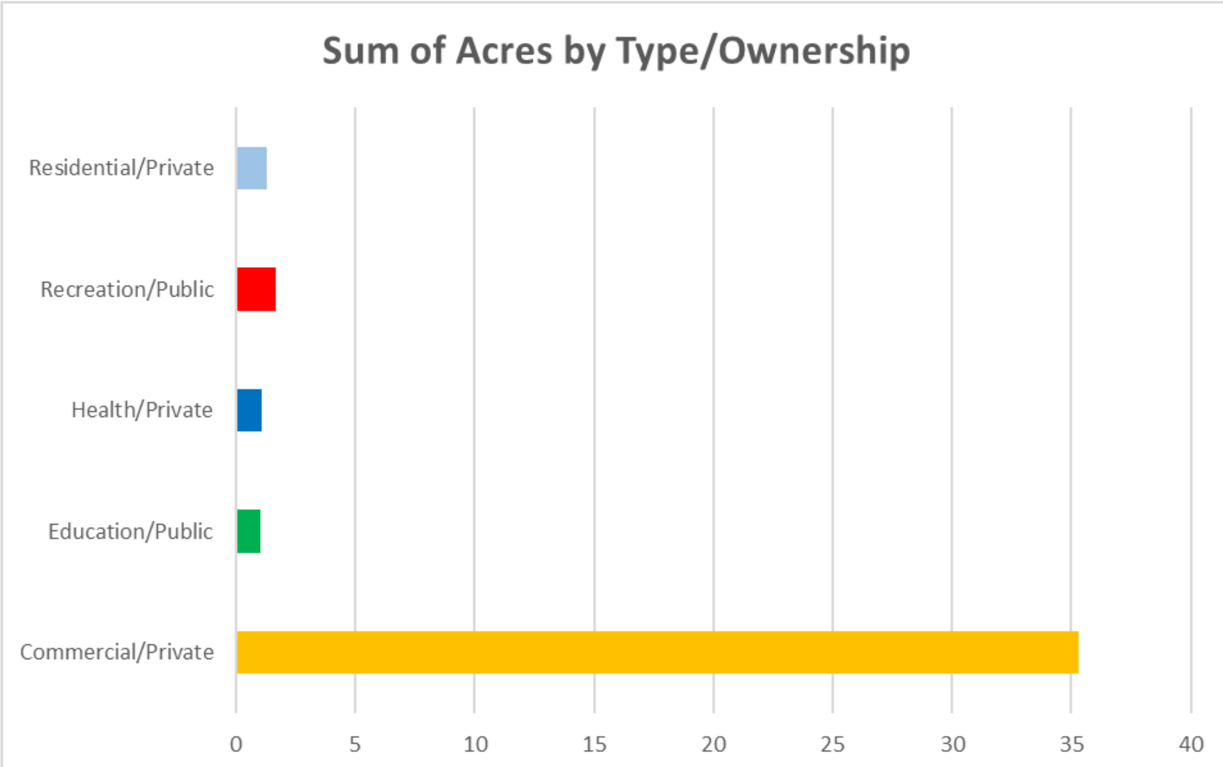


Exhibit 3-1: Sum of Acres by Type/Ownership

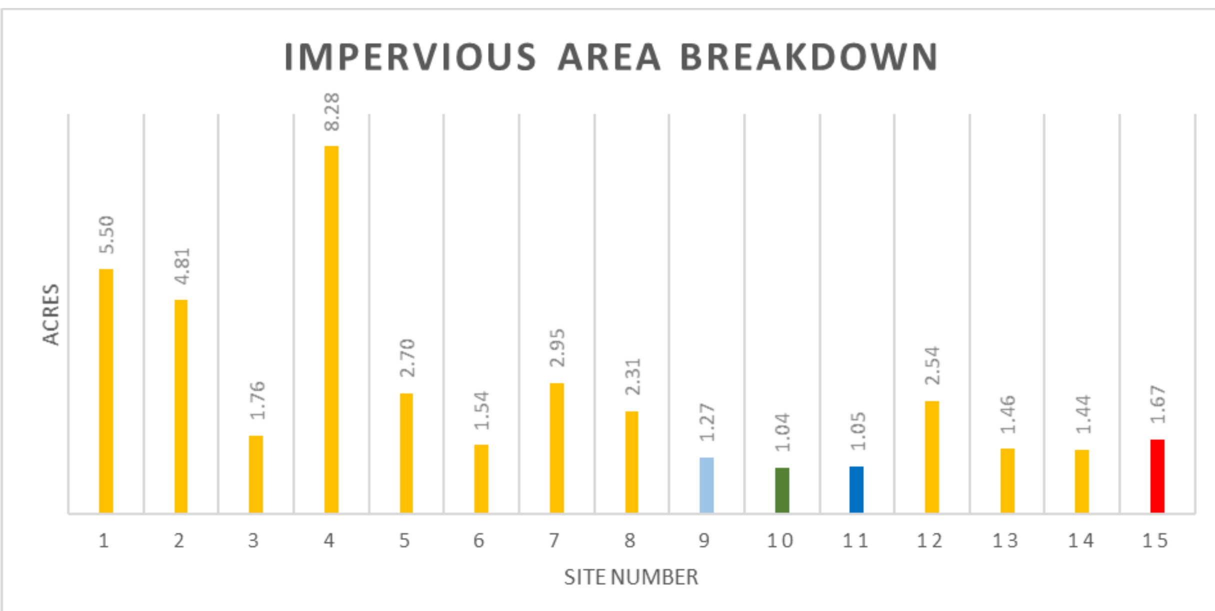
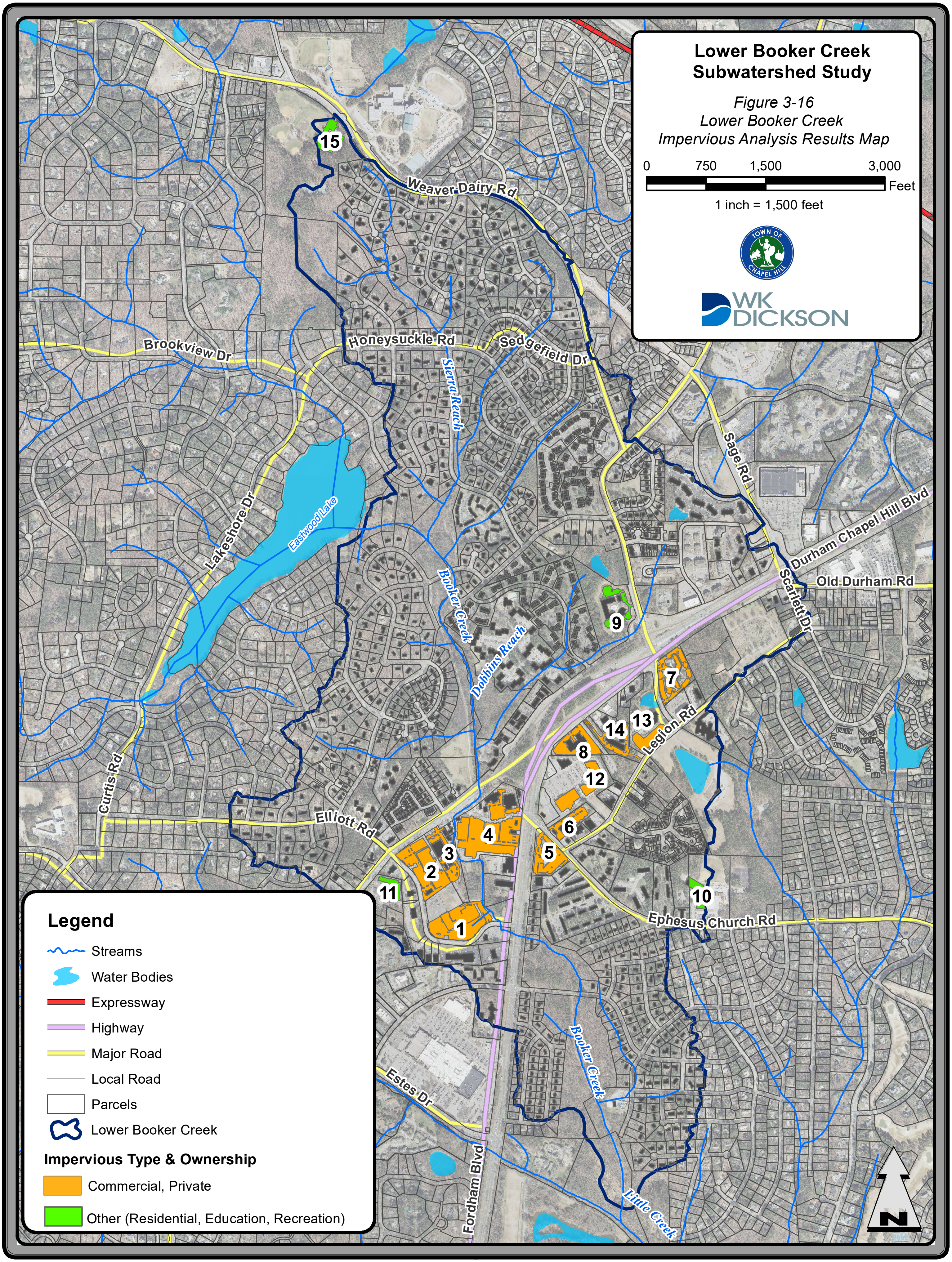


Exhibit 3-2: Impervious Area Breakdown


Lower Booker Creek Subwatershed Study
Figure 3-16
Lower Booker Creek
Impervious Analysis Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Sedgefield Dr
Brookview Dr
Sierra Reach
Sage Rd
Durham Chapel Hill Blvd
Old Durham Rd
Scarlett Dr
Lakeshore Dr
Eastwood Lake
Booker Creek
Dobbins Reach
Legion Rd
Curtis Rd
Elliott Rd
Ephesus Church Rd
Estes Dr
Fordham Blvd
Little Creek
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Legend
Streams
Water Bodies
Expressway
Highway
Major Road
Local Road
Parcels
Lower Booker Creek
Impervious Type & Ownership
Commercial, Private
Other (Residential, Education, Recreation)
N

3.6 NEIGHBORHOOD ANALYSIS

A desktop assessment was conducted on the Lower Booker Creek subwatershed to evaluate single-family neighborhoods for green infrastructure retrofitting potential. The focus of the desktop analysis was on opportunities within the rights-of-way. Identifying individual lot opportunities such as downspout disconnection or driveway retrofits was not carried out, as these are better suited for windshield or related field investigations. Using GIS data provided by the Town of Chapel Hill and other sources, forty-nine (49) neighborhoods were evaluated based on the following physical parameters: average lot size, road slope, road width, total road length and rights-of-way width (See Table 3-11). These parameters were chosen to identify neighborhoods that provide the greatest potential for green infrastructure projects. Representative projects that can be implemented at the neighborhood scale within the right-of-way include vegetated swales (aka bioswales), rain gardens, permeable pavement/pavers, and bioretention cells. These stormwater control measures slow down and treat the stormwater runoff from the roadways, driveways and other impervious surfaces. They provide habitat to important pollinator species and birds, and they can be used for neighborhood safety measures such as traffic calming when implemented strategically.

3.6.1 PROCESS

A GIS neighborhood layer was developed by filtering the tax parcel layer to include neighborhoods comprised of single family homes with an average lot size greater than 0.25 acres. A minimum average lot size of 0.25 acres was targeted as a reasonable lower end to provide adequate space for commonly used linear green infrastructure stormwater control measures, assuming each home had a driveway. For the forty-nine (49) neighborhoods included in the analysis, the neighborhood average lot size ranges from 0.25 acres to 0.95 acres with a mean value of 0.50 acres. The scoring for this parameter is defined as follows (See Exhibit 3-3): a score of one (1) indicates an average lot size between 0.25 acres and 0.33 acres; a score of three (3) indicates an average lot size between 0.34 acres and 0.50 acres; a score of five (5) indicates an average lot size between 0.51 acres and 0.75 acres; and a score of seven (7) indicates an average lot size above 0.75 acres.

Road slope was evaluated along discrete road centerline segments using a GIS surface dataset. A weighted average of these segments was computed to determine the average road slope for the neighborhood as a whole. The neighborhood was then given a score based on this average road slope. Road segments with slopes greater than 4% are considered unsuitable for traditional green infrastructure stormwater control measures due to the high shear stresses and flow velocities associated with concentrated stormflows. The flatter the road slope, the more suitable for green infrastructure stormwater control measures. For the forty-nine (49) neighborhoods included in the analysis, the averaged road slopes ranged from 1.1% to 8.6% with a mean value of 4.4%. The scoring for this parameter is defined as follows (See Exhibit 3-4): a score of one (1) indicates an average road slope above 4.5%; a score of three (3) indicates an average between 3.5% and 4.4%;

a score of five (5) indicates an average road slope between 2.0% and 3.5%; and a score of seven (7) indicates an average road slope below 2%.

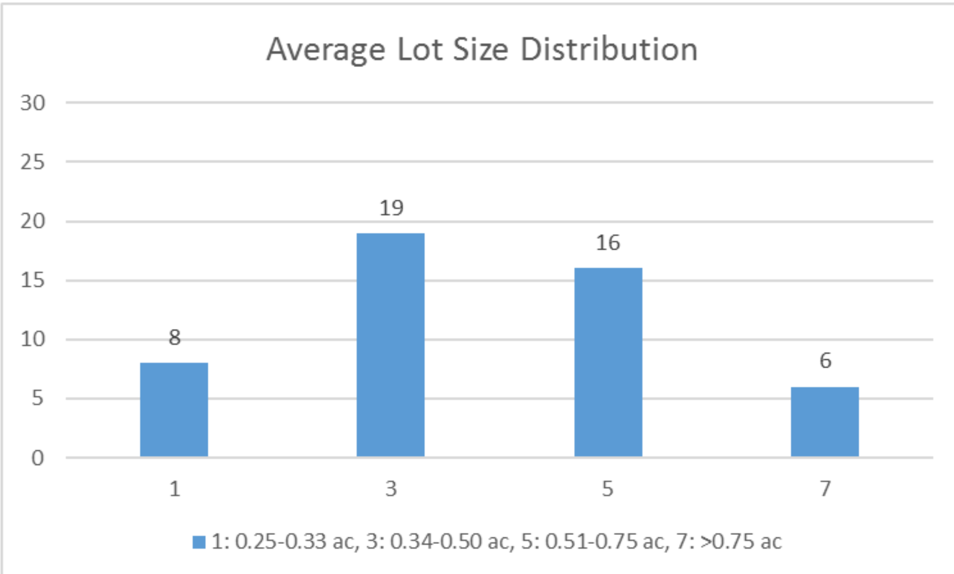


Exhibit 3-3: Average Lot Size Distribution

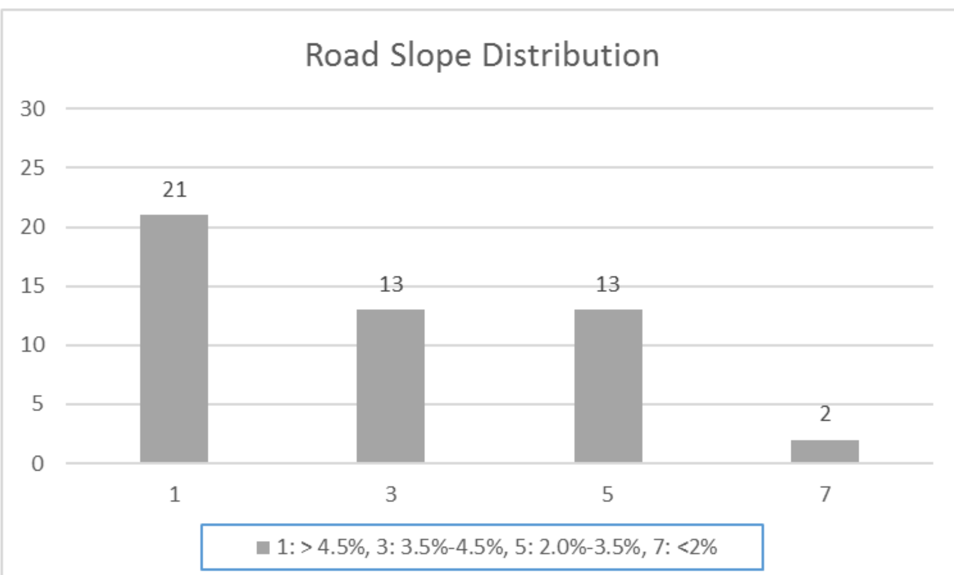


Exhibit 3-4: Road Slope Distribution

Road width was computed in GIS using the impervious layer polygon for discrete road segments. A weighted average of these road widths was computed to determine the average road width for each neighborhood. The neighborhood was then given a score based on this average road width. The scores seek to reflect the potential for installation of "bumpouts" on overwide streets (See Picture 3-9). A minimum street width is nine (9) feet for a one-way residential road and eighteen (18) feet for two-way residential road. For the forty-nine (49) neighborhoods included in the analysis, the neighborhood averaged road widths ranged from 7.8 feet to 36.9 feet with a mean value of 24.8 feet. The scoring for this parameter is defined as follows (See Exhibit 3-5): a score of one (1) indicates an average road width below twenty (20) feet; a score of three (3) indicates an average road width above thirty-one (31) feet as the street is likely to be used for parking; a score of five (5) indicates an average road width between twenty (20) feet and 24.9 feet; and a score of seven (7) indicates an average road width between twenty-five (25) feet and 30.9 feet.

Picture 3-9: Curb Extension Example

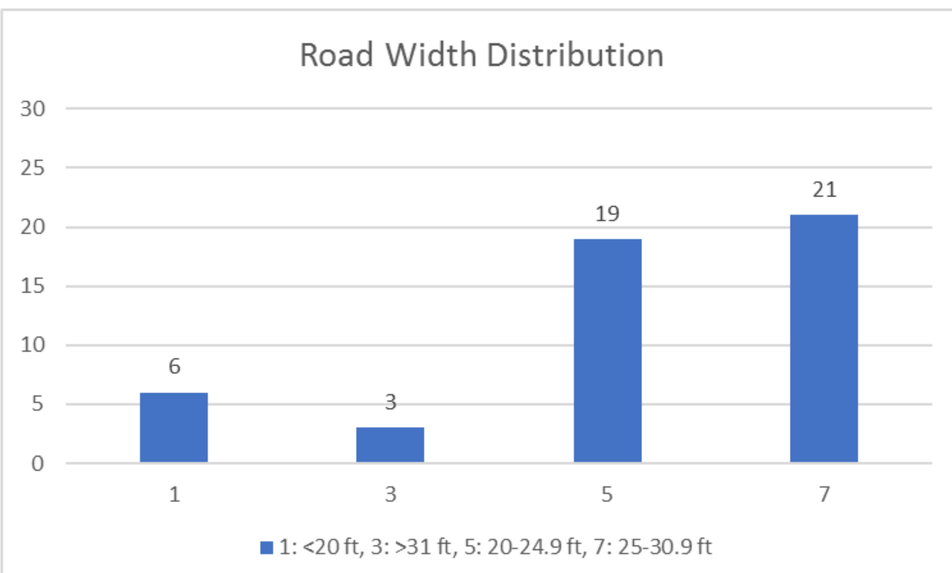


Exhibit 3-5: Road Width Distribution

A rights-of-way width layer was developed in GIS for this project. The rights-of-way area, for the purpose of this analysis, is considered to be the publicly owned space not occupied by a road, driveway, or sidewalk. The width of this area was computed in GIS for each discrete polygon. An average width was then computed for each neighborhood and used for scoring. A width less than six (6) feet is considered to be too limited for optimal surface based green infrastructure stormwater control measures. For the forty-nine (49) neighborhoods included in the analysis, the averaged rights-of-way widths ranged from 0.5 feet to 55.1 feet with a mean value of 14.4 feet. The scoring for this parameter is defined as follows (See Exhibit 3-6): a score of one (1) indicates an average right of way width below seven (7) feet; a score of three (3) indicates an average rights-of-way width between seven (7) feet and 11.9 feet; a score of five (5) indicates an average rights-of-way width between twelve (12) feet and 17.9 feet; and a score of seven (7) indicates an average rights-of-way width greater than eighteen (18) feet.

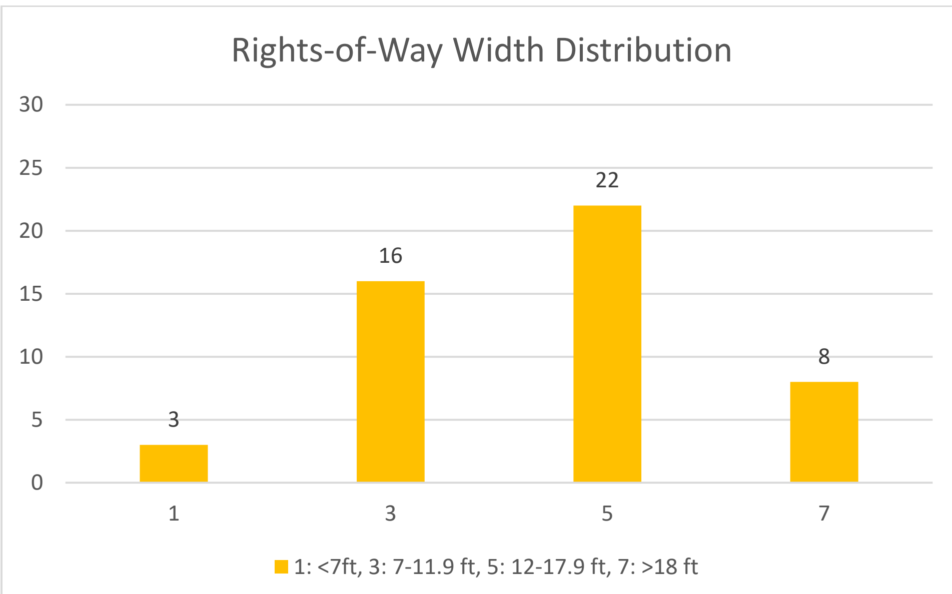


Exhibit 3-6: Rights-of-Way Width Distribution

Total road length was measured using the GIS roadway centerline layer. The length of all road segments within the neighborhood boundary were added together to determine the total road length for each neighborhood. Neighborhoods with more linear feet of roadway were given a higher score. For the forty-nine (49) neighborhoods included in the analysis, the total neighborhood road length ranged from 3 linear feet (for neighborhood most likely bisected by a subwatershed divide) to 15,723 linear feet with a mean value of 4,572 linear feet. The scoring for this parameter is defined as follows: a score of one (1) indicates a total road length below 1,000 linear feet; a score of three (3) indicates a total road length between 1,000 linear feet and 5,280 linear feet; a score of five (5) indicates a total road length between 5,281 linear feet and 12,000 linear feet; and a score of seven (7) indicates a total road length greater than 12,000. Exhibit 3-7 shows the score distribution of this parameter.

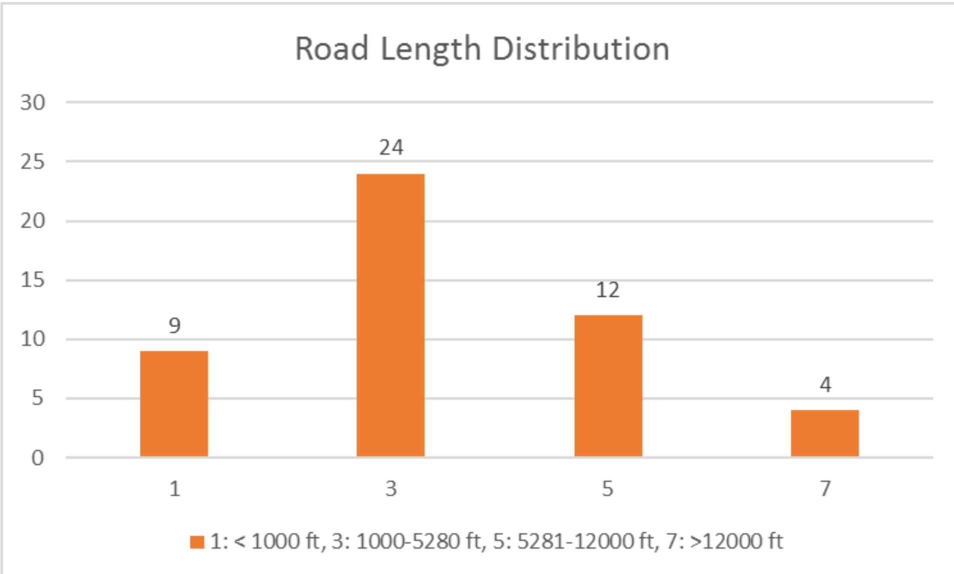


Exhibit 3-7: Road Length Distribution

3.6.2 RESULTS

The scores for each parameter were then added together to compute a final neighborhood score. These total scores were then compiled into four ranking categories (poor, fair, good, very good) to represent the favorability of a neighborhood to retrofitting (See Exhibit 3-8 and Table 3-11). A ranking of poor indicates a total score below sixteen (16), meaning that the neighborhood is unsuitable for retrofit. A ranking of fair corresponds to a total score between seventeen (17) and twenty (20), indicating that the neighborhood most likely scored poorly in one (1) of the five (5) parameters. A ranking of good corresponds to a total score between twenty-one (21) and twenty-four (24), indicating that the neighborhood is likely to be a suitable candidate for retrofit projects. A ranking of very good corresponds to a total score of twenty-five (25) or more, indicating that a neighborhood scored well in all categories.

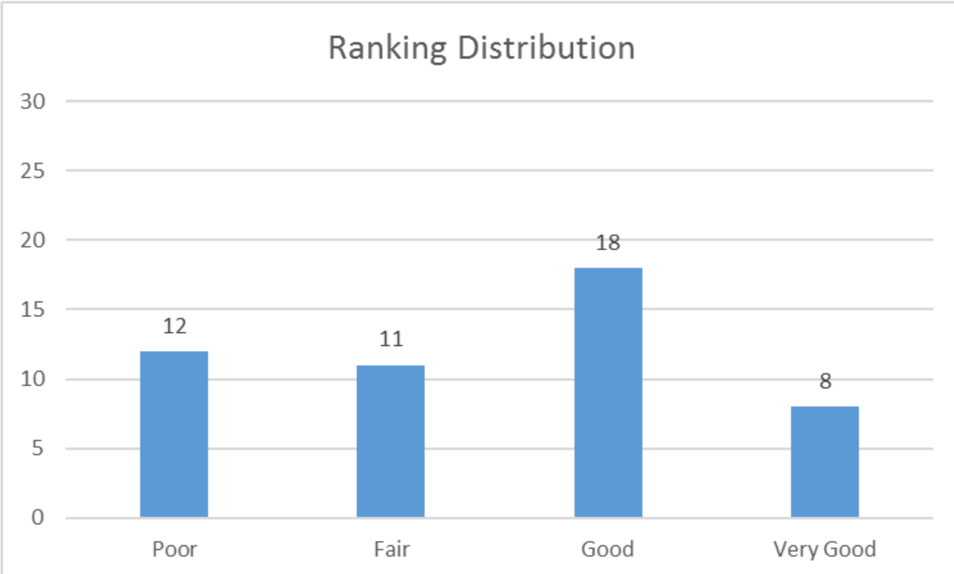


Exhibit 3-8: Ranking Distribution

Table 3-11: Neighborhood Analysis Results

Neighborhood	Subwatershed	Lot Size	Road Length	Road Slope	ROW Width	Road Width	Total Score	Ranking
Cedar Hills	Cedar Fork	7	5	3	7	5	27	Very Good
Ridgefield	Lower Booker Creek	3	7	5	5	7	27	Very Good
Lake Forest	Lower Booker Creek	7	5	3	5	7	27	Very Good
Northwood	Booker Headwaters	5	3	5	7	5	25	Very Good
Booker Creek	Lower Booker Creek	3	5	5	5	7	25	Very Good
Timberlyne	Cedar Fork	5	5	5	5	5	25	Very Good
Lake Forest	Cedar Fork	7	5	1	5	7	25	Very Good
Lake Forest	Eastwood Lake	7	7	1	5	5	25	Very Good
Northwood V	Booker Headwaters	1	7	5	3	7	23	Good
Parkside	Booker Headwaters	1	7	5	3	7	23	Good
Coker Woods West 2	Eastwood Lake	5	5	1	5	7	23	Good
North Forest Hills	Crow Branch	3	3	5	5	7	23	Good
Coker Hills	Eastwood Lake	5	5	1	5	7	23	Good
Steeple Chase	Cedar Fork	5	3	5	3	7	23	Good
Timberlyne	Booker Headwaters	5	3	7	3	5	23	Good
Argonne Hills	Cedar Fork	3	3	5	5	7	23	Good
Forest Creek	Crow Branch	5	1	5	5	7	23	Good
Forest Creek	Eastwood Lake	5	5	1	5	7	23	Good
Eastwood Rd Johnson Farm	Eastwood Lake	5	3	3	7	5	23	Good
Quail Run	Booker Headwaters	7	5	1	5	5	23	Good
Chesley	Lower Booker Creek	5	5	1	3	7	21	Good
Chandler's Green	Cedar Fork	3	3	5	3	7	21	Good
North Forest Hills	Booker Headwaters	3	5	3	5	5	21	Good
Clark Hills	Lower Booker Creek	5	3	1	7	5	21	Good
Countryside	Cedar Fork	5	5	1	3	7	21	Good
Brookview	Cedar Fork	7	3	1	5	5	21	Good
Coker Woods West 1	Eastwood Lake	5	3	3	3	5	19	Fair
North Forest Hills	Cedar Fork	3	3	3	5	5	19	Fair
North Forest Hills	Eastwood Lake	3	3	3	5	5	19	Fair
Coker Hills	Lower Booker Creek	5	3	1	3	7	19	Fair
Partin Hills	Cedar Fork	5	3	1	5	5	19	Fair
Riggsbee Heights Piney Mt	Cedar Fork	5	3	1	5	5	19	Fair
Deerwoods	Lower Booker Creek	3	1	5	3	7	19	Fair
Greene Hills	Cedar Fork	3	3	1	5	7	19	Fair
Glen Heights	Crow Branch	3	3	3	7	1	17	Fair
Oxford Hills	Lower Booker Creek	3	3	3	3	5	17	Fair
Ridgefield North	Lower Booker Creek	1	1	1	7	7	17	Fair
Glen Heights	Booker Headwaters	3	1	3	7	1	15	Poor
Windover	Lower Booker Creek	1	3	3	3	5	15	Poor
Pine Knob	Eastwood Lake	1	3	1	3	7	15	Poor
Cross Creek	Cedar Fork	3	3	1	7	1	15	Poor
Franklin Square	Cedar Fork	3	1	5	5	1	15	Poor
Glenview	Cedar Fork	3	3	1	3	5	15	Poor
Fern Creek	Eastwood Lake	3	1	7	1	3	15	Poor
Coker Woods	Eastwood Lake	1	3	3	1	5	13	Poor
Silver Creek	Lower Booker Creek	3	3	1	1	3	11	Poor
Freeland Place	Booker Headwaters	3	1	3	3	1	11	Poor
Vernon Hills	Eastwood Lake	1	1	1	3	3	9	Poor
Vernon Hills	Lower Booker Creek	1	1	1	5	1	9	Poor

FLOOD MITIGATION ALTERNATIVES

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

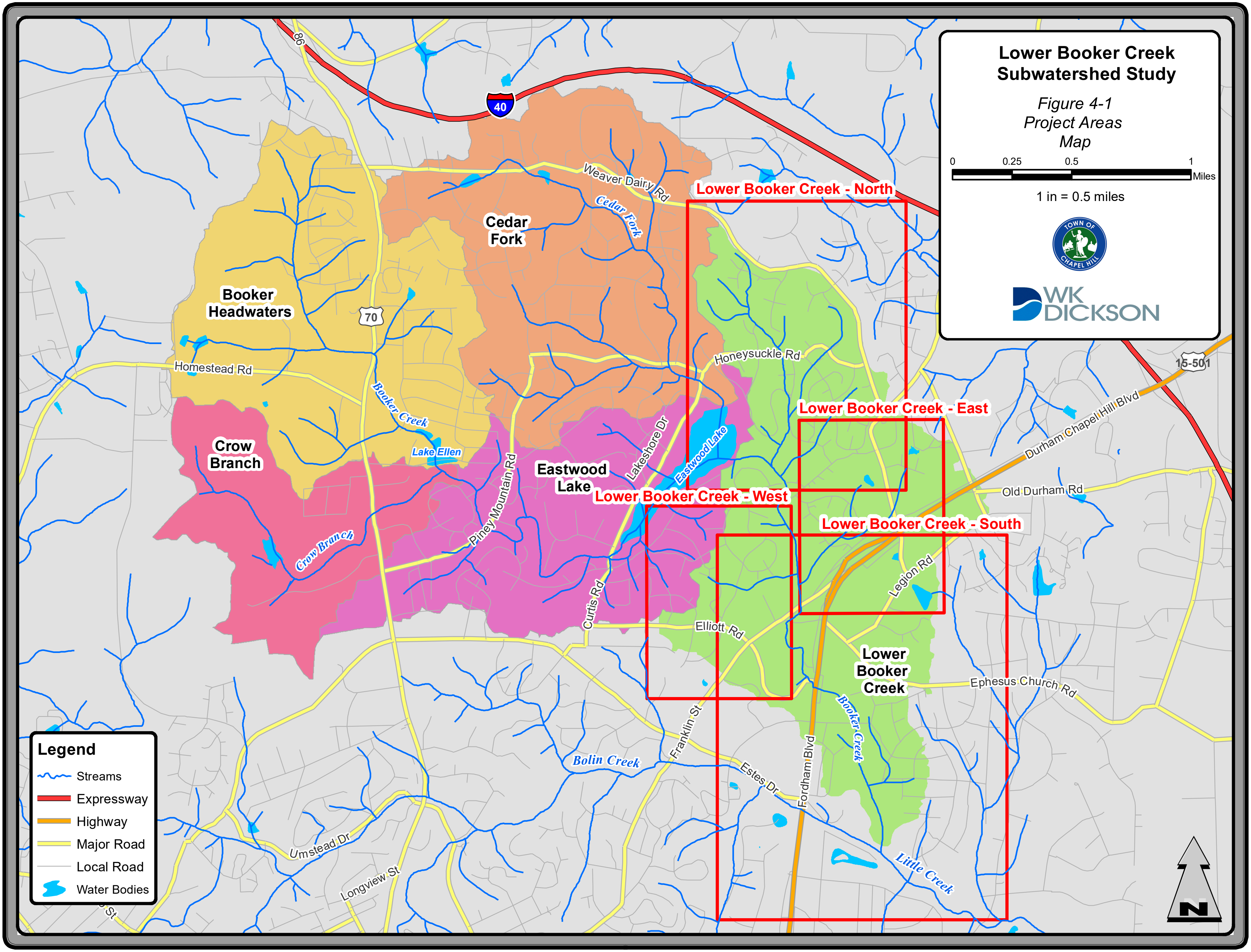
As noted in Section 3, significant development has occurred within the natural floodplain prior to the current federal and local regulations regarding development in a floodplain. The proposed solutions required to reduce the risk of flooding in these areas are a combination of the following:

(1) Infiltration to reduce the volume and rate of runoff;
(2) Flood storage to reduce the rate of runoff by impacting the timing within the overall watershed and reconnect streams to the natural floodplain; and
(3) Infrastructure improvements to increase the capacity of the system to convey runoff from large storm events.

Based on the configuration of the conveyance systems within LBC and how those systems interact with each other, the proposed alternatives are best grouped geographically into five (5) distinct areas as shown in Figure 4.1 and described as follows:

(1) The Overall Booker Creek watershed includes proposed projects that are outside of the LBC subwatershed, but can influence peak flows within the LBC subwatershed.
(2) LBC North consists of the conveyance systems north of the confluence between Booker Creek and the Sierra Reach.
(3) LBC South includes the main branch of Booker Creek from the confluence with Sierra Reach to the confluence with Bolin Creek.
(4) LBC West predominantly consists of secondary systems west of Booker Creek and south of Eastwood Lake within the LBC subwatershed area.
(5) LBC East includes the Dobbins Reach as well as secondary systems located east of Booker Creek and south of Old Oxford Road.

All proposed projects are developed based on built-out land use conditions as described in Section 4.6 and Appendix A. All reported water surface elevations and flood depth reductions are based on future land use conditions.



Lower Booker Creek
Subwatershed Study
Figure 4-1
Project Areas
Map
0
0.25
0.5
1
Miles
1 in = 0.5 miles
WK DICKSON
Lower Booker Creek - North
Lower Booker Creek - East
Lower Booker Creek - West
Lower Booker Creek - South
Cedar Fork
Booker Headwaters
Crow Branch
Eastwood Lake
Lower Booker Creek
Weaver Dairy Rd
Cedar Fork
Honeysuckle Rd
Homestead Rd
Booker Creek
Lake Ellen
Lakeshore Dr
Eastwood Lake
Piney Mountain Rd
Crow Branch
Curtis Rd
Elliott Rd
Franklin St
Fordham Blvd
Booker Creek
Legion Rd
Durham Chapel Hill Blvd
Old Durham Rd
Ephesus Church Rd
Bolin Creek
Estes Dr
Umstead Dr
Longview St
Little Creek
40
70
86
15-501
Legend
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
N

4.1 OVERALL BOOKER CREEK WATERSHED

While the focus of this study is to improve infrastructure within the LBC subwatershed, over 70% of the drainage area contributing to the overall watershed is outside of the LBC subwatershed. Therefore, potential projects were evaluated within the Booker Creek watershed to determine if strategically increasing floodplain storage in the upper portions of the watershed could potentially impacts peak flows in the LBC subwatershed. Available sites that could make a significant impact on downstream flows were limited based on the extensive existing development within the watershed and topographic constraints.

The largest potential floodplain storage facility in the Booker Creek watershed is Eastwood Lake. Eastwood Lake is a 50-acre privately owned neighborhood facility generally located near the center of the watershed. The lake is predominantly utilized as a recreational facility and amenity to the Lake Forest community. Residential homes are located around the perimeter of the lake with numerous fixed docks and other structures. The configuration of the existing spillway allows water to quickly overflow out of the lake during a storm event to avoid significant rises in water surface elevation, protecting the surrounding properties. The facility is not designed to detain flows and to provide significant detention would require a reconfiguration of the spillway and normal water surface. To obtain additional storage, some combination of raising the dam or lowering the water surface level would be required. Due to the proximity of residential structures around the perimeter of the lake, it is unlikely the dam could be raised without increasing the risk of flooding to those residents and nearby roads. Therefore, the primary alternative for significantly increasing flood storage in Eastwood Lake would be to lower the water surface elevation. As part of this study, lowering the normal water surface elevation by one (1) foot was evaluated to determine if significant benefits could be achieved. It was assumed that further reductions in water surface elevation would adversely impact the recreational use of the lake. Even lowering the water surface by one (1) foot would require significant reconstruction of docks and recreational facilities. The benefit of lowering the normal water surface by one (1) foot was not found to be significant due to the size of the watershed at that location and the constraints listed above. Any publicly funded project on a private lake would need to demonstrate significant benefits to the community. The proposed projects assume that no significant modification will occur at Eastwood Lake.

The following projects are recommended as potential floodplain storage areas that can positively impact downstream peak flows in Booker Creek. Due to the limited land availability in the watershed, the Town should make use of multi-objective projects if possible. Additionally, the proposed storage areas could be configured to provide water quality treatment as well as flood control benefits. Excavation within the proposed floodplain storage areas should minimize the removal of significant tree stands to the extent possible to comply with Town ordinances and State buffer regulations. The locations of the three (3) proposed floodplain storage areas are shown in Figure 4.2.

New Parkside Drive – The proposed New Parkside Drive Storage Area is located on Town-owned property immediately north of New Parkside Drive in the northwest corner of the watershed as shown in Figure 4.2. The proposed 7.5-acre project area is surrounded by residential homes within the Parkside subdivision along Booker Creek.

While the drainage area at this location is relatively small (138 acres), the available area allows for a significant reduction in peak flow at this location which will slow runoff and reduce downstream flows. By excavating fill above the ordinary high-water mark, water can temporarily pool behind New Parkside Drive and the 25-year peak flow can be reduced by almost 90%. Immediately upstream of Eastwood Lake, the New Parkside Drive project would result in an 8% reduction in the 25-year peak flow when assessed independently of other projects. Downstream of Eastwood Lake, the New Parkside Drive project would not have a measurable impact by itself, but as noted above would provide benefits if implemented in additional to the other proposed storage areas. Considerations would need to be given to maintaining base flow and avoiding stream impacts since Booker Creek is a perennial stream at this location.

Since the project area is owned by the Town, land and easement acquisition would not be required, however coordination with OWASA would be necessary since a sanitary sewer line is located to the east of the stream. Manhole adjustments and maintenance access of the sanitary line would need to be addressed. Tree removal would be significant. While trees could be replanted that could withstand temporary inundation, the loss of mature trees would need to be accounted for as an impact of the project. There could be potential for creating recreational facilities in the project area and connecting those facilities to Homestead Park immediately to the south of the project.

The total estimated cost for this project is $2,786,000.

Martin Luther King Jr. Boulevard – The proposed Martin Luther King Jr. Boulevard Storage Area is located on the east side of Martin Luther King Jr. Boulevard, just north of the intersection with Homestead Road (See Figure 4-2). While the proposed 2-acre project is located on private property (partially on the Orange United Methodist Church property), a portion of the property is encumbered by floodplain, RCD regulations and a utility easement.

To maximize flood attenuation benefits at this location, significant excavation would be required, which would be costly particularly if there was not a nearby spoil site. All excavation would need to occur above the ordinary high-water mark of Booker Creek. Considerations would need to be given to maintaining base flow and avoiding stream impacts since Booker Creek is a perennial stream at this location.

The drainage area at this location is over 700 acres. Given the relatively low surface area to drainage area ratio, the proposed project has a greater impact with slowing the timing of the runoff downstream than significant peak reduction at the site. Immediately upstream of East Franklin Street, the Martin Luther King Jr. Boulevard project would result in a 2% reduction in the 25-year peak flow when assessed independently of other projects. The peak flow reduction results in a 0.13-foot reduction in water surface elevation.

Land acquisition costs are estimated to be approximately $215,000 based on Orange County parcel data, however since the property has regulatory restrictions, the land costs could be negotiable. The total estimated cost for this project is $3,789,000.

Piney Mountain Road – The proposed Piney Mountain Road Storage Area is located on the west side of Piney Mountain Road approximately 0.5 miles east of the intersection with Martin Luther King Jr. Boulevard (See Figure 4-2). The existing Booker Creek bridge crossing at Piney Mountain Road provides a 10-year level of service and impounds water behind the crossing during larger storm events. The upstream storage area can be expanded into a 5.5-acre temporary storage area.

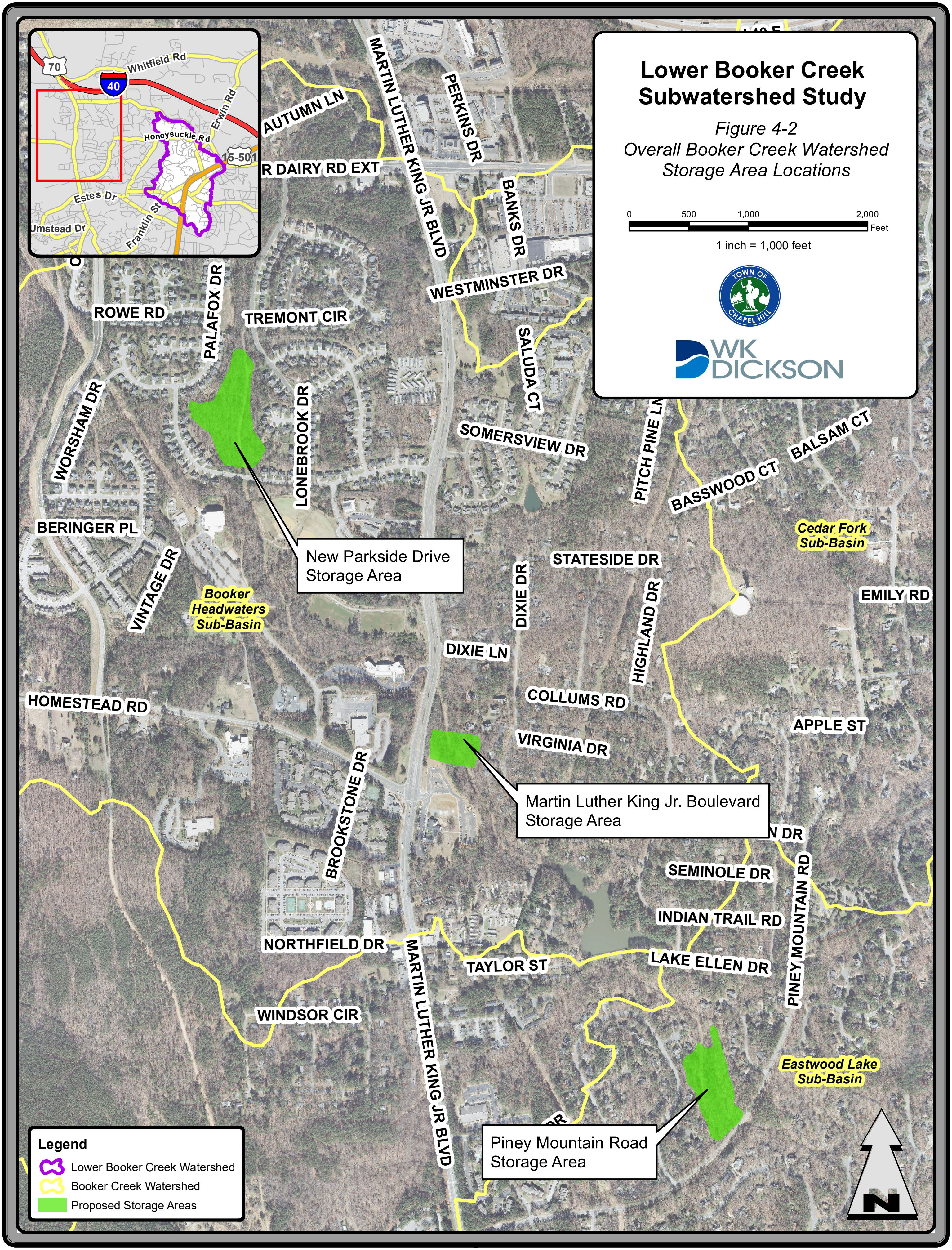
The proposed project is located in open space area in the Forest Creek subdivision, however the majority of the project is in the FEMA floodplain. Orange County parcel data does not list a land value for the property. The open space, utility easement, and regulatory floodplain requirements could influence the terms for obtaining temporary and permanent easements. The Town could also potentially include passive recreational features such as greenways to provide additional benefits of the project.

To maximize flood attenuation benefits at this location, significant excavation would be required, which would be costly particularly if there was not a nearby spoil site. All excavation would need to occur above the ordinary high-water mark of Booker Creek. Considerations would need to be given to maintaining base flow and avoiding stream impacts since Booker Creek is a perennial stream at this location. Significant trees stands should be identified during design and mature trees should be preserved to the extent possible.

The drainage area at this location is over two (2) square miles. Given the relatively low surface area to drainage area ratio, the proposed project has a greater impact with slowing the timing of the runoff downstream than significant peak reduction at the site. The Piney Mountain Road storage project would provide approximately 3% peak reduction in the 25-year storm upstream of East Franklin Street resulting in a 0.13-foot reduction in water surface elevation when assessed independently of other projects.

The total estimated cost for this project is $1,906,000.

Each of the three (3) recommended flood storage projects has a limited impact on peak flows in Booker Creek, however the combination of the three projects results in a 11% reduction in the 25-year peak flow downstream of Eastwood Lake.


Lower Booker Creek Subwatershed Study
Figure 4-2
Overall Booker Creek Watershed Storage Area Locations
0 500 1,000 2,000 Feet
1 inch = 1,000 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Lower Booker Creek Watershed
Booker Creek Watershed
Proposed Storage Areas
New Parkside Drive Storage Area
Martin Luther King Jr. Boulevard Storage Area
Piney Mountain Road Storage Area
Booker Headwaters Sub-Basin
Cedar Fork Sub-Basin
Eastwood Lake Sub-Basin
Whitfield Rd
Erwin Rd
Honeysuckle Rd
Estes Dr
Franklin St
Umstead Dr
15-501
70
40
AUTUMN LN
R DAIRY RD EXT
MARTIN LUTHER KING JR BLVD
PERKINS DR
BANKS DR
WESTMINSTER DR
SALUDA CT
ROWE RD
PALAFOX DR
TREMONT CIR
WORSHAM DR
LONEBROOK DR
SOMERSVIEW DR
PITCH PINE LN
BASSWOOD CT
BALSAM CT
BERINGER PL
VINTAGE DR
STATESIDE DR
DIXIE DR
HIGHLAND DR
EMILY RD
DIXIE LN
COLLUMS RD
HOMESTEAD RD
VIRGINIA DR
APPLE ST
BROOKSTONE DR
SEMINOLE DR
INDIAN TRAIL RD
PINEY MOUNTAIN RD
NORTHFIELD DR
TAYLOR ST
LAKE ELLEN DR
WINDSOR CIR
N

4.2 LOWER BOOKER CREEK NORTH

The LBC North portion of the study consists of the area north of the confluence between Booker Creek (discharging from Eastwood Lake) and Sierra Branch. Sierra Branch is the tributary that generally drains north to south and collects runoff from an area south and west of Weaver Dairy Road. LBC North generally consists of four (4) different types of projects as follows:

(1) Storage areas to provide localized flood reduction as well as reduction in downstream flows along Booker Creek;
(2) Roadway culvert improvements;
(3) Secondary system infrastructure improvements; and
(4) Stream stabilization (Described in detail in Section 6.1).

Red Bud Storage Area – The proposed Red Bud Storage Area is located between Red Bud Lane and Chelsey Lane, approximately 800 feet upstream of the Honeysuckle Road culvert crossing (See Figure 4-3). This storage area is an expansion of an existing storage area controlled by a v-notch weir as shown in Picture 4-1. It is likely that the existing detention area was constructed to meet Town requirements during development of the adjacent subdivision. The proposed project would include additional excavation within the storage area and modification of the v-notch weir to maximize the detention potential in the northern portion of the watershed, creating a 2-acre temporary storage area. The proposed modifications would provide 49% reduction in the 25-year peak flow and allow for less costly upgrades for the required downstream infrastructure improvements at Honeysuckle Road and Booker Creek Road. The proposed storage area would reduce the 25-year peak water surface elevation at Honeysuckle Road by 0.27 feet without any downstream culvert improvements. Most of the Red Bud Storage Area is located on Town-owned property. However, depending on the final configuration and design, some permanent easements may be required for this project. The total estimated cost for this project is $914,000.

Picture 4-1 Weir between Red Bud Lane and Chesley Lane

During a preliminary inspection, there were several potential site restrictions and utility conflicts that were identified including an 8" ductile iron sanitary sewer pipe along the western portion of the project area. The proposed project will need to ensure adequate protection of the sanitary sewer pipe as well as continued maintenance access. To install the proposed storage areas, some tree removal will be required. The installation of construction staging areas and entrances may require additional tree removal and temporary construction easements.

Honeysuckle Road – Based on the results obtained from the existing conditions analysis, the existing 54" CMP at Honeysuckle Road is not passing the desired 25-year storm. Model results show that the road is overtopped during the 10-year event. Residents at 2411 and 2415 Honeysuckle Road, immediately upstream of the culvert, noted property flooding and roadway overtopping on a frequent basis.

The proposed alternative includes increasing the culvert capacity by replacing and upsizing the existing CMP. As shown in Figure 4-3, the proposed culvert is an 8' x 4' RCBC. The upsized culvert will provide the desired 25-year during future land use conditions with less than one (1) inch of freeboard by lowering the 25-year water surface by approximately one (1) foot.

Picture 4-2: Honeysuckle Road – Existing CMP

Residents upstream of Honeysuckle Road would have between 0.4 and 1.0 foot reductions in the 25-year storm and between 0.35 and 0.45 foot reductions in the 100-year storm.

The proposed improvements assume the Red Bud Storage Area would be constructed as proposed above. If the Red Bud Storage Area was not constructed, the proposed culvert size at Honeysuckle Road would need to be a 11' x 4' RCBC.

There were several potential site restrictions and utility conflicts that were identified including sanitary sewer and potable water lines along Honeysuckle Road. These lines may need to be replaced or relocated as part of the culvert upgrades at this crossing. Impacts to traffic flow during construction were considered. This section of Honeysuckle Road is a two-lane minor thoroughfare. It is anticipated that a road closure or flagged two-way one-lane operation will be required. If a road closure is required detours would likely utilize Red Bud Road, Lakeshore Lane, and Booker Creek Road. The total estimated cost for this project is $336,000.

Due to the close proximity, the proposed replacement of the Honeysuckle Road culvert should be coupled with the upstream flood storage (See Red Bud storage above) and stream stabilization (See Project 1 – Sierra 3 in Section 6.1) projects.

Picture 4-3: Booker Creek Road – Existing RCP

Booker Creek Road – U/S – The existing 54" RCP at this crossing is currently providing a 2-year level of service. It overtops during the 10-year storm event and therefore is not providing the desired 10-year level of service. To meet the desired level of service, the culvert capacity at Booker Creek Road will be increased. The proposed alternative entails replacing and upsizing the existing RCP with an 8′ x 4′ RCBC. Figure 4-3 summarizes the improvements proposed at Booker Creek Road. The resulting 25-year water surface elevation upstream of this crossing ranges from 0.7 to 0.9 feet.

The size of the culverts installed at Honeysuckle Road and Booker Creek Road will impact the proposed flow reaching the downstream channel and connecting series of driveway culverts. To accommodate the increase in flow, the six (6) existing driveway culverts which consist of 54" RCPs and CMPs will be replaced with a series of 8′ x 4′ RCBCs. The box culverts should be buried to enhance fish passage and habitat. The current culverts are perched and do not easily allow for aquatic passage. The impacted driveways include access to the following properties: 2540, 2542, 2544, 2546, 2548, and 2556 Booker Creek Road. Along with upsizing the driveway culverts, the stream segments connecting them will be stabilized as necessary particularly the left bank along 2540 Booker Creek Road where erosion has occurred. Figure 4-4 summarizes the improvements proposed for this segment of the project. The total estimated cost for completing the culvert improvements and stream stabilization along Booker Creek Road is $1,285,000.

Significant utility impacts are not anticipated unless the water and sewer services on the east side of Booker Creek Road have to be replaced. Periodic traffic control will be required on Booker Creek Road and allowances will be required for driveway access during replacement of the culverts. A temporary crossing may need to be constructed for vehicular and pedestrian traffic. Proposed improvements will likely require 401/404 permitting. Improvements will be designed to meet the criteria of a Nationwide permit if possible. Early coordination with the permitting agencies is recommended.

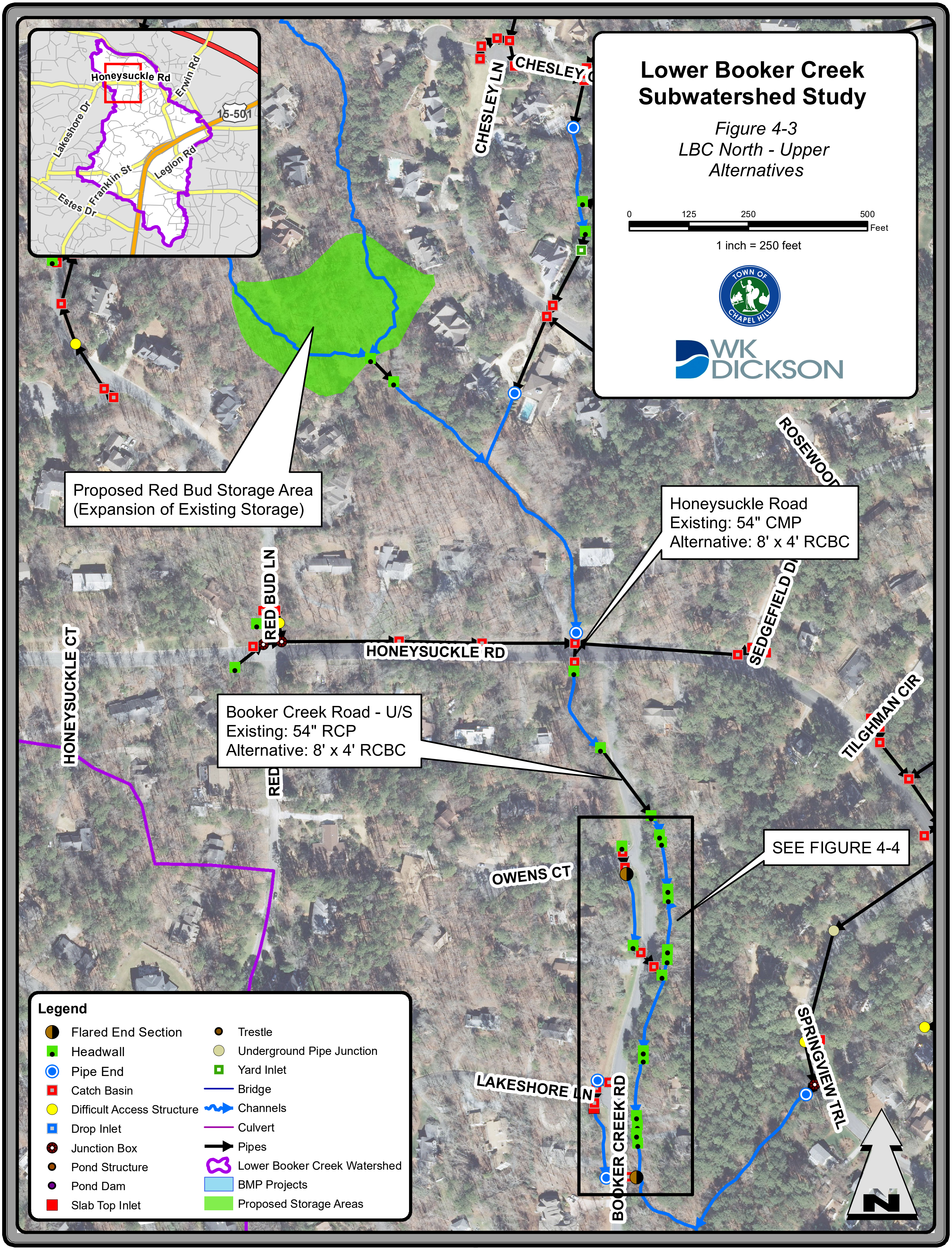
Booker Creek Road – D/S – Due to the poor condition of the downstream Booker Creek Road culvert, proposed culvert improvements were designed and constructed concurrently with this study. As shown on Figure 4-5, the existing CMP arch culverts were replaced with twin 5′ x 6′ RCBCs.

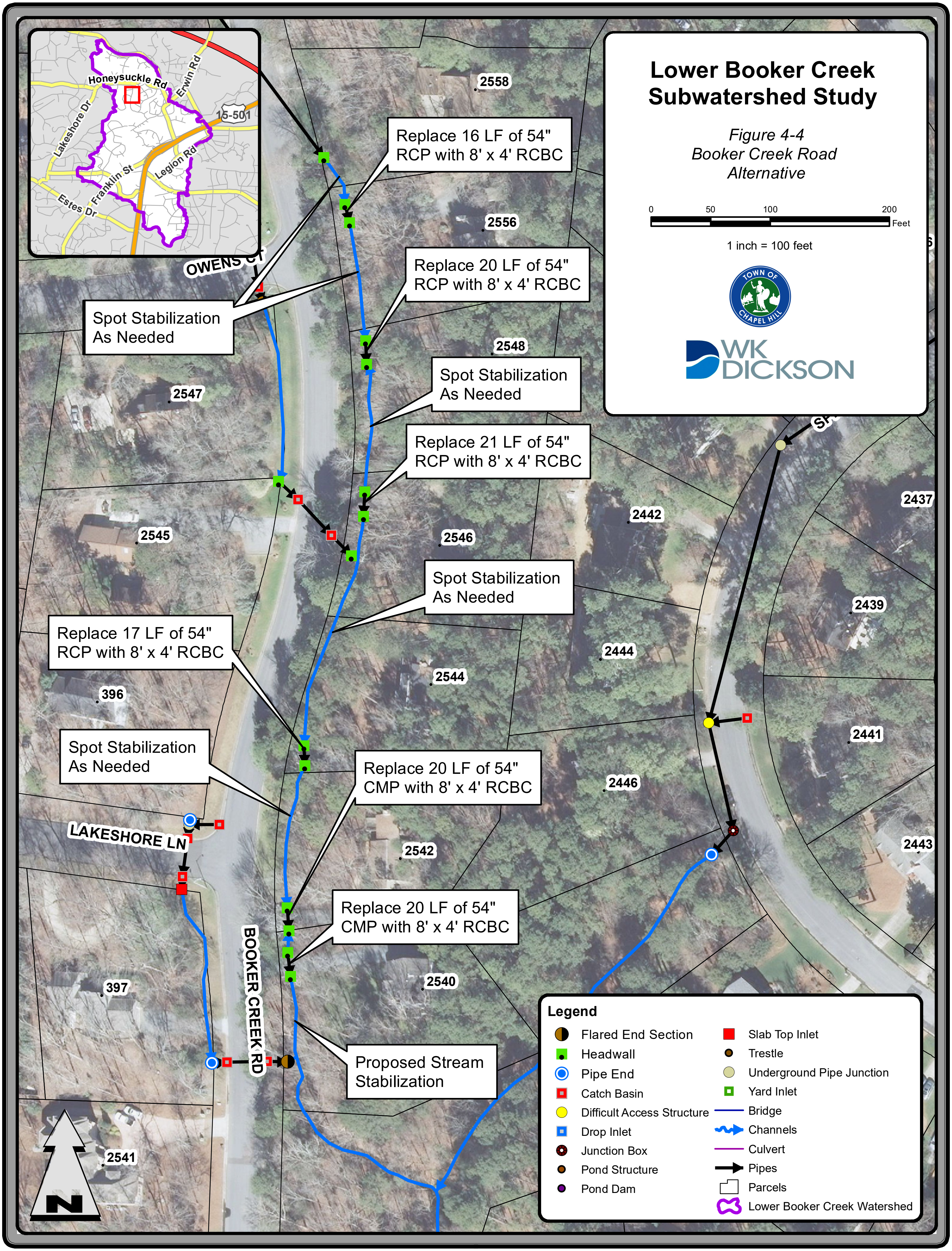
Daley Road Storage Area – The proposed Daley Road Storage Area is located predominantly on Town-owned property immediately downstream of the Booker Creek Road – D/S crossing and west of the Booker Creek Townhomes. The location includes the confluence of Booker Creek (discharging from Eastwood Lake) and the Sierra Reach, which drains the northern portion of Lower Booker Creek. The 15-acre Town-owned property is predominantly wooded and located in the regulatory floodplain. The Lower Booker Creek greenway and a 12" sanitary sewer line are located along the east side of the property.

While the property is generally located in a low-lying floodplain area, excavation above the ordinary high-water mark could provide additional storage in the watershed that would slow down peak flows from both Booker Creek and Sierra Branch thereby lowering flows at Franklin Street and those areas south. The proposed project shown in Figure 4-5 is approximately eleven (11) acres in size partially located on Town property. The storage area can also be expanded to include the undeveloped properties at 2123 and 2127 Markham Drive. Both of these properties are located within the regulatory floodplain. The proposed project could potentially reduce the 25-year peak flow from the Sierra Branch by approximately 27%.

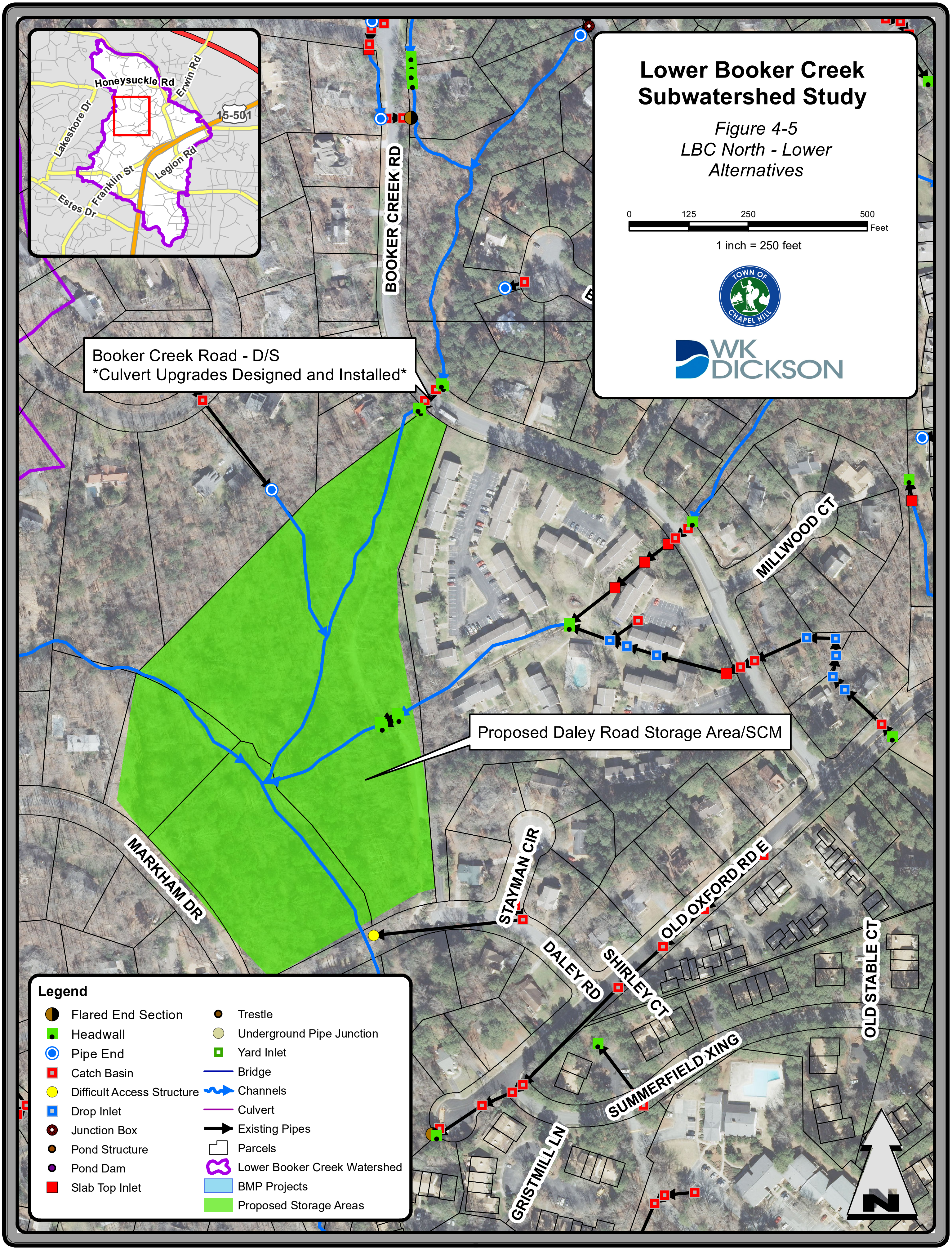
During a preliminary site inspection, there were several potential site restrictions and utility conflicts that were identified including overhead power lines above Markham Drive, which may possibly be used as a construction entrance. These overhead power lines may need to be temporarily relocated based on where the contractor accesses the site. In order to install the proposed storage areas, significant tree removal will be required. Replanting of trees is anticipated in a portion of the storage area however, it will take significant time for the trees to mature. The installation of construction staging areas and entrances may require additional tree removal and temporary construction easements.

The total estimated cost for this project is $3,140,000. Given the high cost and the limited land resources within the watershed, it is recommended the Town consider using the property for multiple purposes including potential park facilities. The storage areas could be tiered to maintain some dry areas during the smaller storm events.


Lower Booker Creek Subwatershed Study
Figure 4-3
LBC North - Upper Alternatives
0 125 250 500 Feet
1 inch = 250 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
CHESLEY LN
CHESLEY C
Proposed Red Bud Storage Area (Expansion of Existing Storage)
ROSEWOOD
Honeysuckle Road
Existing: 54" CMP
Alternative: 8' x 4' RCBC
SEDGEFIELD D
RED BUD LN
HONEYSUCKLE RD
HONEYSUCKLE CT
TILGHMAN CIR
Booker Creek Road - U/S
Existing: 54" RCP
Alternative: 8' x 4' RCBC
RED
SEE FIGURE 4-4
OWENS CT
SPRINGVIEW TRL
LAKESHORE LN
BOOKER CREEK RD
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Pipes
Lower Booker Creek Watershed
BMP Projects
Proposed Storage Areas
N



Lower Booker Creek Subwatershed Study
Figure 4-4
Booker Creek Road Alternative
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
OWENS CT
LAKESHORE LN
BOOKER CREEK RD
Replace 16 LF of 54" RCP with 8' x 4' RCBC
Replace 20 LF of 54" RCP with 8' x 4' RCBC
Spot Stabilization As Needed
Spot Stabilization As Needed
Replace 21 LF of 54" RCP with 8' x 4' RCBC
Spot Stabilization As Needed
Replace 17 LF of 54" RCP with 8' x 4' RCBC
Spot Stabilization As Needed
Replace 20 LF of 54" CMP with 8' x 4' RCBC
Replace 20 LF of 54" CMP with 8' x 4' RCBC
Proposed Stream Stabilization
2558
2556
2548
2547
2545
2546
2442
2437
2439
2444
2544
396
2441
2446
2542
2443
397
2540
2541
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Pipes
Parcels
Lower Booker Creek Watershed



Lower Booker Creek Subwatershed Study
Figure 4-5
LBC North - Lower Alternatives
0
125
250
500
Feet
1 inch = 250 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
BOOKER CREEK RD
Booker Creek Road - D/S
Culvert Upgrades Designed and Installed
Proposed Daley Road Storage Area/SCM
MILLWOOD CT
MARKHAM DR
STAYMAN CIR
OLD OXFORD RD E
DALEY RD
SHIRLEY CT
OLD STABLE CT
SUMMERFIELD XING
GRISTMILL LN
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Existing Pipes
Parcels
Lower Booker Creek Watershed
BMP Projects
Proposed Storage Areas

Chesley Lane Closed System

WK Dickson recommends the following improvements for the Chesley Lane Closed System as shown in Figure 4-6:

- Install 44 LF of 15" RCP along Chesley Lane;
- Install 139 LF of 18" RCP along Chesley Lane;
- Remove and replace 2 existing inlets; and
- Install 2 additional inlets.

The proposed improvements will continue to provide the desired 10-year level of service while reducing the spread to within allowable limits for the Chesley Lane Closed System. The project is located within the public ROW, so there will be minimal impacts to private properties. It should be noted that Chesley Lane is a cul-de-sac road with no outlet. Therefore, these proposed improvements may require staged construction that will allow continuous traffic flow providing ingress and egress for the affected homeowners. Sections of the curb and gutter along Chesley Lane will need to be removed and replaced as part of the proposed improvements. Underground power, water and sanitary sewer lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $146,000.

There is one (1) report of flooding in this area. It is a report of yard and driveway flooding at 226 Chesley Lane several times per year. The installation of the additional RCPs and inlets to capture and convey the water will reduce the frequency and severity of flooding at this residence.

Booker Creek Road/ Lakeshore Lane System

WK Dickson recommends the following improvements for the Booker Creek Road/Lakeshore Lane System as shown in Figure 4-7:

- Install 199 LF of 30" RCP along Booker Creek Road;
- Replace 64 LF of 18" RCP with 36" RCP across Booker Creek Road;
- Install 2 additional inlets; and
- Remove and replace 2 existing inlets.

The proposed improvements will provide the desired 10-year level of service. The majority of the project is located within the public right-of-way thereby resulting in minimal impacts to private properties. Underground water and sewer lines were identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $263,000.

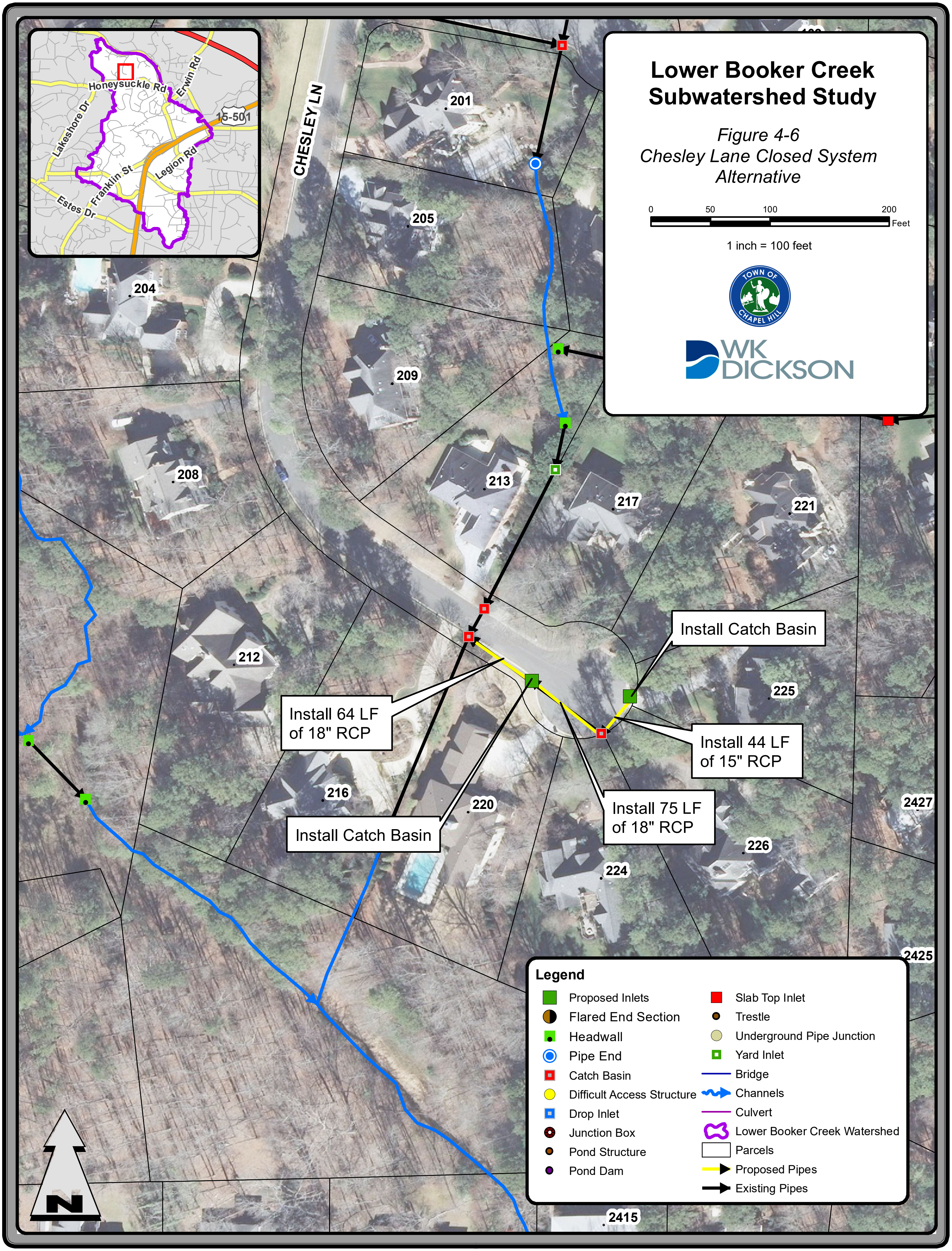
Old Oxford Road/Booker Creek Road System

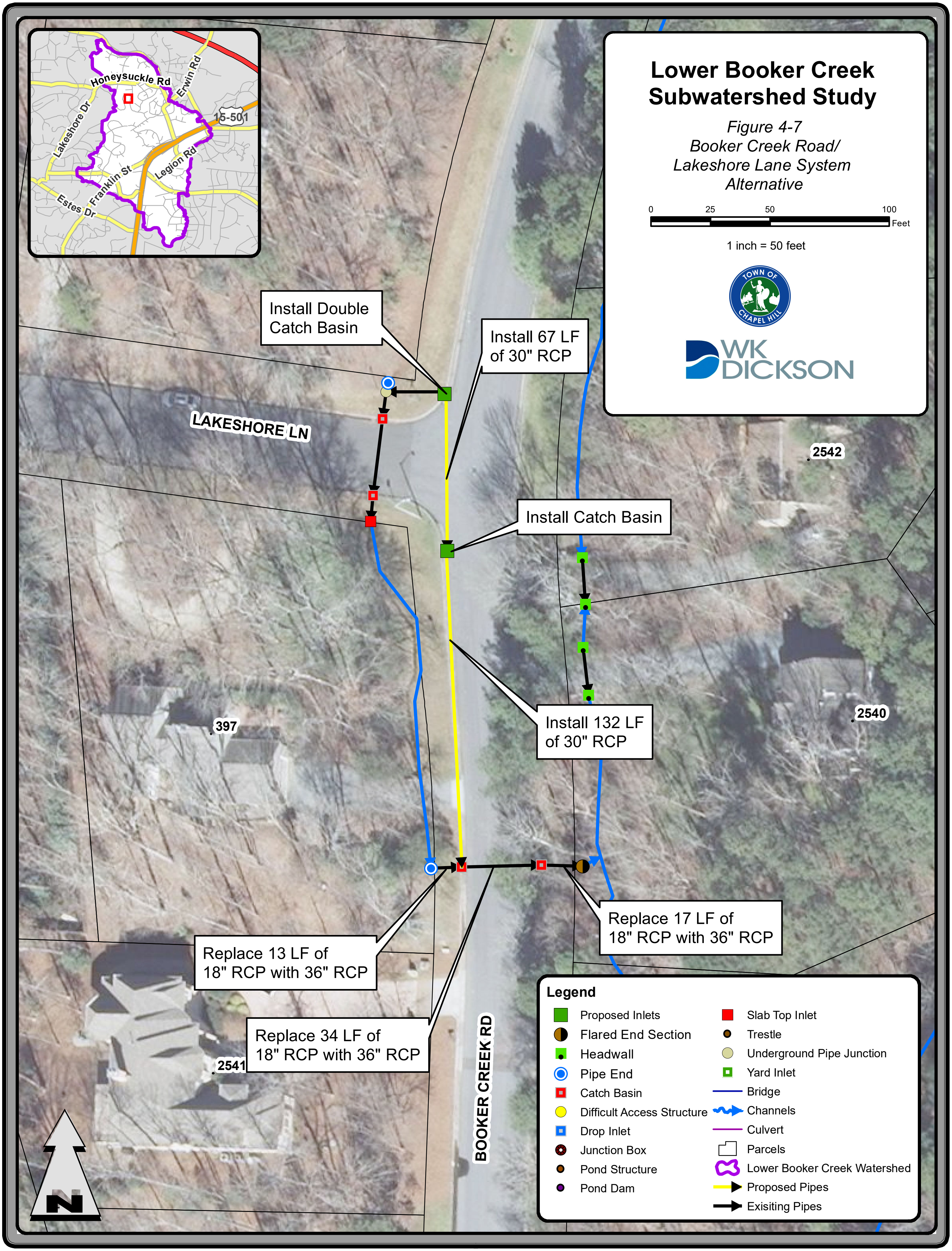
WK Dickson recommends the following improvements for the Old Oxford Road/Booker Creek Road System as shown in Figure 4-8:

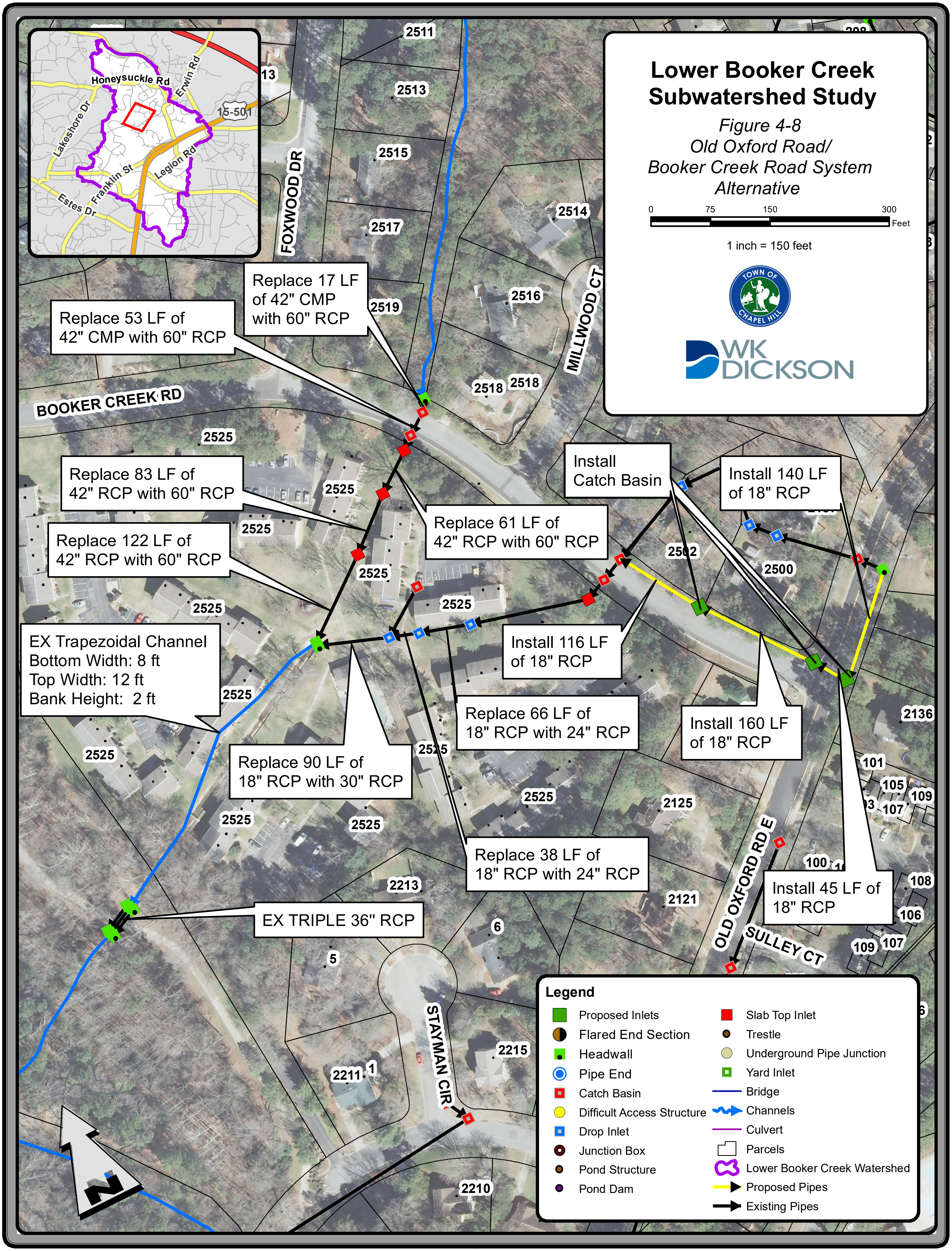
- Replace 70 LF of 42″ CMP with 60″ RCP across Booker Creek Road;
- Replace 266 LF of 42″ RCP with 60″ RCP in the Booker Creek Townhouse Apartments common area;
- Replace 90 LF of 18″ RCP with 30″ RCP in the Booker Creek Townhouse Apartments common area;
- Replace 104 LF of 18″ RCP with 24″ RCP in the Booker Creek Townhouse Apartments common area;
- Install 276 LF of 18″ RCP along Booker Creek Road;
- Install 185 LF of 18″ RCP across Old Oxford Road East;
- Install 3 inlets; and
- Remove and replace 9 inlets.

The proposed improvements will provide a 10–year level of service for the Old Oxford Road/Booker Creek Road System. A significant portion of the project will be located in the common areas of the Booker Creek Townhouse Apartments. The section of the existing system located on 2500 and 2502 Booker Creek will be plugged and remain in place. The flow will be rerouted to the proposed system located within the ROW. Underground water and sewer lines were identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $634,000.

Due to the close proximity, the proposed improvements to the Oxford Road/Booker Creek Road System should be coupled with the downstream stream restoration recommendations shown in as Project 5 – Foxwood 3 in Section 6.1.


Lower Booker Creek Subwatershed Study
Figure 4-6
Chesley Lane Closed System Alternative
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
CHESLEY LN
201
205
204
209
208
213
217
221
212
225
216
220
2427
226
224
2425
2415
Install Catch Basin
Install 64 LF of 18" RCP
Install 44 LF of 15" RCP
Install 75 LF of 18" RCP
Install Catch Basin
Legend
Proposed Inlets
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Lower Booker Creek Watershed
Parcels
Proposed Pipes
Existing Pipes
N


Lower Booker Creek
Subwatershed Study
Figure 4-7
Booker Creek Road/
Lakeshore Lane System
Alternative
0
25
50
100
Feet
1 inch = 50 feet
TOWN OF
CHAPEL HILL
WK
DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
Install Double
Catch Basin
Install 67 LF
of 30" RCP
LAKESHORE LN
Install Catch Basin
Install 132 LF
of 30" RCP
2542
2540
397
Replace 17 LF of
18" RCP with 36" RCP
Replace 13 LF of
18" RCP with 36" RCP
Replace 34 LF of
18" RCP with 36" RCP
2541
BOOKER CREEK RD
N
Legend
Proposed Inlets
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Proposed Pipes
Exisiting Pipes


Lower Booker Creek Subwatershed Study
Figure 4-8
Old Oxford Road/
Booker Creek Road System
Alternative
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
BOOKER CREEK RD
FOXWOOD DR
MILLWOOD CT
OLD OXFORD RD E
SULLEY CT
STAYMAN CIR
Replace 17 LF of 42" CMP with 60" RCP
Replace 53 LF of 42" CMP with 60" RCP
Replace 83 LF of 42" RCP with 60" RCP
Replace 122 LF of 42" RCP with 60" RCP
Replace 61 LF of 42" RCP with 60" RCP
Install Catch Basin
Install 140 LF of 18" RCP
Install 116 LF of 18" RCP
EX Trapezoidal Channel
Bottom Width: 8 ft
Top Width: 12 ft
Bank Height: 2 ft
Replace 66 LF of 18" RCP with 24" RCP
Install 160 LF of 18" RCP
Replace 90 LF of 18" RCP with 30" RCP
Replace 38 LF of 18" RCP with 24" RCP
Install 45 LF of 18" RCP
EX TRIPLE 36" RCP
Legend
Proposed Inlets
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Proposed Pipes
Existing Pipes
N

4.3 LOWER BOOKER CREEK SOUTH

The LBC South portion of the project consists of the downstream segment of Booker Creek from the East Franklin Street crossing to its confluence with Little Creek. LBC South generally consists of three (3) different types of projects as follows:

(1) Floodplain storage areas to provide localized flood reduction as well as reduction in downstream flows along Booker Creek;
(2) Roadway culvert improvements; and
(3) Secondary system infrastructure improvements.

East Franklin Street – As determined by the existing conditions analysis, the existing triple 11′ x 11′ RCBCs at this crossing provides a 10-year level of service. The desired level of service for this North Carolina Department of Transportation (NCDOT) maintained roadway, located within a FEMA regulated floodway, is the 100-year design storm. Currently, the road is overtopped by 0.91 feet during the 25-year storm event.

Picture 4-4: East Franklin Street – Existing RCBCs

With the improvements proposed downstream (See Figure 4-9) including the proposed storage area adjacent to the Eastgate Shopping Center upstream of South Elliott Road, the water surface elevations will be lowered along this segment of Booker Creek. At East Franklin Street, water surface elevations will be reduced by 1.5 feet during the 25-year storm event and 0.4 feet in the 100-year storm event. These reductions will improve the performance of East Franklin Street culverts and bring it up to a 25-year level of service with future flows. The existing culverts are in good condition; therefore, no infrastructure improvements are proposed for this location.

Eastgate Crossing Road – Based on results obtained from the existing conditions analysis, the existing 35′ x 10.5′ RCBC at this crossing does not meet the desired 100-year level of service without overtopping. Currently, it is operating at a 2-year level of service.

The hydraulic performance at Eastgate Crossing Road is affected by the backwater from downstream. With the improvements proposed upstream and downstream, the resultant 25-year water surface elevation is reduced by 1.8 feet and the 100-year by 0.9 feet. The culvert at this crossing still does not meet the desired 100-year level of service; however, it will be improved to a 10-year level of service. Increasing the size of the existing culvert at Eastgate has a minimal impact on water surface elevations since the culvert is in outlet control. Therefore, upstream detention and downstream improvements designed to lower the tailwater on the Eastgate culvert are critical for improving the level of service at this location.

The WK Dickson team also evaluated replacing the existing culvert with an open channel (daylighting) which would provide some environmental benefits by creating an open stream. However, due to the urbanized nature of the watershed, significant armoring of the stream would likely be required. Replacing the culvert with an open stream would not have a significant impact on water surface elevations without implementation of the Elliott Storage Area referenced below. A 200-foot wide section would still only convey the 10-year storm and would necessitate the significant removal of buildings and parking in the Eastgate shopping area. Areas adjacent to the stream would still be in the regulatory floodplain and experience flooding during larger storm events. If the Elliott Storage Area is constructed, then the open channel width could be reduced to approximately seventy (70) feet to achieve similar water surface elevations as the existing culverts under Eastgate. It is estimated daylighting the pipe under this scenario would result in the loss of approximately 70,000 square feet in commercial property, although the exact configuration of any redeveloped commercial area in Eastgate would be dependent on the specific architecture and design of the area. Regardless, the Eastgate Crossing area would still be floodprone during large storm events.

Elliott Storage Area/Passive Green Space – The proposed Elliott Storage Area is located between the outlet of the Eastgate Culvert and South Elliott Road, on private property (See Figure 4-9). The storage area is proposed to be approximately 5½ acres in size. The Town would be required to obtain temporary and permanent easements on multiple parcels to implement the proposed project. The Elliott Storage Area is critical in order to provide substantial flood level reductions in the Eastgate Crossing area.

The project would consist of grading, excavation, and disposal of earthen material. An 18" sanitary sewer line is located within the proposed project area and coordination with OWASA would be required. The proposed project also presents an opportunity to the Town to have a signature green space project located in the Ephesus Fordham District that could provide flood level reductions, water quality treatment, and recreational features.

The project would require significant coordination with a variety of stakeholders including Town staff, private property owners, FEMA, USACE, NCDEQ, and OWASA.

The total estimated cost for this project is $1,140,000 which does not include easement or land acquisition costs. The majority of the project area is within the floodway, floodplain, or RCD, which may reduce the potential easement cost, but it is advised to complete appraisals early in the design process.

South Elliott Road – Currently, the existing triple 19.5' x 9.6' elliptical CMPs at South Elliott Road do not meet the desired 100-year level of service. The culvert overtops during the existing and future 100-year storm by 0.6 and 0.8 feet, respectively. The implementation of the proposed downstream floodplain benching combined with the proposed upstream storage will reduce the water surface elevation at this crossing by 0.3 feet during the 100-year storm event. It should be noted that during inventory collection, heavy corrosion was observed on the downstream side of the middle elliptical CMP. Consequently, the Town rehabilitated the existing pipes with a steel liner in the Fall of 2016.

Highway 15-501/Fordham Boulevard – Based on the results obtained from the hydraulic analysis, the existing triple 11.5′ x 11.5′ RCBCs at Highway 15-501/Fordham Boulevard meet the desired 100-year level of service for both existing and future land use conditions.

Picture 4-5: Highway 15-501/Fordham Boulevard – Existing RCBCs

The proposed downstream improvements (See Willow Drive below) will reduce the water surface elevations at Highway 15-501/Fordham Boulevard by 0.8 feet in the 25-year storm event and 0.5 feet in the 100-year storm event. With these lower water surface elevations, this crossing will continue to pass the 100-year storm event with additional freeboard. The existing culverts are in good condition; therefore, no improvements are proposed for this location.

Increasing the size of the culverts at 15-501 would increase flows downstream and potentially cause flows to be higher along Little Creek.

Willow Drive – The existing bridge at this crossing is currently exceeding a 100-year level of service. However, in order to lower the upstream tailwater and improve the performance of the culvert at Eastgate Crossing Road, the capacity at Willow Drive needs to be increased. This alternative proposes the installation of twin 72″ floodplain culverts. Additionally, it is recommended that floodplain benching be included upstream and downstream of the Willow Drive crossing. As shown in Figure 4-10, the proposed floodplain benching is located in the right and left overbank for approximately 1,800 linear feet downstream of Willow Drive and in the right overbank for 700 linear feet upstream of Willow Drive.

The resulting 25-year water surface elevation reductions at Willow Drive will be 1.7 feet and will range between 0.1 to 1.1 feet in the areas downstream of Willow Drive. Lowering the tailwater at the Willow Drive crossing is the only feasible alternative for lowering the upstream water surface elevations. There are twenty-six (26) structures located in the existing conditions 25-year floodplain downstream of Willow Drive and an additional eight (8) structures in the 100-year floodplain. If this alternative is implemented, three (3) structures will be removed from the 25-year floodplain and an additional two (2) structures from the 100-year floodplain. The remaining properties will continue to be in the floodplain; however, the severity, duration, and frequency of flooding will be reduced. These properties in the lower end of the watershed are being impacted by backwater flooding from Bolin Creek and Little Creek.

During a field visit, there were several potential site restrictions and utility conflicts that were identified including overhead power lines that are located above Willow Drive. The overhead power lines may need to be relocated based on where the contractor accesses the site. Downstream of Willow Drive, there is a sanitary sewer line (30” ductile iron) that runs parallel to Booker Creek in the proposed project area. This line may need to be replaced or relocated based on its elevation. Impacts to traffic during construction were considered. Willow Drive is a two-lane roadway. It is anticipated that a road closure or a flagged two-way one-lane operation will be required during construction.

In order to gain access and to install the floodplain benching, significant tree removal will be required which will be costly and can be considered a negative impact of the project to some stakeholders. It should be noted that the proposed grading areas can be replanted following completion of construction. For the portions of the proposed floodplain benching located on private property, easements will be required to complete the project and for future maintenance.

The location of the proposed floodplain benching also provides an opportunity to enhance the existing greenway system. A greenway trail can be installed downstream of Willow Drive and tie-in to the existing Booker Creek Trail. If the extension of the greenway trail and the floodplain benching could be constructed concurrently, economy of savings could be provided.

Coordination with FEMA, USACE, NCDEQ, and OWASA will be critical for implementation of this project. The project is located in the FEMA floodway and wetlands are likely within the project area. Since the proposed project is predominantly excavation, it is expected that any impacts to the wetlands will be temporary as wetlands will reestablish at the lower elevation. Early coordination with the Corps will be critical to determining the extent of permitting effort required. A 30” DIP sanitary pipe is also located along the west end of the stream at this location. Coordination with OWASA will be required to maintain access to this facility.

The total estimated cost for the proposed Willow Drive floodplain culverts and floodplain benching is $4,010,000.

The Town could consider floodplain buyouts for eligible properties downstream of Fordham Boulevard and Willow Drive that are within the Booker Creek floodplain. There are many issues to consider when acquiring floodplain properties including the additional administration, legal, demolition, and ongoing maintenance costs of the properties as well as the loss of tax value. Additionally, since the program would be voluntary, it is likely that not all eligible residents would participate, so that there would still be flood damages. Finally, the Town would need to consider how floodplain buyouts would impact the neighborhoods and surrounding property values. Twenty-six (26) properties were identified within the FEMA floodplain between Fordham

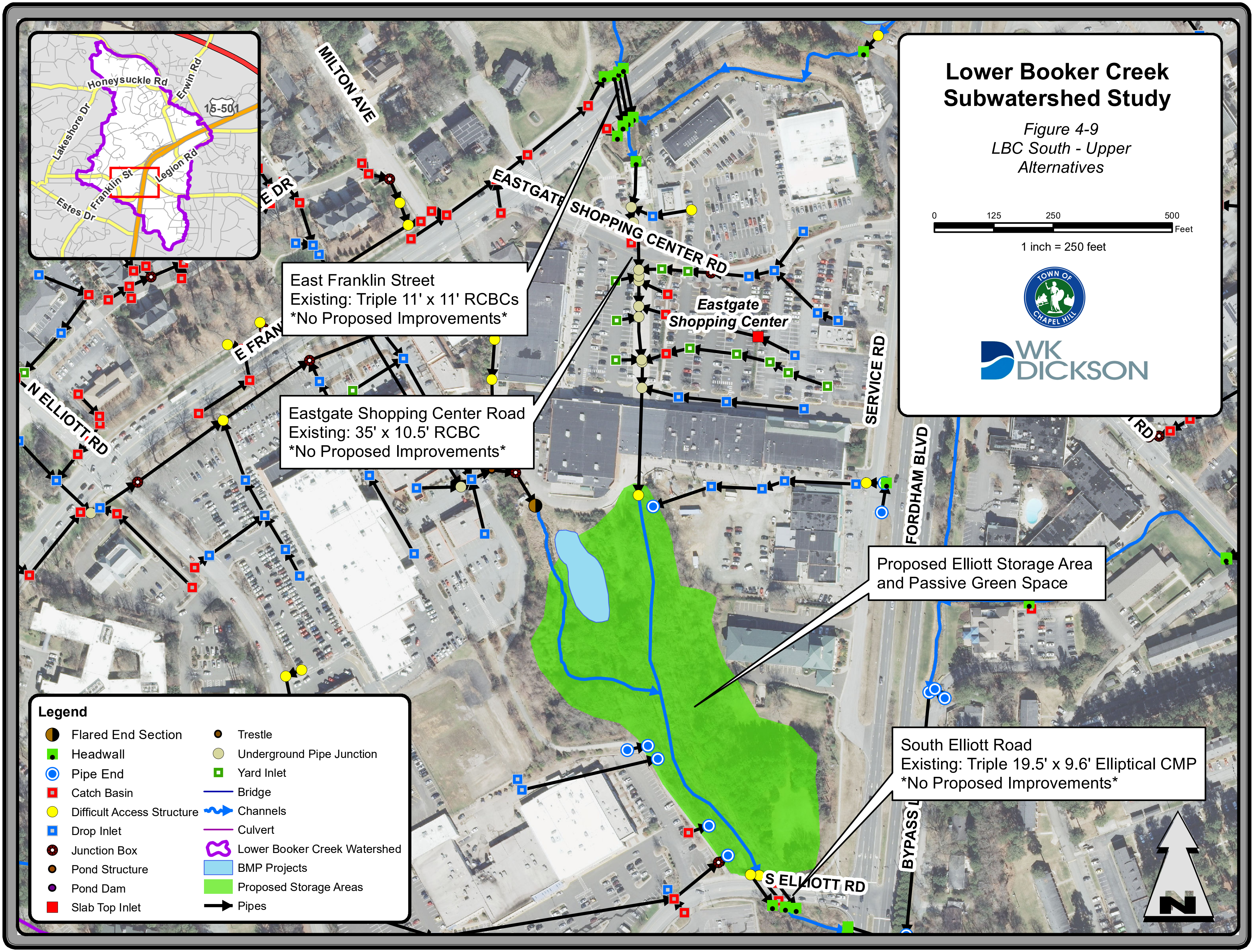
Boulevard and the confluence with Bolin Creek. It is likely that some of the homes are elevated above the floodplain, however finished floor elevations were not available as part of this study. Based on the Orange County parcel data, the total value of the twenty-six (26) properties is $6,508,000, which does not include the additional costs noted above that are required as part of any acquisition project. FEMA acquisition and demolition grants are available for repetitive loss properties. Additional data and engineering are required for these applications including structure elevation surveys and a detailed benefit cost analysis.

Ephesus Church Road System

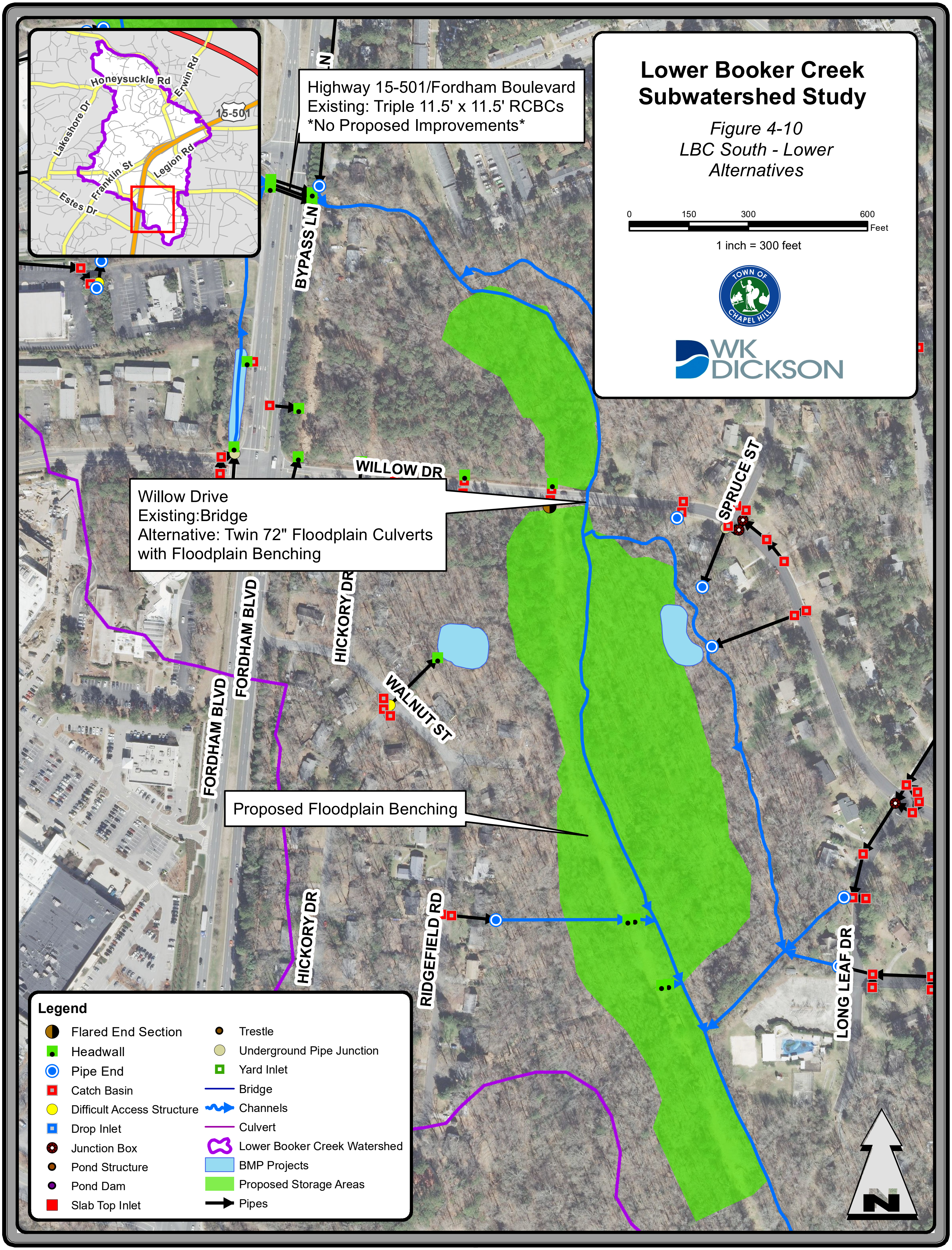
The secondary system crossing Ephesus Church Road and draining to Fordham Boulevard is undersized and requires infrastructure improvements starting at Clover Drive to increase capacity and address stream erosion issues. This area will be reconfigured as part of the road extensions of Elliott Road and Legion Road. Therefore, the new stormwater conveyance system should be improved as part of the roadway projects to adequately convey the flows from the Clover Drive and Hamlin Park areas. The proposed projects shown in Figure 4-11 and described below are intended to provide preliminary information for the needed infrastructure improvements, with the understanding that the final configuration may be different. Town staff should work closely with the designer of the roadway improvements to ensure the required stormwater infrastructure is included in the final design documents. WK Dickson recommends the following improvements for the Ephesus Church Road System as shown in Figure 4-11:

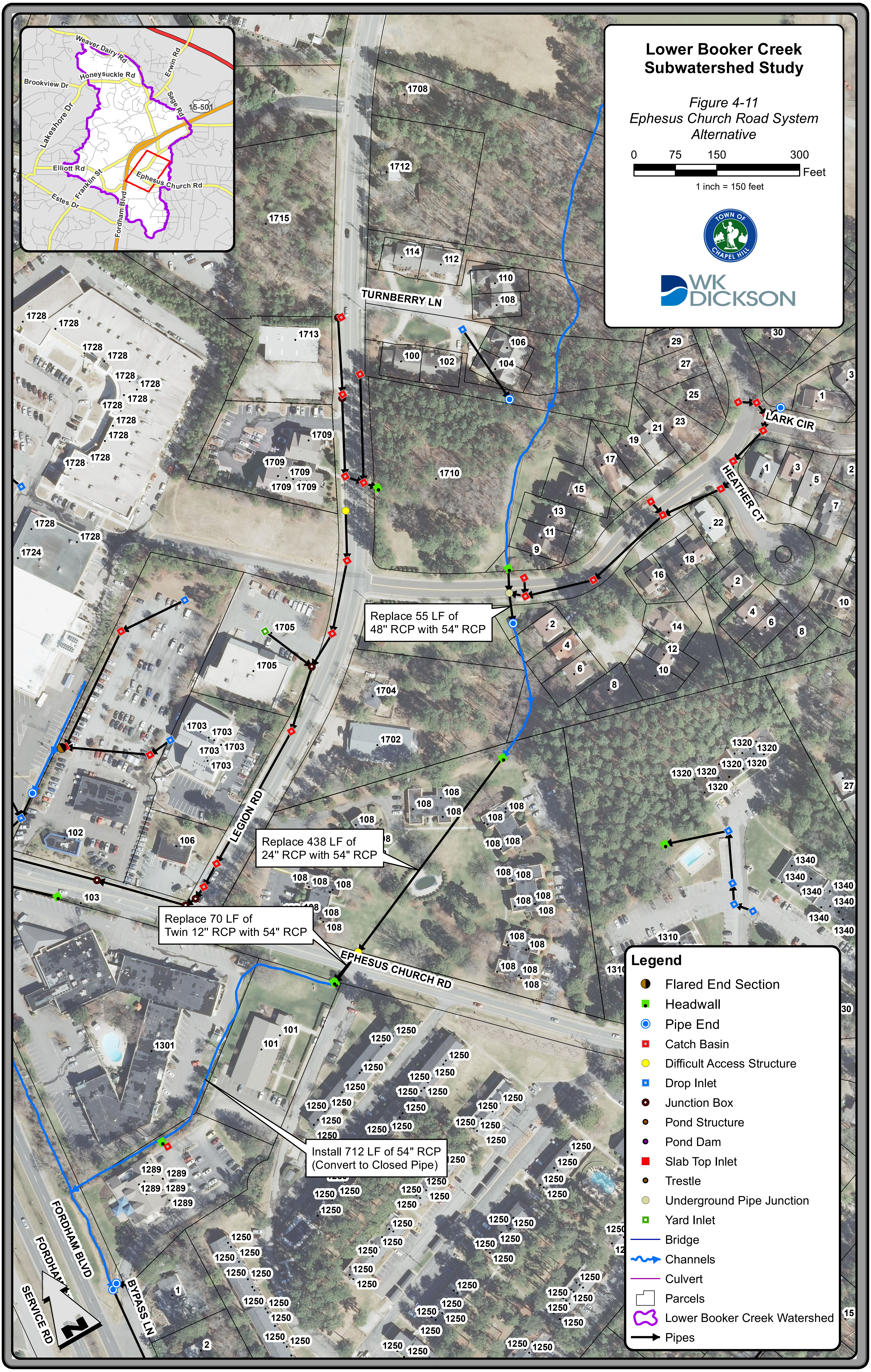
- Replace 55 LF of 48″ RCP with 54″ RCP across Clover Drive;
- Replace 438 LF of 24″ RCP with 54″ RCP through Hamlin Park;
- Replace 70 LF of twin 12″ RCPs with 54″ RCP across Ephesus Church Road; and
- Covert 712 LF of channel to closed pipe (54″ RCP) downstream of the Ephesus Church Road crossings.

The proposed improvements will provide a 10–year level of service. Based on final elevations of the roadways, sizing of the pipes may need to be adjusted; however, any new configuration should include pipes sized to carry the same or additional capacity as provided by the 54″ RCP. A significant portion of the project will be located in the common areas of the Hamlin Park Apartments. Sections of the curb and gutter along Clover Drive and Ephesus Church Road will need to be removed and replaced as part of the proposed improvements. Underground water and sanitary sewer lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $1,045,000.



Lower Booker Creek Subwatershed Study
Figure 4-9
LBC South - Upper Alternatives
0 125 250 500 Feet
1 inch = 250 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
MILTON AVE
EASTGATE SHOPPING CENTER RD
E FRAN
N ELLIOTT RD
SERVICE RD
FORDHAM BLVD
BYPASS
S ELLIOTT RD
Eastgate Shopping Center
East Franklin Street
Existing: Triple 11' x 11' RCBCs
No Proposed Improvements
Eastgate Shopping Center Road
Existing: 35' x 10.5' RCBC
No Proposed Improvements
Proposed Elliott Storage Area and Passive Green Space
South Elliott Road
Existing: Triple 19.5' x 9.6' Elliptical CMP
No Proposed Improvements
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Lower Booker Creek Watershed
BMP Projects
Proposed Storage Areas
Pipes
N


Lower Booker Creek
Subwatershed Study
Figure 4-10
LBC South - Lower
Alternatives
0
150
300
600
Feet
1 inch = 300 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
Lakeshore Dr
15-501
Legion Rd
Franklin St
Estes Dr
Highway 15-501/Fordham Boulevard
Existing: Triple 11.5' x 11.5' RCBCs
No Proposed Improvements
BYPASS LN
WILLOW DR
SPRUCE ST
Willow Drive
Existing:Bridge
Alternative: Twin 72" Floodplain Culverts
with Floodplain Benching
FORDHAM BLVD
HICKORY DR
WALNUT ST
Proposed Floodplain Benching
RIDGEFIELD RD
LONG LEAF DR
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Lower Booker Creek Watershed
BMP Projects
Proposed Storage Areas
Pipes
N


Lower Booker Creek Subwatershed Study
Figure 4-11
Ephesus Church Road System Alternative
0 75 150 300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Brookview Dr
Erwin Rd
Sage Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
TURNBERRY LN
LARK CIR
HEATHER CT
LEGION RD
EPHESUS CHURCH RD
FORDHAM BLVD
FORDHAM BLVD
SERVICE RD
BYPASS LN
Replace 55 LF of
48" RCP with 54" RCP
Replace 438 LF of
24" RCP with 54" RCP
Replace 70 LF of
Twin 12" RCP with 54" RCP
Install 712 LF of 54" RCP
(Convert to Closed Pipe)
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Pipes
N

4.4 LOWER BOOKER CREEK WEST

The LBC West portion of the project consists of the areas located west of the Booker Creek primary system. LBC West generally consists of three (3) different types of projects as follows:

(1) Roadway culvert improvements;
(2) Secondary system infrastructure improvements; and
(3) Stream stabilization (Described in detail in Section 6.1).

Old Oxford Road System
WK Dickson recommends the following improvements for the Old Oxford Road System as shown in Figure 4-12:

- Replace 34 LF of 24" RCP with 36" RCP along Old Oxford Road;
- Install 617 LF of 18" RCP along Old Oxford Road; and
- Install 3 inlets.

The proposed improvements will provide a 10–year level of service for the new alignment along Old Oxford Road. The project is located within the public ROW; there will be minimal impacts to private properties. Sections of the curb and gutter along Old Oxford Road will need to be removed and replaced as part of the proposed improvements. Underground water and sanitary sewer lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $295,000. If funds allow, the Town should consider constructing the proposed stream improvements downstream of the Old Oxford Road System at the same time which may provide some economy of savings. See Section 6.1 for more details on the proposed stream project (See Project 9 – Oxford 2).

Markham Drive/Old Oxford Road Closed System
WK Dickson recommends the following improvements for the Markham Drive/Old Oxford Road Closed System as shown in Figure 4-13:

- Install 285 LF of 18" RCP along Old Oxford Road;
- Replace 33 LF of 15" RCP with 24" RCP under Old Oxford Road;
- Replace 339 LF of 18" RCP with 24" RCP along Old Oxford Road;
- Replace 70 LF of 24" RCP with 30" RCP at the intersection Old Oxford Road and Oxford Hills Drive;
- Replace 119 LF of 24" RCP with 30" RCP along Oxford Hills Drive;
- Replace 83 LF of 24" RCP with 30" RCP adjacent to 224 Oxford Hills Drive;
- Install 2 inlets; and
- Remove and replace 5 inlets.

The proposed improvements will provide a 10–year level of service for the Markham Drive/Old Oxford Road Closed System without the hydraulic grade line surcharging any pipes. While a significant portion of the project will be located in the ROW, there will be approximately 90 linear feet of replaced on private property. The driveways and/or landscaping at the following properties will be impacted: 213 and 224 Oxford Hills Drive. Sections of curb and gutter along Old Oxford Road and Oxford Hills Drive will need to be removed and replaced to complete the proposed improvements. Underground water lines and a power pole were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $451,000.

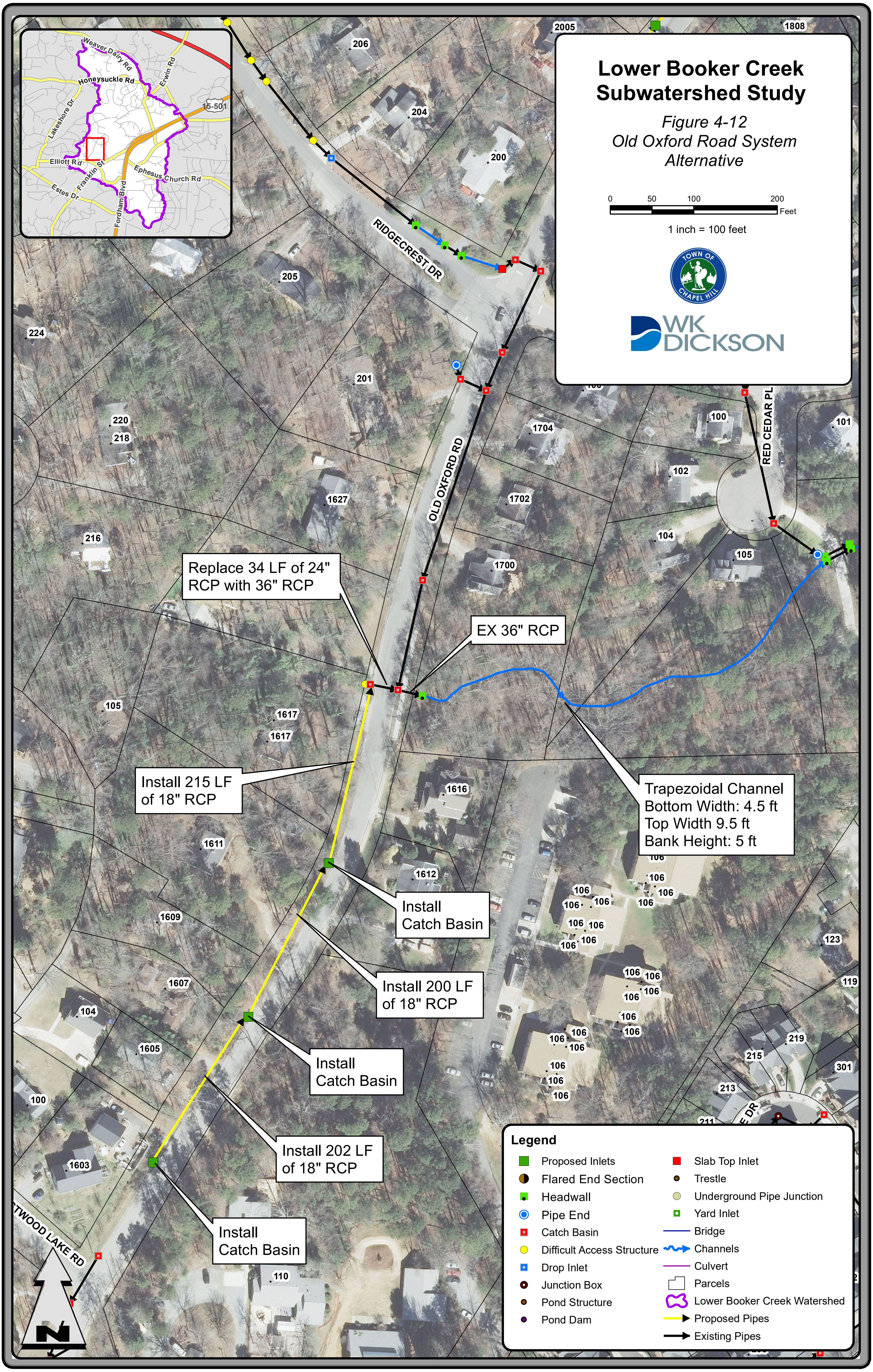
The Town could consider phasing the project and only install the 18″ RCP and new inlets between 1802 and 1808 Old Oxford Road to determine if these improvements resolve the flooding issue. If flooding continues in this area or if deteriorating infrastructure requires replacement of the existing pipes along Old Oxford Road and Oxford Hills Drive, then the Town should install the larger pipes proposed above.

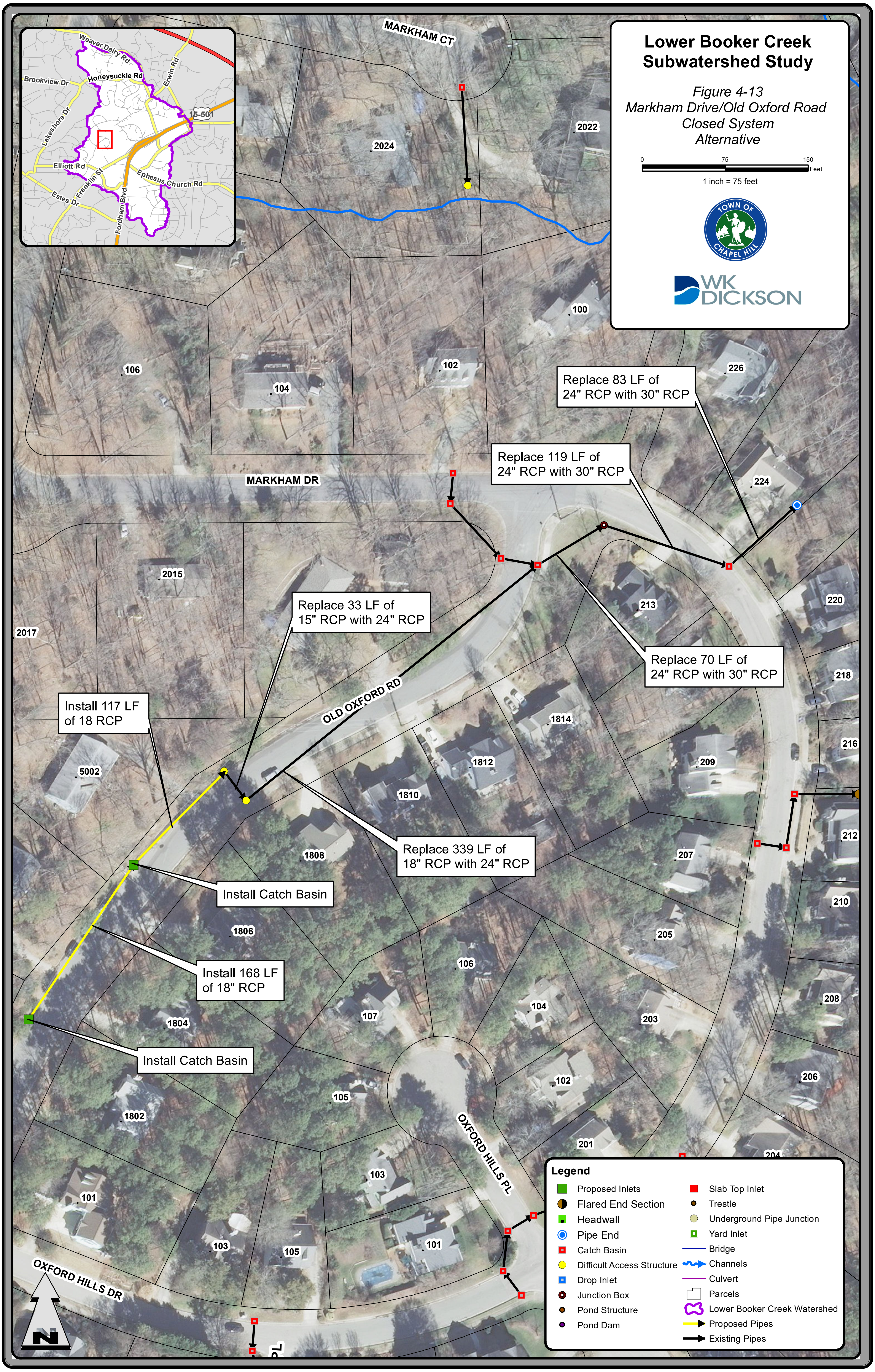
Wood Circle/Velma Road System

WK Dickson recommends the following improvements for the Wood Circle/Velma Road System as shown in Figure 4-14:

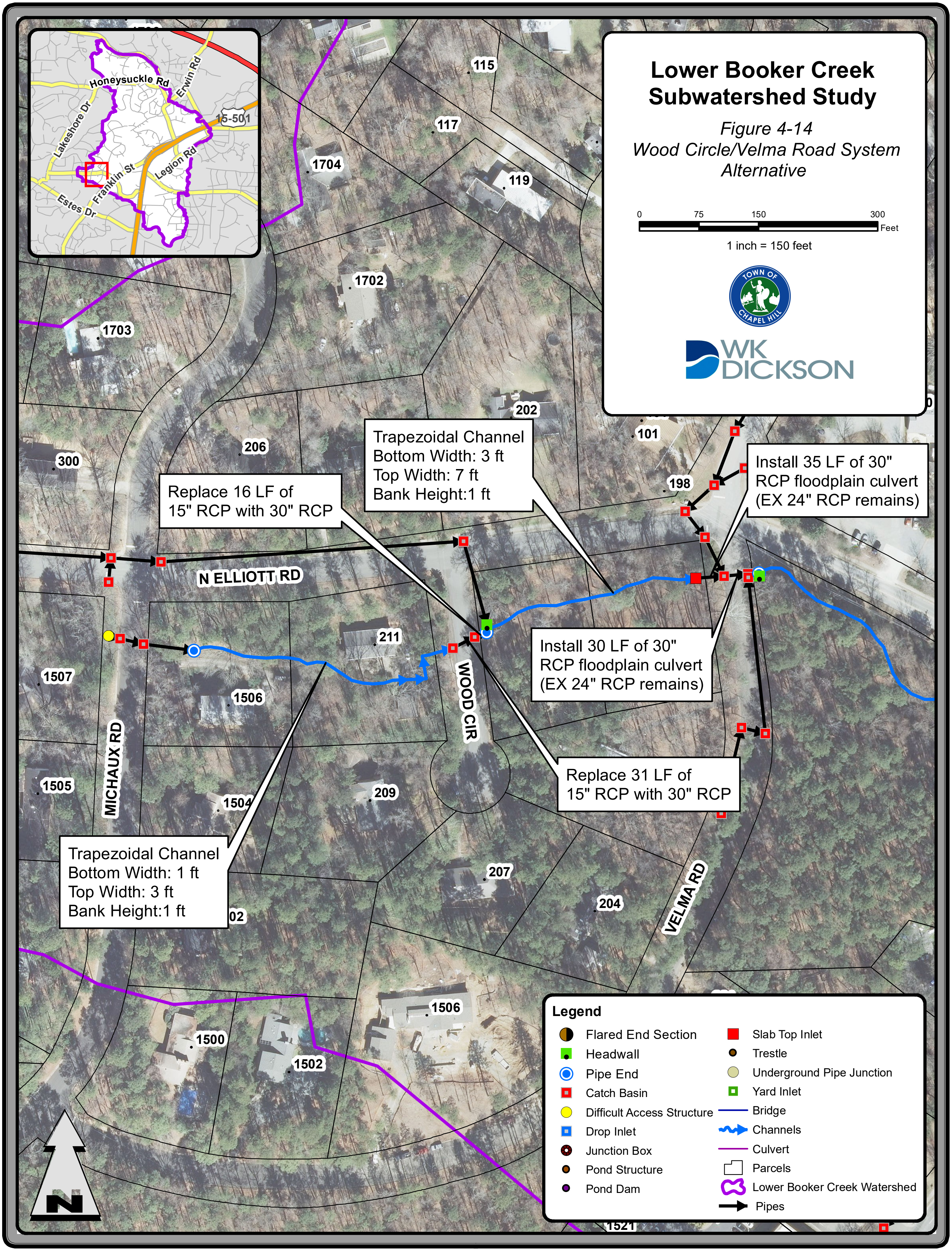
- Replace 47 LF of 15″ RCP with 30″ RCP across Wood Circle; and
- Install 65 LF of 30″ RCP across Velma Road as floodplain culvert.

The proposed improvements will provide the desired 10-year level of service for the Wood Circle/Velma Road System. The project is located within the public ROW, so there will be minimal impacts to private properties. It should be noted that Wood Circle is a cul-de-sac road with no outlet. Therefore, these proposed improvements may require staged construction that will allow continuous traffic flow providing ingress and egress for the affected homeowners. Sections of the curb and gutter along Wood Circle and Velma Road will need to be removed and replaced as part of the proposed improvements. Underground water and sanitary sewer lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $166,000. If funds allow, the Town should consider installing the proposed stream stabilization project downstream of the Wood Circle/Velma Road system concurrently.


Lower Booker Creek Subwatershed Study
Figure 4-12
Old Oxford Road System Alternative
0 50 100 200 Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Weaver Dairy Rd
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
RIDGECREST DR
OLD OXFORD RD
RED CEDAR PL
Replace 34 LF of 24" RCP with 36" RCP
EX 36" RCP
Install 215 LF of 18" RCP
Trapezoidal Channel
Bottom Width: 4.5 ft
Top Width 9.5 ft
Bank Height: 5 ft
Install Catch Basin
Install 200 LF of 18" RCP
Install Catch Basin
Install 202 LF of 18" RCP
Install Catch Basin
Legend
Proposed Inlets
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Proposed Pipes
Existing Pipes



Lower Booker Creek Subwatershed Study
Figure 4-13
Markham Drive/Old Oxford Road Closed System Alternative
0
75
150
Feet
1 inch = 75 feet
TOWN OF CHAPEL HILL
WK DICKSON
MARKHAM CT
MARKHAM DR
OLD OXFORD RD
OXFORD HILLS PL
OXFORD HILLS DR
Weaver Dairy Rd
Honeysuckle Rd
Brookview Dr
Erwin Rd
15-501
Lakeshore Dr
Elliott Rd
Franklin St
Ephesus Church Rd
Estes Dr
Fordham Blvd
Replace 83 LF of 24" RCP with 30" RCP
Replace 119 LF of 24" RCP with 30" RCP
Replace 33 LF of 15" RCP with 24" RCP
Replace 70 LF of 24" RCP with 30" RCP
Install 117 LF of 18 RCP
Replace 339 LF of 18" RCP with 24" RCP
Install Catch Basin
Install 168 LF of 18" RCP
Install Catch Basin
Legend
Proposed Inlets
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Proposed Pipes
Existing Pipes
N



Lower Booker Creek Subwatershed Study
Figure 4-14
Wood Circle/Velma Road System Alternative
0
75
150
300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 7 ft
Bank Height:1 ft
Replace 16 LF of
15" RCP with 30" RCP
Install 35 LF of 30"
RCP floodplain culvert
(EX 24" RCP remains)
Install 30 LF of 30"
RCP floodplain culvert
(EX 24" RCP remains)
Replace 31 LF of
15" RCP with 30" RCP
Trapezoidal Channel
Bottom Width: 1 ft
Top Width: 3 ft
Bank Height:1 ft
N ELLIOTT RD
MICHAUX RD
WOOD CIR
VELMA RD
115
117
1704
119
1702
1703
202
101
206
300
198
211
1507
1506
1505
1504
209
207
204
1506
1500
1502
1521
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Parcels
Lower Booker Creek Watershed
Pipes
N

4.5 LOWER BOOKER CREEK EAST

The LBC East portion of the project consists of Dobbins Branch, which is the tributary that generally drains east to west and collects runoff from an area along Dobbins Drive including the Foxcroft Apartments, Summerfield Crossing Condominiums, and Franklin Square Offices. LBC East generally consists of two (2) different types of projects as follows:

(1) Roadway culvert improvements; and
(2) Stream stabilization (Described in detail in Section 6.1).

Dobbins Drive – As determined by the existing conditions analysis, the existing 72" CMP at Dobbins Drive is undersized and does not meet the desired 25-year level of service without overtopping. Currently, it provides a 2-year level of service. In order to meet the Town's desired level of service, the recommended alternative is to replace and upsize the culverts at this crossing.

As part of this alternative, the existing CMP will be removed and replaced with twin 54" RCPs. The upsized culverts will provide the desired 25-year level of service. Figure 4-15 summarizes the improvements at Dobbins Drive. The Dobbins Drive water surface level can be reduced further if this project is paired with the Foxcroft Drive project listed below.

There are several potential site restrictions and utility conflicts that were identified at this project location including overhead power lines located along Dobbins Drive, which may need to be temporarily relocated. Impacts to traffic flow during construction were considered. Dobbins Drive is a two-lane minor thoroughfare and it is anticipated that a road closure or flagged two-lane operation will be required. The total estimated cost for the Dobbins Drive culvert improvements is $200,000. If funds allow, the Dobbins Drive improvements should be constructed currently with the downstream stream stabilization project detailed in Section 6.1 (See Project 8 – Dobbins 5).

Picture 4-6: Summerfield Crossing – Existing RCPs

Summerfield Crossing – The existing twin 66" RCPs at Summerfield Crossing meet the desired 10-year level of service. The culvert is in good condition (See Picture 4-6) and passes the future 100-year flows with almost one foot of freeboard. Consequently, no improvements are proposed at this location.

Foxcroft Drive– Based on the results obtained from the existing conditions analysis, the existing triple 48" RCPs (See Picture 4-7) at Foxcroft Drive are passing the desired 10-year storm. However, in order to lower the water surface elevations and reduce flooding at the adjacent properties, it is proposed that the culverts at Foxcroft Drive be oversized.

The recommended alternative for this crossing is to replace and upsize the culverts at Foxcroft Drive. The existing triple RCPs will be replaced by a single 12′ x 4′ RCBC. Figure 4-15 summarizes the improvements proposed at Foxcroft Drive. The resulting water surface elevations will be reduced by 1.4 feet in the 25-year storm event at Foxcroft Drive.

Picture 4-7: Foxcroft Drive – Existing RCPs

There are several buildings in the Foxcroft apartment complex and Franklin Square office complex that are classified as floodprone structures in the 100-year storm. The water surface elevation will be reduced for all of these properties. If this alternative is implemented, three (3) properties will be removed from the 100-year floodplain. The remaining properties will continue to be in the floodplain; however, the severity, duration, and frequency of flooding will be reduced.

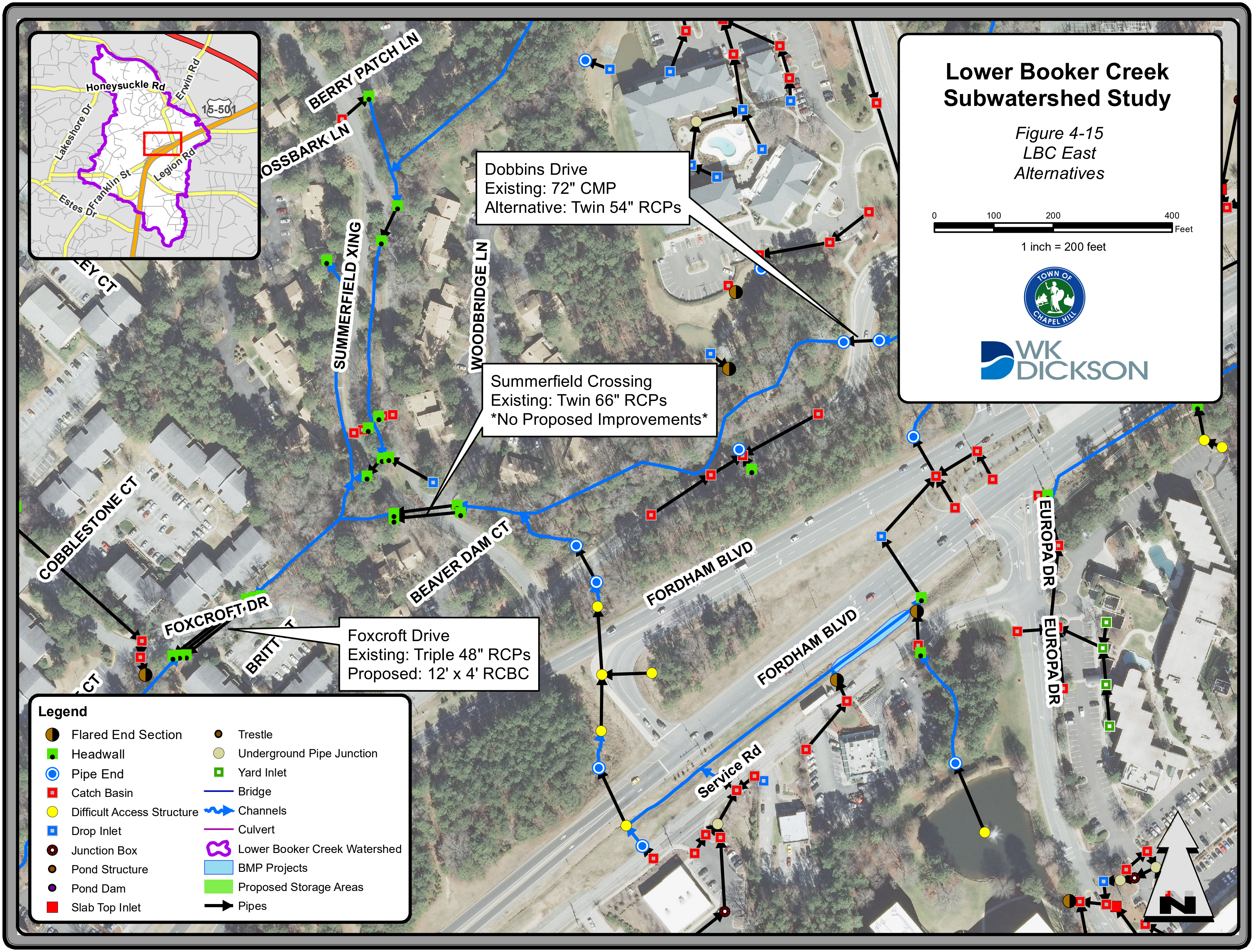
There are several potential site restrictions and utility conflicts that were identified at this project location. There appears to be sanitary sewer and water lines that may need to be replaced or relocated. Impacts to traffic flow during construction were considered. Foxcroft Drive is a two-lane residential roadway. It is anticipated that a road closure or a flagged two-way one-lane operation will be required. The total estimated costs for this project is $664,000.

<u>Summerfield Crossing System</u>

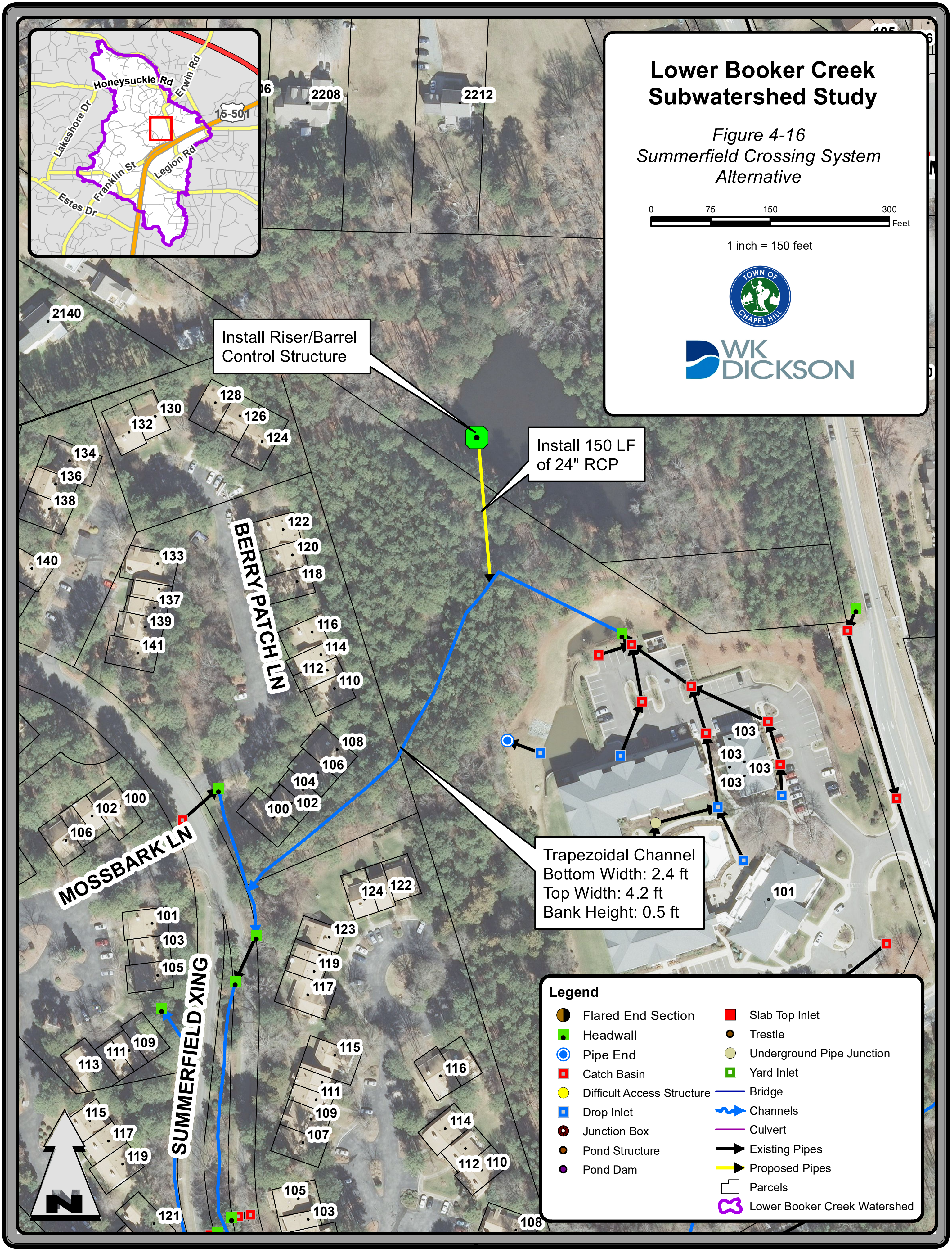
As noted in Section 3, flooding occurs along several of the residences at Berry Patch Lane when the existing upstream pond overtops during storm events. The existing pond does not have a defined outfall causing water to overtop in an uncontrolled manner. The natural channel appears to drain to the south and collect drainage from the Residence Inn. As the pond overtops, drainage also is conveyed in an undefined channel from the southwest corner of the pond draining towards Berry Patch Lane. The existing conveyance system and inlets along Berry Patch Lane do not appear to be sized to accept offsite drainage from the pond. The pond is located on private property and does not appear to receive public runoff.

The proposed solution is to install a riser/barrel control structure in the existing pond that will direct all outflow from the pond to the defined channel draining south to Summerfield Crossing

(See Figure 4-16). The estimated cost of the project is $97,000. There is a proposed development, Oxford Reserve, that could potentially develop the parcel with the existing pond. If this development moves forward, the Town should work with the developer to design a controlled outlet from the pond or otherwise discharge stormwater from the site in a controlled manner that does not cause downstream flooding along Berry Patch Lane.



Lower Booker Creek Subwatershed Study
Figure 4-15
LBC East
Alternatives
0 100 200 400 Feet
1 inch = 200 feet
TOWN OF CHAPEL HILL
WK DICKSON
Dobbins Drive
Existing: 72" CMP
Alternative: Twin 54" RCPs
Summerfield Crossing
Existing: Twin 66" RCPs
No Proposed Improvements
Foxcroft Drive
Existing: Triple 48" RCPs
Proposed: 12' x 4' RCBC
BERRY PATCH LN
SUMMERFIELD XING
WOODBRIDGE LN
COBBLESTONE CT
FOXCROFT DR
BEAVER DAM CT
FORDHAM BLVD
EUROPA DR
Service Rd
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Lower Booker Creek Watershed
BMP Projects
Proposed Storage Areas
Pipes
N


Lower Booker Creek Subwatershed Study
Figure 4-16
Summerfield Crossing System Alternative
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Legion Rd
Franklin St
Estes Dr
Install Riser/Barrel Control Structure
Install 150 LF of 24" RCP
Trapezoidal Channel
Bottom Width: 2.4 ft
Top Width: 4.2 ft
Bank Height: 0.5 ft
BERRY PATCH LN
MOSSBARK LN
SUMMERFIELD XING
2208
2212
2140
Legend
Flared End Section
Headwall
Pipe End
Catch Basin
Difficult Access Structure
Drop Inlet
Junction Box
Pond Structure
Pond Dam
Slab Top Inlet
Trestle
Underground Pipe Junction
Yard Inlet
Bridge
Channels
Culvert
Existing Pipes
Proposed Pipes
Parcels
Lower Booker Creek Watershed
N

A summary of the hydraulic performance for the improvements proposed are included in Tables 4-1 through 4-3. Water surface elevations are included for existing conditions, future land use conditions with no improvements, and future land use conditions with all proposed primary system improvements constructed. The level of improvement will be reduced if all projects are not implemented.

Table 4-1: Hydraulic Performance for LBC North

Location	**Minimum Elevation at Top of Road (feet NAVD)**	**Desired Level of Service (Year)**	**Calculated Water Surface Elevations (feet NAVD)**				
			2-year flood EXISTING FUTURE FUTURE W/ ALL PROJECTS	**10-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**25-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**50-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**100-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS
Honeysuckle Road (Proposed 8′ x 4′ RCBC)	294.58	25	293.97 294.03 292.36	**295.39** **295.4** 293.78	**295.61** **295.59** 294.53	**295.76** **295.75** **294.99**	**295.84** **295.83** **295.38**
Booker Creek Road – Upstream (Proposed 8′ x 4′ RCBC)	291.01	10	289.94 290.01 287.98	**291.24** **291.25** 289.36	**291.39** **291.38** 290.47	**291.48** **291.48** 290.94	**291.57** **291.54** **291.19**
Booker Creek Road – Downstream (Constructed)	274.01	10	272.02 272.13 271.22	**274.26** **274.38** 272.48	**275.02** **275.08** 273.09	**275.36** **275.39** 273.88	**275.63** **275.65** **274.34**

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

Table 4-2: Hydraulic Performance for LBC South

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service (Year)	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood EXISTING FUTURE FUTURE W/ ALL PROJECTS	**10-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**25-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**50-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**100-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS
East Franklin Street (Existing Triple 11′ x 11′ RCBCs) *	263.48	100	258.37 258.79 257.69	262.50 262.81 260.71	**264.39** **264.66** 263.15	**265.13** **265.27** **264.71**	**265.56** **265.66** **265.23**
Eastgate Crossing Road (Existing 35′ x 10.5′ RCBC)	260.81	100	258.10 258.47 257.36	**261.67** **261.84** 259.79	**263.1** **263.51** **261.74**	**264.26** **264.49** **263.33**	**265.03** **265.19** **264.30**
South Elliott Road (Existing Triple 16′ x 9′ Elliptical CMPs)	262.95	100	256.87 257.15 256.91	259.09 259.41 258.85	260.68 261.18 260.36	262.30 262.65 262.10	**263.56** **263.75** **263.43**
Highway 15-501/Fordham Boulevard (Existing Triple 11.5′ x 11.5′ RCBCs)	264.21	100	255.40 255.67 255.38	257.58 257.88 257.09	258.83 259.14 258.37	259.81 260.01 259.58	260.67 260.87 260.39
Willow Drive (Existing Bridge with Proposed Floodplain Culverts and Benching)	259.11	100	252.87 253.02 252.34	254.63 254.93 253.24	255.40 255.66 253.98	256.19 256.35 254.82	257.66 257.84 256.25

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

Table 4-3: Hydraulic Performance for LBC East

Location	Minimum Elevation at Top of Road (feet NAVD)	Desired Level of Service (Year)	Calculated Water Surface Elevations (feet NAVD)				
			2-year flood EXISTING FUTURE FUTURE W/ ALL PROJECTS	**10-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**25-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**50-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS	**100-year flood** EXISTING FUTURE FUTURE W/ ALL PROJECTS
Dobbins Drive (Proposed Twin 54" RCPs)	282.01	10	281.17 281.33 279.72	**282.54** **282.60** 281.09	**282.85** **282.88** 282.01	**283.00** **283.01** **282.45**	**283.09** **283.11** **282.69**
Summerfield Crossing (Existing 66" RCPs)	275.86	10	271.08 271.31 271.31	272.62 272.76 272.68	273.32 273.43 273.42	273.89 274.05 274.04	274.65 274.92 274.73
Foxcroft Drive (Proposed 12' x 4' RCBC)	272.49	10	268.01 268.10 268.10	269.32 269.51 268.90	270.54 270.72 269.32	271.48 271.70 269.61	272.33 **272.59** 270.11

*Bold text indicates the existing water surface has exceeded the rim elevation at the road thereby causing flooding.
**Green shade indicates crossing meets desired level of service. Red shade indicates crossing does not meet desired level of service.

Tables 4-4 through 4-6 shows the 2-,10-, 25-, 50-, and 100-year WSEL reductions at primary system roadway crossings when comparing the future conditions with and without the implementation of the improvements proposed as part of this section.

Table 4-4: WSEL Reductions for LBC North

Location	Decrease in Water Surface Elevations (feet NAVD)				
	2-year flood	**10-year flood**	**25-year flood**	**50-year flood**	**100-year flood**
Honeysuckle Road	1.67	1.62	1.06	0.76	0.45
Booker Creek Road – Upstream	2.03	1.89	0.91	0.54	0.35
Booker Creek Road – Downstream	0.91	1.90	1.99	1.51	1.31

Table 4-5: WSEL Reductions for LBC South

Location	Decrease in Water Surface Elevations (feet NAVD)				
	2-year flood	**10-year flood**	**25-year flood**	**50-year flood**	**100-year flood**
East Franklin Street	1.10	2.10	1.51	0.56	0.43
Eastgate Crossing Road	1.11	2.05	1.77	1.16	0.89
South Elliott Road	0.24	0.56	0.82	0.55	0.32
Highway 15-501/Fordham Boulevard	0.29	0.79	0.77	0.43	0.48
Willow Drive	0.68	1.69	1.68	1.53	1.59

Table 4-6: WSEL Reductions for LBC East

Location	Decrease in Water Surface Elevations (feet NAVD)				
	2-year flood	10-year flood	25-year flood	50-year flood	100-year flood
Dobbins Drive	1.61	1.51	0.87	0.56	0.42
Summerfield Crossing	0.00	0.08	0.01	0.01	0.19
Foxcroft Drive	0.00	0.61	1.40	2.09	2.48

4.6 HYDROLOGY

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

Peak flows for the primary systems were developed for the 2-, 10-, 25-, 50-, and 100-year storm events considering the future conditions and proposed alternatives. The future conditions peak flows are summarized in Table 4-7. In comparison to the existing conditions flows, the future conditions flow increases in the 25-year storm are as follows:

- Booker Creek – 0 to 11%
- Dobbins Reach – 3 to 4%
- Sierra Reach – 1 to 2%

Table 4-7: Future Conditions Flows from HEC-HMS for Lower Booker Creek Subwatershed

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Storm Event				
			2-year (cfs) EXISTING FUTURE FUTURE W/ ALL PROJECTS	10-year (cfs) EXISTING FUTURE FUTURE W/ ALL PROJECTS	25-year (cfs) EXISTING FUTURE FUTURE W/ ALL PROJECTS	50-year (cfs) EXISTING FUTURE FUTURE W/ ALL PROJECTS	100-year (cfs) EXISTING FUTURE FUTURE W/ ALL PROJECTS
BOOKER CREEK							
ADD-LBC-40-50	Confluence of Sierra Reach and Booker Creek	10024	780 929 694	1,902 2,048 1,530	2,578 2,731 2,102	3,067 3,124 2,564	3,326 3,395 2,788
ADD-LBC-70-130	Confluence of Dobbins Reach and Booker Creek	7024	807 956 806	1,961 2,116 1,781	2,671 2,836 2,485	3,205 3,294 3,062	3,502 3,576 3,366
East Franklin Street	East Franklin Street	6733	856 966 857	2,155 2,334 1,935	2,951 3,132 2,771	3,531 3,639 3,412	3,904 3,999 3,789
Fordham Blvd-Downstream	South Elliott Road/Fordham Blvd – Downstream	4696	832 955 832	1,964 2,132 1,792	2,686 2,860 2,558	3,225 3,336 3,148	3,597 3,706 3,531
Willow Drive	Willow Drive	3185	849 971 846	1,990 2,165 1,818	2,732 2,909 2,599	3,281 3,396 3,204	3,665 3,779 3,598
DOBBINS REACH							
Dobbins Drive	Dobbins Drive	2697	120 127 127	208 216 216	261 268 268	302 309 309	343 350 350
Summerfield Crossing	Summerfield Crossing	1890	138 148 148	239 250 250	300 310 310	347 358 358	394 404 404
Foxcroft Drive	Foxcroft Drive	1485	162 174 174	282 294 294	359 370 370	415 428 428	467 480 480
SIERRA REACH							
Honeysuckle Road	Honeysuckle Road	2867	89 91 55	177 180 124	232 235 164	277 280 192	320 323 247
Booker Creek Road	Booker Creek Road	955	141 148 117	275 282 229	357 365 291	423 431 358	484 492 448

The future flows with all projects were developed from the future conditions considering attenuation for the proposed culvert sizes and the proposed storage areas. The detention proposed in the watershed causes the alternative flows to be less than the future flows. The peak flows used for the proposed alternatives are summarized in Table 4-7. The reductions in flows provided by the proposed detention projects in the alternative are presented in Table 4-8.

Table 4-8: Comparison of Future vs. Future with All Projects Flows for Lower Booker Creek Subwatershed

HEC-HMS Node	Road Name / Location	HEC-RAS Station	Percent Reduction				
			2-year (%)	10-year (%)	25-year (%)	50-year (%)	100-year (%)
BOOKER CREEK							
ADD-LBC-40-50	Confluence of Sierra Reach and Booker Creek	10024	25%	25%	23%	18%	18%
ADD-LBC-70-130	Confluence of Dobbins Reach and Booker Creek	7024	16%	16%	12%	7%	6%
East Franklin Street	East Franklin Street	6733	11%	17%	12%	6%	5%
Fordham Blvd-Downstream	South Elliott Road/Fordham Blvd – Downstream	4696	13%	16%	11%	6%	5%
Willow Drive	Willow Drive	3185	13%	16%	11%	6%	5%
DOBBINS REACH							
Dobbins Drive	Dobbins Drive	2697	0%	0%	0%	0%	0%
Summerfield Crossing	Summerfield Crossing	1890	0%	0%	0%	0%	0%
Foxcroft Drive	Foxcroft Drive	1485	0%	0%	0%	0%	0%
SIERRA REACH							
Honeysuckle Road	Honeysuckle Road	2867	40%	31%	30%	31%	23%
Booker Creek Road	Booker Creek Road	955	21%	19%	20%	17%	9%

4.7 HYDRAULICS

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

CONDITION ASSESSMENT

As part of the LBC Subwatershed Study, a preliminary condition assessment was completed to identify high priority areas for detailed CCTV and/or maintenance needs. The prioritization is based on the likelihood of asset failure, as well as the consequence of asset failure. By evaluating the likelihood of asset failure in relation to the consequence of asset failure, a combined criticality score is then developed for each asset. This criticality score can enable the Town to more strategically evaluate which assets to focus capital improvement resources on for repair, rehabilitation or further condition assessments. This section summarizes the results of a GIS audit and the scoring criteria and methodology used in developing the condition assessment.

5.1 PROJECT BACKGROUND

WK Dickson collected and analyzed the stormwater infrastructure data which included GIS stormwater data, building and transportation locations, and geographic features. This data were audited to determine the availability of necessary attribute information to conduct the criticality analysis. The results of the GIS data audit were shared with the Town and resolution of critical data gaps was coordinated with Town staff. Upon resolution of the identified data gaps, WK Dickson performed an initial criticality assessment by running the criticality toolset to generate preliminary results. These results were necessary to gauge the impact of scoring criteria on the overall criticality rating for assets which provided a basis for adjusting criteria scoring parameters.

With an initial criticality assessment and prioritization of assets complete, it was possible for WK Dickson and the Town to determine additional attribute information necessary for the criticality assessment and to make adjustments to criteria weighting. Upon making these final adjustments, WK Dickson completed a second running of the criticality assessment toolset. The results of this second prioritization are included in this report as the findings of asset criticality within the LBC subwatershed. The detailed methodology for customizing the prioritization tool for the Town can be found in Appendix I.

5.2 CRITICALITY ANALYSIS

Once the scoring criteria and attribute analysis was completed, the pipe and structure matrices (See Appendix I) were populated and the asset criticality analysis was run. Initial results were reviewed with the Town to determine if adjustments should be made related to the weighting factors in the matrices as well as the assumptions for infrastructure age.

The results presented in Exhibit 5-1, Figure 5-1, and Figure 5-2 indicate color coded scoring ranges based on a statistical Jenks optimization method for distribution among the asset scores. As a result, the highest scoring assets indicate the most critical assets in terms of overall risk due to consequence and likelihood of failure. The critical assets for stormwater pipes and structures are indicated in red on both the maps and the graphs. Since there are a different number of assets for each utility system grouping, the distribution range differs slightly.

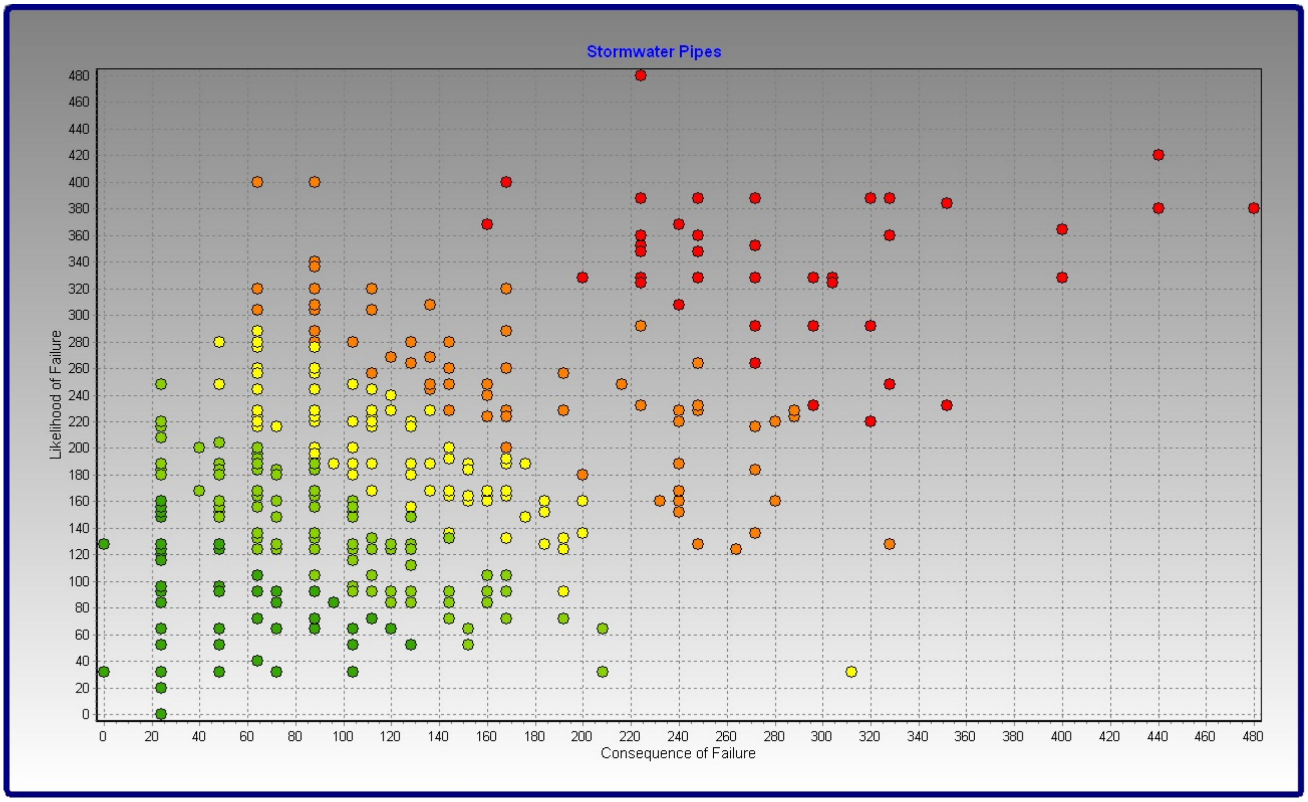
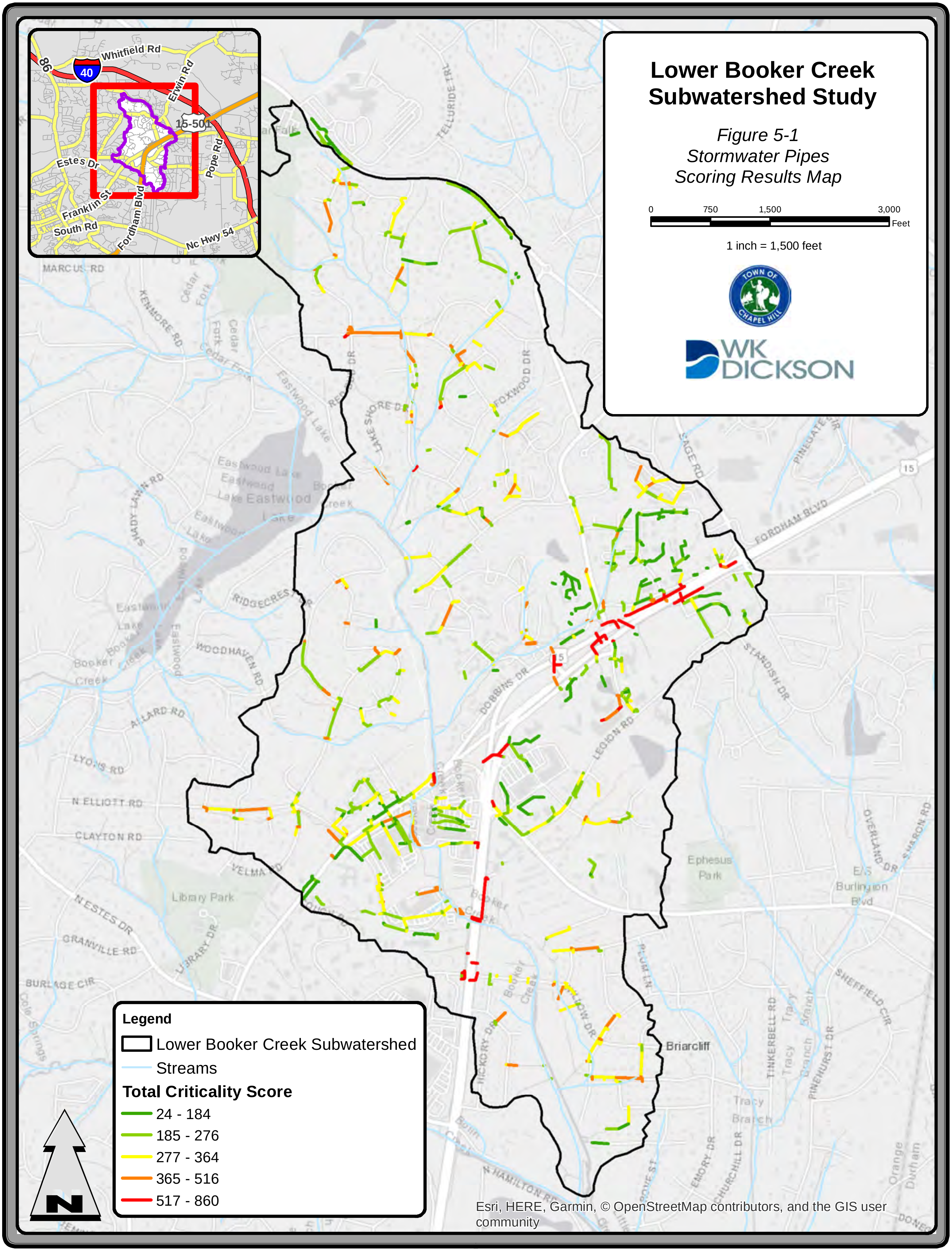
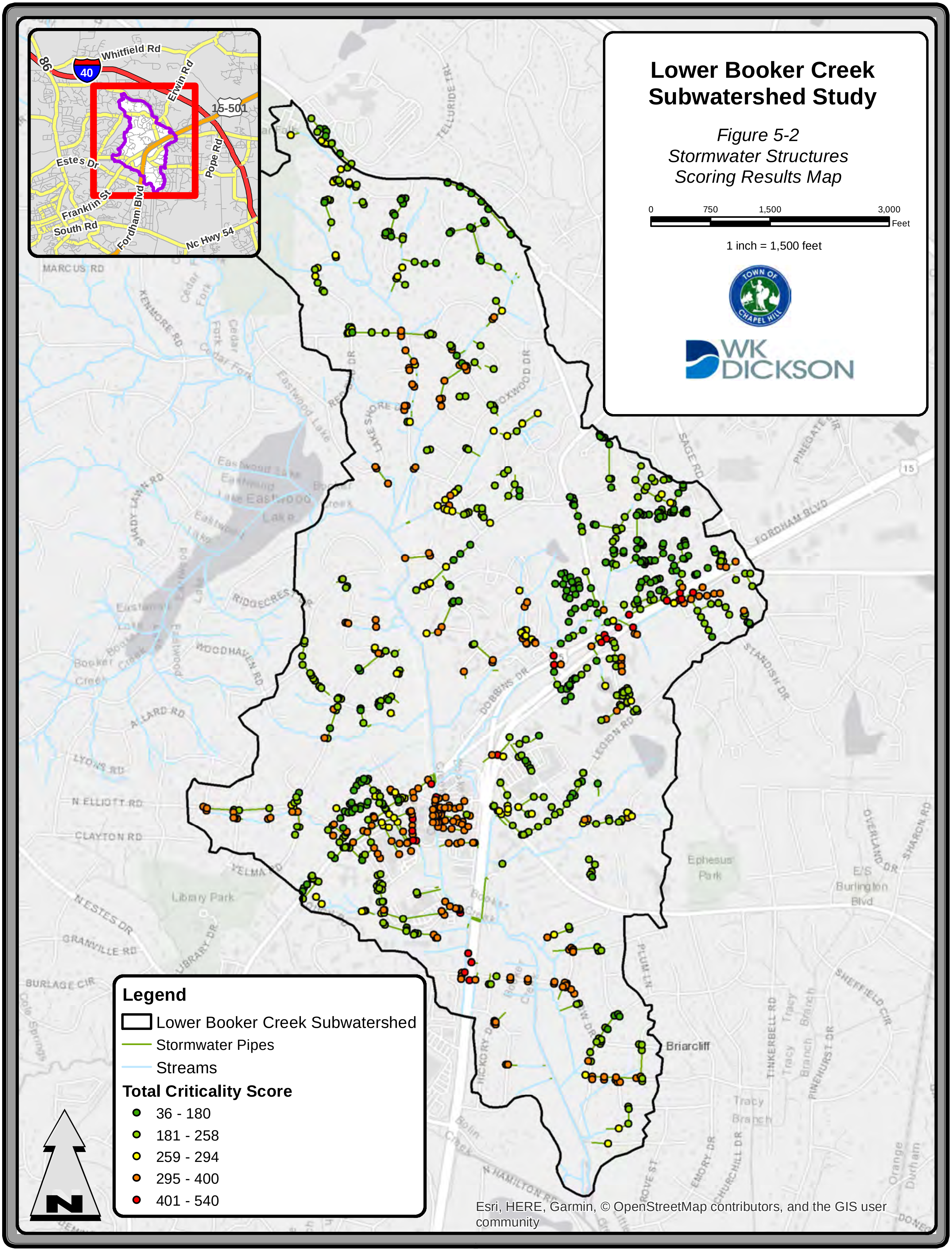


Exhibit 5-1: Stormwater Pipes Scoring Results



Lower Booker Creek Subwatershed Study
Figure 5-1
Stormwater Pipes
Scoring Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Lower Booker Creek Subwatershed
Streams
Total Criticality Score
24 - 184
185 - 276
277 - 364
365 - 516
517 - 860
N
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community
Whitfield Rd
40
86
Erwin Rd
15-501
Estes Dr
Pope Rd
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
MARCUS RD
KENMORE RD
Cedar Fork
TELLURIDE TRL
Eastwood Lake
Lake Eastwood
Booker Creek
SHADY LAWN RD
RIDGECREST DR
WOODHAVEN RD
ALLARD RD
LYONS RD
N ELLIOTT RD
CLAYTON RD
VELMA RD
Library Park
N ESTES DR
GRANVILLE RD
LIBRARY DR
BURLAGE CIR
FOXWOOD DR
LAKE SHORE DR
DOBBINS DR
LEGION RD
SAGE RD
PINEGATE CIR
FORDHAM BLVD
STANDISH DR
Ephesus Park
E/S Burlington Blvd
OVERLAND DR
SHARON RD
PLUM LN
Briarcliff
TINKERBELL RD
Tracy Branch
PINEHURST DR
SHEFFIELD CIR
HICKORY DR
WILLOW DR
N HAMILTON RD
EMORY DR
CHURCHILL DR
Orange Durham



Lower Booker Creek Subwatershed Study
Figure 5-2
Stormwater Structures Scoring Results Map
0 750 1,500 3,000 Feet
1 inch = 1,500 feet
WK DICKSON
Legend
Lower Booker Creek Subwatershed
Stormwater Pipes
Streams
Total Criticality Score
36 - 180
181 - 258
259 - 294
295 - 400
401 - 540
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community
Whitfield Rd
40
Erwin Rd
15-501
Estes Dr
Pope Rd
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
MARCUS RD
KENMORE RD
TELLURIDE TRL
LAKE SHORE LN
FOXWOOD DR
Eastwood Lake
SAGE RD
FORDHAM BLVD
RIDGECREST DR
WOODHAVEN RD
DOBBINS DR
STANDISH DR
LEGION RD
N ELLIOTT RD
CLAYTON RD
Library Park
N ESTES DR
GRANVILLE RD
LIBRARY DR
BURLAGE CIR
Ephesus Park
E/S Burlington Blvd
Briarcliff
HICKORY DR
PLUM LN
TINKERBELL RD
PINEHURST DR
N HAMILTON RD
EMORY DR
CHURCHILL DR
Tracy Branch
Booker Creek
Bolin Creek

5.3 IDENTIFICATION OF CRITICAL INFRASTRUCTURE

Table 5-1 summarizes the number of stormwater pipe assets falling into each scoring range. A single pipe asset is defined as a section of pipe between either two (2) structures or between a structure and an outfall. The table presents the total criticality score as well as the likelihood and consequence scores.

When reviewing the table, it is important to recognize the purpose of establishing natural breaks within the data is to determine a criticality level for evaluating each asset. This criticality level is used to determine the overall scoring of assets that will be targeted during a rehabilitation project. Typically, those assets scoring in criticality level 4 or 5 are classified as the highest priority for rehabilitation efforts. Assets ranked in criticality level 3 are typically considered to need rehabilitation or further condition assessment evaluation.

Table 5-1 shows the criticality levels for stormwater pipes. Of the 941 pipes evaluated, 19% scored at Level 4 or 5 indicating the highest need for stormwater rehabilitation efforts. Similarly, 27% of stormwater pipes scored in criticality Level 3. These assets should be evaluated further to determine whether rehabilitation is necessary or whether the 'consequence of failure' criteria are the skewing factors for the elevated criticality scores. An example of this scenario would be a stormwater pipe in overall good condition located close to a structure, a critical facility, and/or under major transportation infrastructure. The pipe's good condition would yield a lower 'likelihood of failure' score but the pipe's location would cause a higher 'consequence of failure' rating, resulting in a higher criticality score.

Table 5-1: Stormwater Pipes Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		→		**High**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	0-184	**185-276**	**277-364**	**365-516**	**>516**
Stormwater Pipes	190	314	257	122	58
Likelihood Score Distribution					
	0-104	**105-168**	**169-232**	**233-304**	**>304**
Stormwater Pipes	167	265	275	137	97
Consequence Score Distribution					
	0-48	**49-112**	**113-200**	**201-296**	**>296**
Stormwater Pipes	220	493	143	63	22

5.4 TOWN-MAINTAINED ASSET ANALYSIS

The ROW within the LBC subwatershed falls under three (3) separate jurisdictions: NCDOT, Town, and private owners. In an effort to further refine the prioritization of assets, the Town requested WK Dickson provide a separate analysis of criticality scoring for stormwater structures and pipes that lie within Town-maintained rights-of-way.

Limiting the criticality analysis to Town-maintained ROW eliminated the following major thoroughfares from the project area:

- Fordham Boulevard;
- East Franklin Street;
- Sage Road;
- Erwin Road; and
- Weaver Dairy Road.

Stormwater assets adjacent to privately-owned roads were also eliminated from the study. Overall, 79.8% of stormwater structures and 80.1% of stormwater pipes fall within Town-maintained areas. Exhibit 5-2 present the detailed results of this analysis in the same manner as the overall criticality analysis.

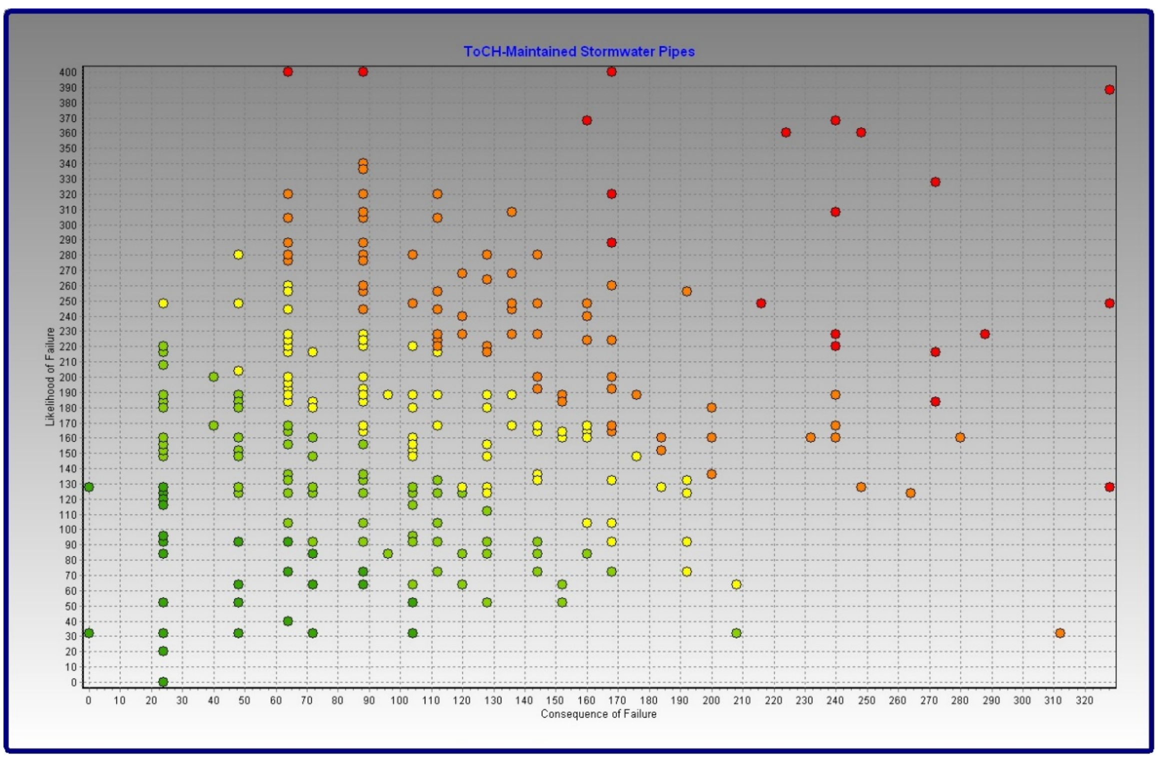
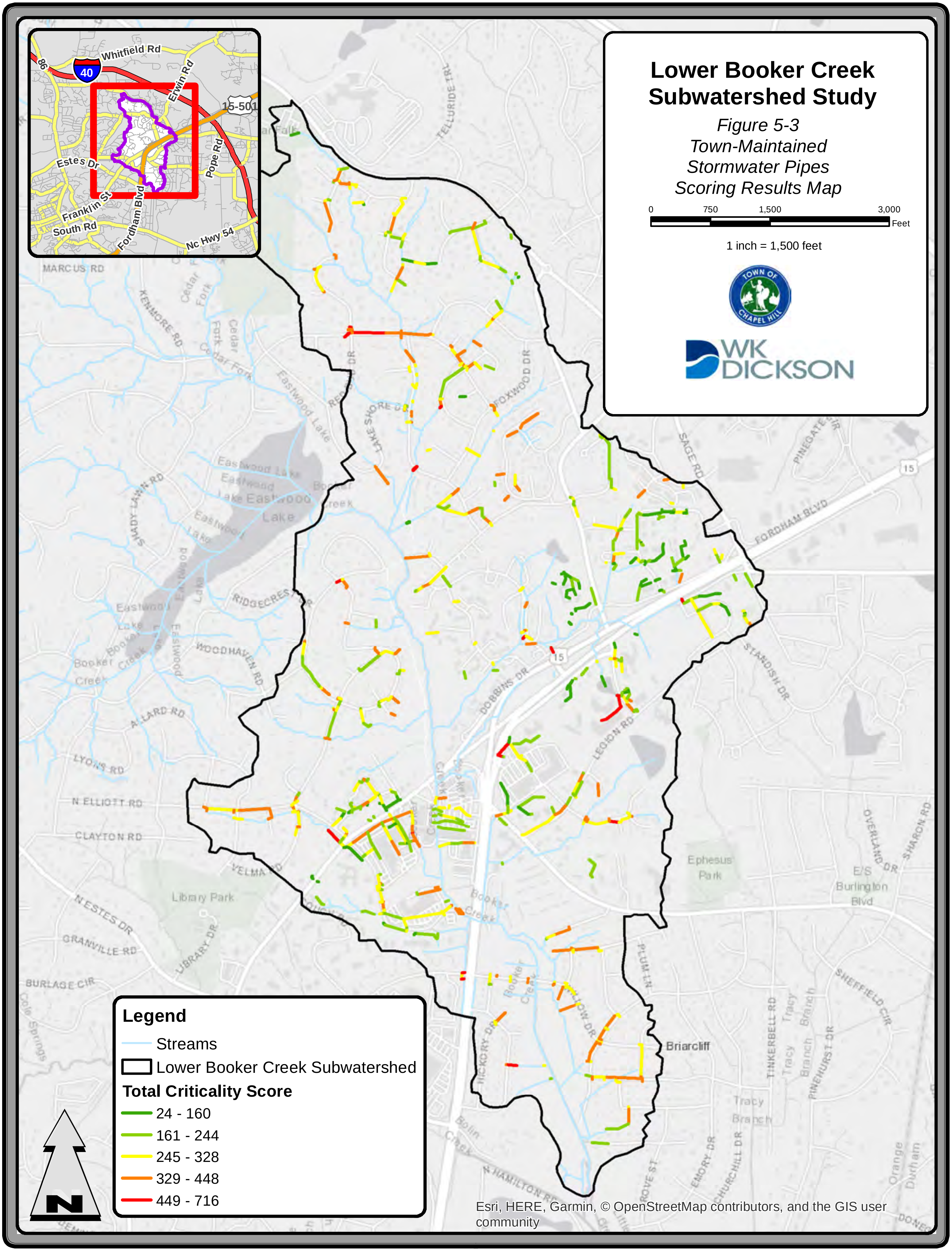
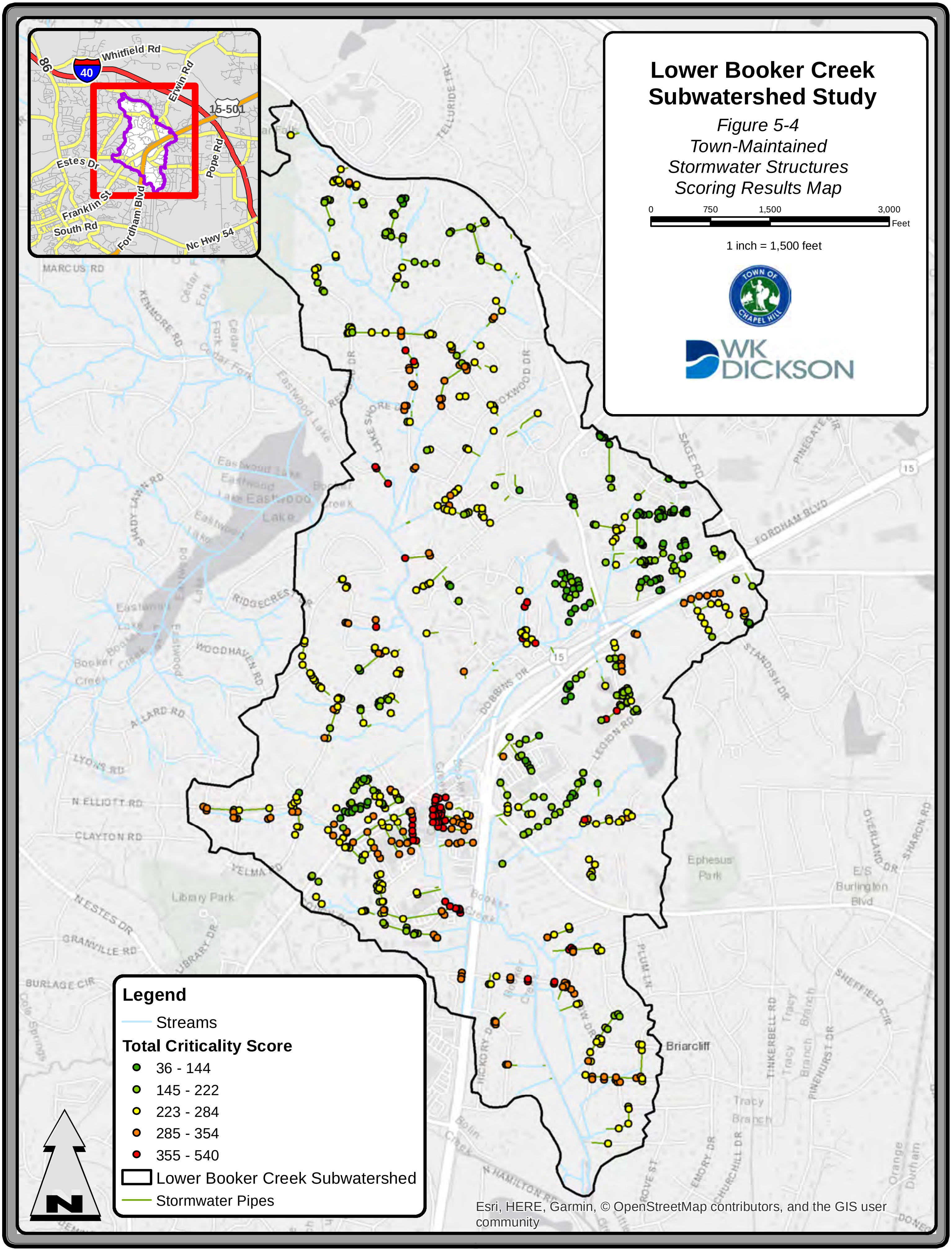


Exhibit 5-2: Town-Maintained Stormwater Pipes Scoring Results



Lower Booker Creek Subwatershed Study
Figure 5-3
Town-Maintained Stormwater Pipes Scoring Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Lower Booker Creek Subwatershed
Total Criticality Score
24 - 160
161 - 244
245 - 328
329 - 448
449 - 716
N
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community
Whitfield Rd
40
86
Erwin Rd
15-501
Estes Dr
Pope Rd
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
MARCUS RD
KENMORE RD
TELLURIDE TRL
FOXWOOD DR
LAKE SHORE DR
SHADY LAWN RD
RIDGECREST DR
WOODHAVEN RD
ALLARD RD
LYONS RD
N ELLIOTT RD
CLAYTON RD
VELMA RD
N ESTES DR
GRANVILLE RD
BURLAGE CIR
LIBRARY DR
Library Park
DOBBINS DR
LEGION RD
SAGE RD
PINEGATE CIR
FORDHAM BLVD
STANDISH DR
15
Ephesus Park
E/S Burlington Blvd
OVERLAND DR
SHARON RD
PLUM LN
Briarcliff
TINKERBELL RD
PINEHURST DR
SHEFFIELD CIR
EMORY DR
CHURCHILL DR
HICKORY DR
N HAMILTON RD
Booker Creek
Bolin Creek
Tracy Branch
Eastwood Lake
Cedar Fork


Lower Booker Creek
Subwatershed Study
Figure 5-4
Town-Maintained
Stormwater Structures
Scoring Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Total Criticality Score
36 - 144
145 - 222
223 - 284
285 - 354
355 - 540
Lower Booker Creek Subwatershed
Stormwater Pipes
N
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community
Whitfield Rd
40
86
Erwin Rd
15-501
Estes Dr
Pope Rd
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
MARCUS RD
KENMORE RD
Cedar Fork
TELLURIDE TRL
BOXWOOD DR
LAKE SHORE LN
Eastwood Lake
Booker Creek
SHADY LAWN RD
RIDGECREST DR
WOODHAVEN RD
ALLARD RD
LYONS RD
N ELLIOTT RD
CLAYTON RD
VELMA RD
Library Park
N ESTES DR
GRANVILLE RD
LIBRARY DR
BURLAGE CIR
DOBBINS DR
LEGION RD
FORDHAM BLVD
SAGE RD
PINEGATE CIR
STANDISH DR
Ephesus Park
E/S Burlington Blvd
OVERLAND DR
SHARON RD
SHEFFIELD CIR
PLUM LN
Briarcliff
TINKERBELL RD
Tracy Branch
PINEHURST DR
CHURCHILL DR
EMORY DR
HICKORY DR
Bolin Creek
N HAMILTON RD
Orange Durham

Tables 5-2 and 5-3 indicate the number of Town-maintained assets falling into each scoring range for the stormwater pipes and structures, respectively. The tables present the total criticality score as well as the likelihood and consequence scores.

Table 5-2 shows the criticality levels for Town-maintained stormwater pipe assets falling into each scoring range. Of the 762 pipes evaluated 25% scored in Level 4 or 5 indicating the highest need for stormwater rehabilitation efforts. Similarly, 33% of stormwater pipes scored in criticality Level 3. These assets should be evaluated further to determine whether rehabilitation is necessary or whether the 'consequence of failure' criteria are the skewing factors for the elevated criticality scores.

Table 5-2: Town Stormwater Pipes Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		**→**		**High**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	0-160	**161-244**	**245-328**	**329-448**	**>448**
Stormwater Pipes	107	211	252	165	27
Likelihood Score Distribution					
	0-84	**85-148**	**149-208**	**209-279**	**>276**
Stormwater Pipes	88	168	239	171	96
Consequence Score Distribution					
	0-48	**49-104**	**105-176**	**177-248**	**>248**
Stormwater Pipes	186	397	138	27	14

Table 5-3 shows the criticality levels for Town-maintained stormwater structures. Within the assets evaluated 29% of the structures scored in Level 4 or 5 indicating the highest need for stormwater structure rehabilitation efforts. Similarly, 31% of stormwater structures score in criticality Level 3. These assets should be evaluated further to determine whether rehabilitation is necessary or whether the 'consequence of failure' criteria are the skewing factors for the elevated criticality scores.

Table 5-3: Town Stormwater Structures Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		→		High
	Level 1	Level 2	Level 3	Level 4	Level 5
	0-144	**145-222**	**223-284**	**285-354**	**>354**
Stormwater Structures	131	184	252	162	70
Likelihood Score Distribution					
	0-36	**37-72**	**73-108**	**109-152**	**>152**
Stormwater Structures	134	45	94	207	319
Consequence Score Distribution					
	0-80	**81-150**	**151-210**	**211-230**	**>230**
Stormwater Structures	381	292	67	28	31

5.5 FUTURE USE OF PRIORITIZATION TOOL

Because the data in the GIS database is dynamic, the results of the prioritization tool are a static representation based upon when the tool is run. As data is updated in the database, the tool can be utilized and the results of the prioritization process can be updated easily. Typically, a jurisdiction may use a prioritization tool such as this on an annual or semi-annual basis as budgets are developed and capital plans and O&M plans are revised.

It should be noted that the criticality rating system will always generate assets that are rated as high-risk components. The rating system is a relative one, where the risk of a particular asset is rated relative to the other assets that are also evaluated. Therefore, the Town will always have assets that rank in the level 4 or level 5 risk category. As these assets are rehabilitated, replaced or repaired their likelihood of failure score will improve and their total risk rating can be reduced. Meanwhile, lower at-risk components will age and deteriorate over time and their risk scores will increase.

A valuable component of this dynamic prioritization tool is the ability to quickly perform difference scenario analyses in order to determine the relative benefit of capital and O&M projects. The Town can determine if the at-risk score of a particular component can be dramatically reduced by improvement. In some cases, the consequence of failure score is so high that an improved asset will always remain in the high-risk category. These assets can be monitored on a frequent basis to consistently check its condition and proactively work to prevent a failure. Conversely, assets with the greatest likelihood of failures scores are often the target of initial condition assessment and rehabilitation programs. Town staff can perform scenario analysis to determine where condition assessment and rehabilitation programs can most reduce the at-risk scores of critical assets.

WATER QUALITY RECOMMENDATIONS

Traditional drainage management has typically been designed to reduce flooding by collecting runoff from impervious surfaces and discharging it directly into a stream causing erosion and deterioration of water quality. Runoff from impervious areas can collect high concentrations of pollutants and nutrients that, if left untreated, can cause negative impacts to water quality in the receiving waters. Negative impacts may include less biodiversity, poor habitat, hazards to macroinvertebrate health, as well as human health hazards. Many communities in North Carolina now require some form of water quality treatment for new development; however existing developments typically have little or no water quality treatment.

This study considered both stream stabilization and SCM retrofit projects as means of improving water quality. Stream stabilization projects can be constructed to reduce instream sediment loads and to protect private property from further erosion. SCMs can be constructed to treat runoff prior to being discharged to the stormwater conveyance system and the receiving waters of the system. Adding or retrofitting SCMs in existing developments can be difficult due to limited space and other constraints. Stream stabilization and SCM retrofit projects identified in the LBC Subwatershed Study are described below.

6.1 STREAM STABILIZATION PROJECTS

Based on the field assessments, eleven (11) stream reaches were identified as candidates for improvements. One (1) of the eleven (11) stream reaches identified as a candidate was stabilized as part of the Booker Creek culvert replacement constructed in the Fall of 2016. Therefore, ten (10) projects are proposed in this section. The locations of these reaches are shown on Figures 6-1 through 6-3. A list of stream stabilization techniques, arranged in order of less intensive to more intensive in implementation, follows:

1. Riparian buffer enhancement
2. Streambank stabilization
3. Head-cut stabilization and stream channel grade control
4. Perched culvert rectification
5. Stream channel restoration/relocation
6. Regenerative stormwater conveyances (RSC)

See Appendix K for pictures and a more detailed description of the listed stream stabilization techniques. These techniques were considered separately and in combination to determine an appropriate plan for each respective reach. Table 6-1 summarizes the proposed improvements for each reach.

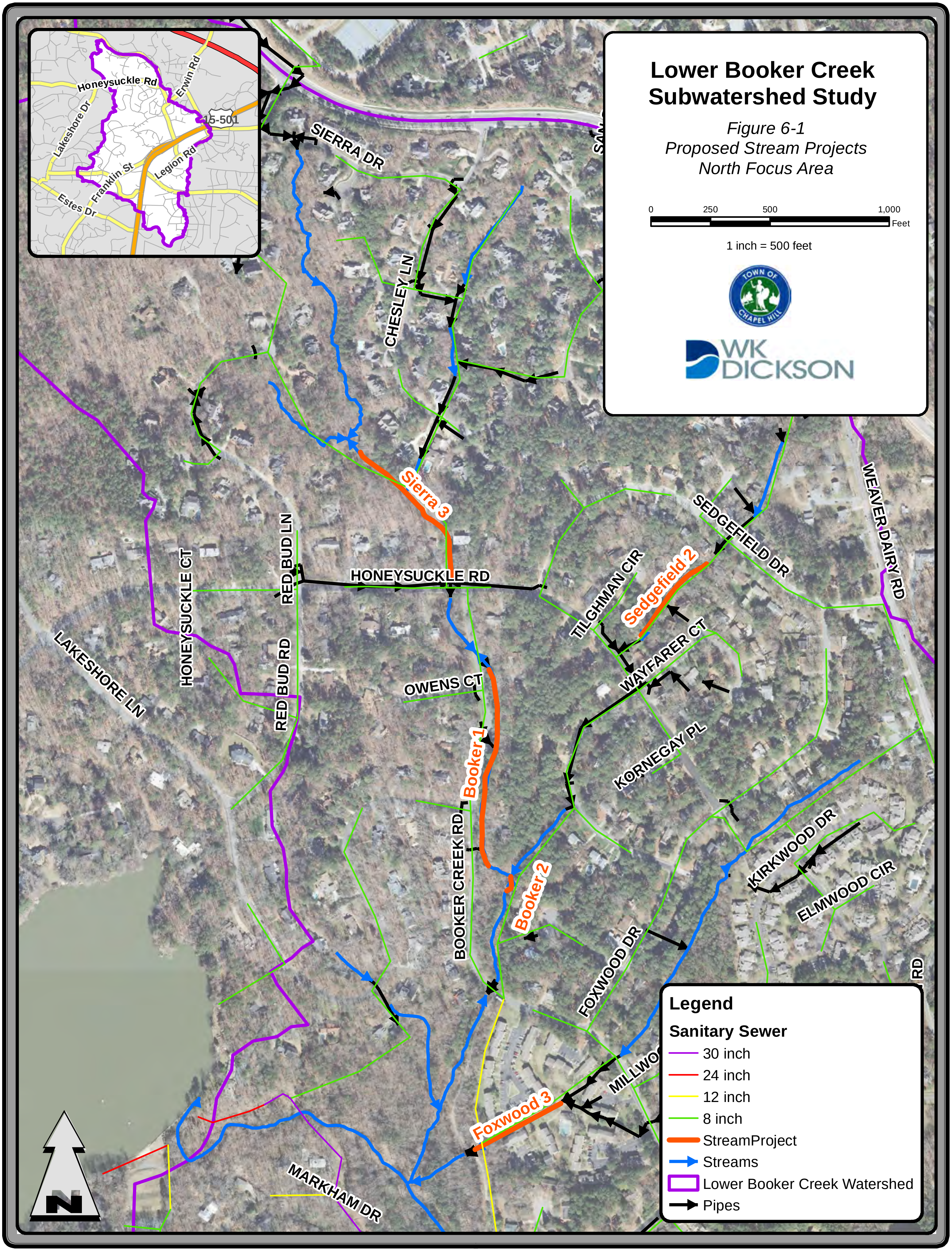
The most common recommendation was streambank stabilization, which in relative comparison, is usually less expensive on a linear foot basis than the techniques that follow it in the list above.

A RSC is listed as a potential improvement at three (3) locations. This technique utilizes stream bank and channel stabilization structures, consisting of boulders, cobble and gravel, over a bed of a sand and mulch mixture. RSCs have been shown to stabilize eroding stream channels, reduce pollutant loads, provide a measure of stormwater storage and potentially create aquatic habitat.

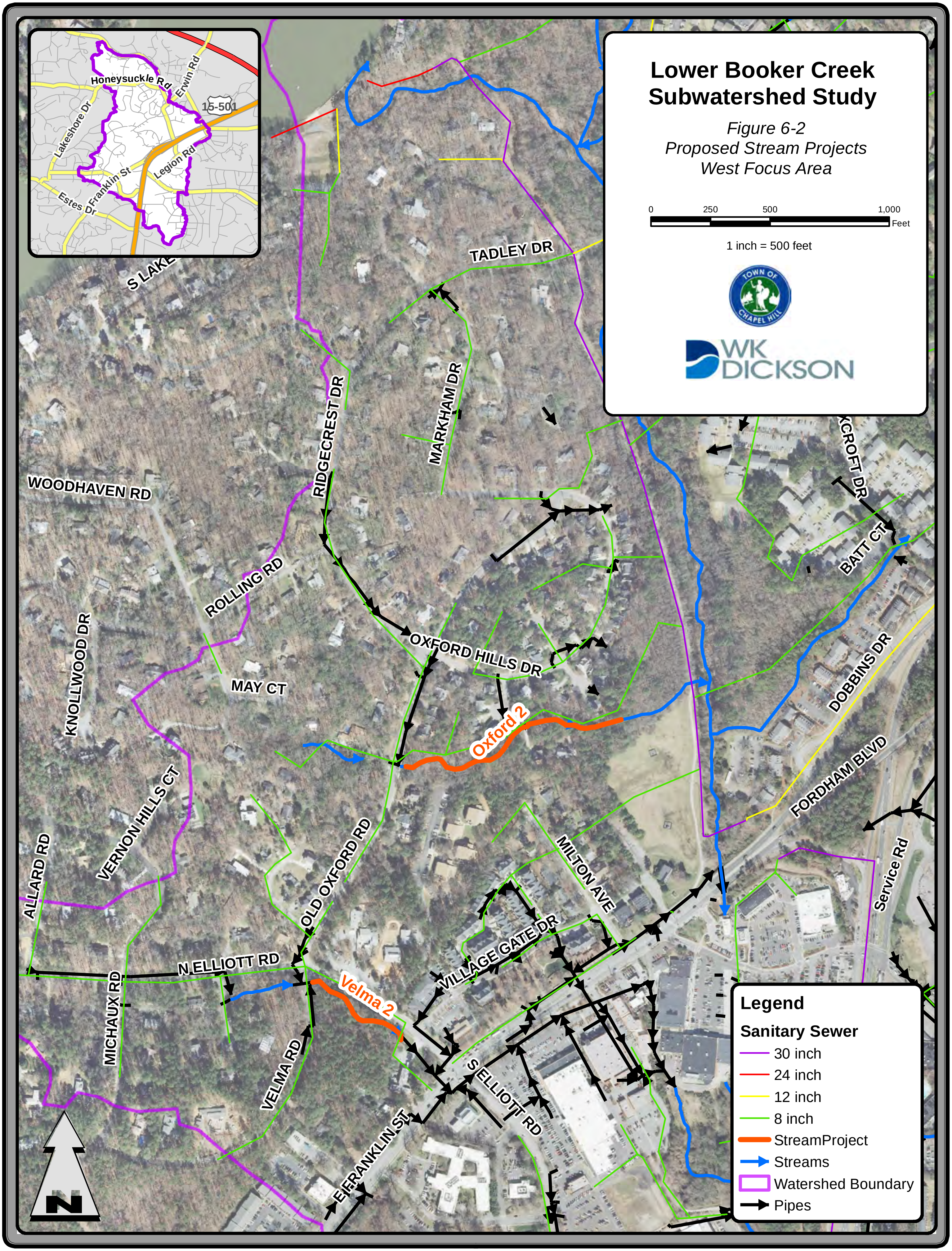
Table 6-1: Summary of Stream Stabilization Projects*

Project	Reach Name	Project Type	Reach and Habitat Score	Reach Length (feet)	Approx. Project Length (LF)
1	Sierra 3	Stabilize large head-cut, stream banks, enhance buffer	163	692	400
2	Sedgefield 2	Repair retaining wall/stabilize bank, stream channel grade control	136	412	200
3	Booker 1	Repair perched culverts, stabilize steep banks	179	845	600
4	Booker 2	Stabilize steep banks and channel grade control at confluence	192	70	70
5	Foxwood 3	Restore concrete channel to stream or RSC	105	408	408
6	Dobbins 1	Stabilize steep banks, channel grade control, or RSC, protect road	155	601	601
7	Dobbins 3	bank stabilization, channel grade control, buffer enhancement	136	394	394
8	Dobbins 5	Stabilize banks/relocate channel, channel grade control, protect road	172	790	790
9	Oxford 2	Bank stabilization, stabilize head-cut/channel grade control, buffer enhancement	160	1,020	540
10	Velma 2	Stabilize banks, stabilize head-cut, or RSC	195	483	483
		TOTALS		5,815	4,486

*Projects are not listed in order of priority in Table 6-1. See Section 9 for prioritization list.

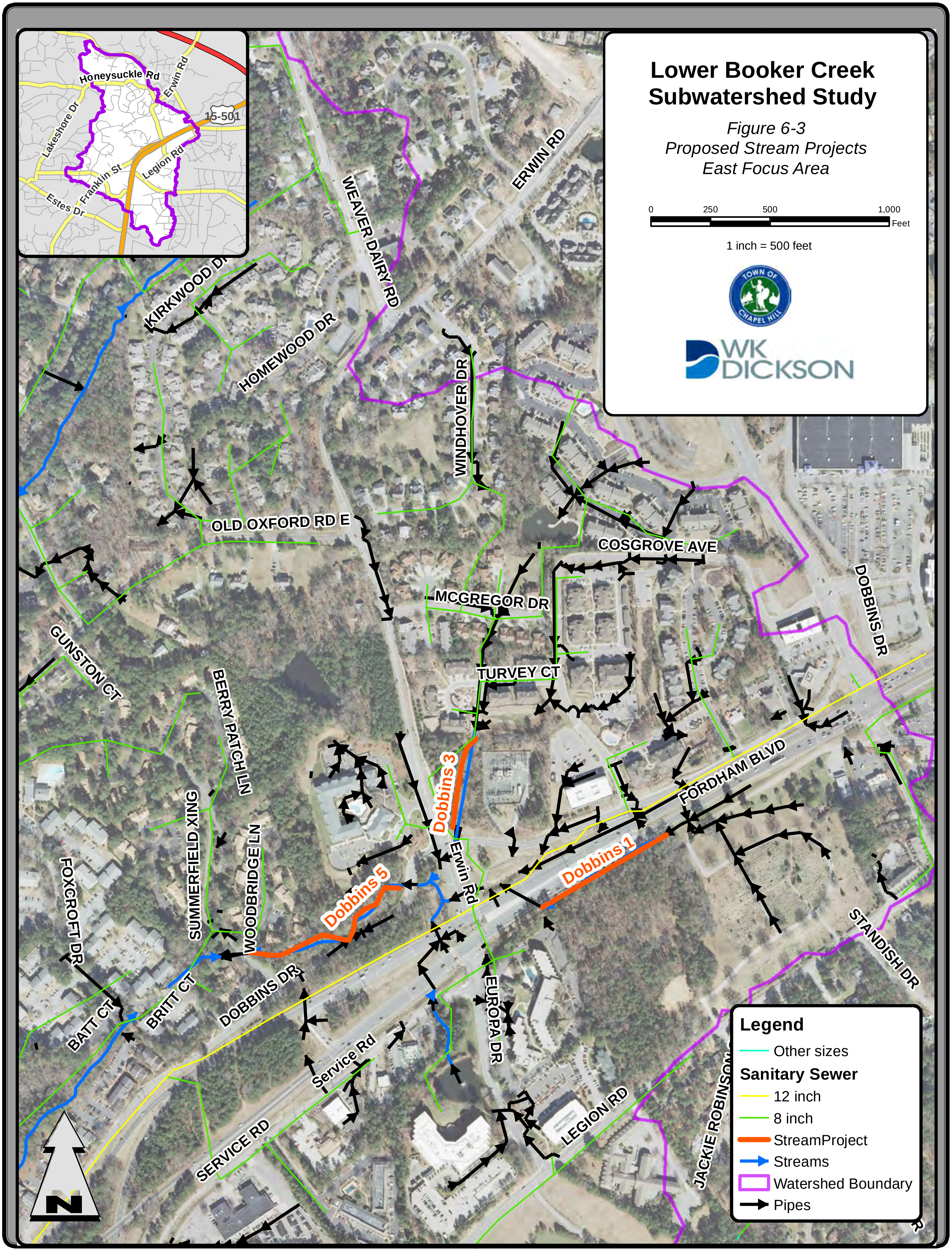


Lower Booker Creek Subwatershed Study
Figure 6-1
Proposed Stream Projects
North Focus Area
0 250 500 1,000 Feet
1 inch = 500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
SIERRA DR
CHESLEY LN
HONEYSUCKLE RD
RED BUD LN
HONEYSUCKLE CT
RED BUD RD
LAKESHORE LN
OWENS CT
BOOKER CREEK RD
SEDGEFIELD DR
TILGHMAN CIR
WAYFARER CT
KORNEGAY PL
WEAVER DAIRY RD
KIRKWOOD DR
ELMWOOD CIR
FOXWOOD DR
MARKHAM DR
Sierra 3
Booker 1
Booker 2
Sedgefield 2
Foxwood 3
Legend
Sanitary Sewer
30 inch
24 inch
12 inch
8 inch
StreamProject
Streams
Lower Booker Creek Watershed
Pipes



Lower Booker Creek Subwatershed Study

Figure 6-2
Proposed Stream Projects
West Focus Area


Lower Booker Creek Subwatershed Study
Figure 6-3
Proposed Stream Projects
East Focus Area
0 250 500 1,000 Feet
1 inch = 500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Honeysuckle Rd
Erwin Rd
15-501
Lakeshore Dr
Franklin St
Legion Rd
Estes Dr
ERWIN RD
WEAVER DAIRY RD
KIRKWOOD DR
HOMEWOOD DR
WINDHOVER DR
OLD OXFORD RD E
COSGROVE AVE
MCGREGOR DR
TURVEY CT
DOBBINS DR
GUNSTON CT
BERRY PATCH LN
SUMMERFIELD XING
WOODBRIDGE LN
FOXCROFT DR
Dobbins 3
Dobbins 1
Dobbins 5
Erwin Rd
FORDHAM BLVD
STANDISH DR
BATT CT
BRITT CT
DOBBINS DR
EUROPA DR
Service Rd
SERVICE RD
LEGION RD
JACKIE ROBINSON
Legend
Other sizes
Sanitary Sewer
12 inch
8 inch
StreamProject
Streams
Watershed Boundary
Pipes
N

Stream Stabilization Project 1: Sierra 3

Sierra 3 is located north of Honeysuckle Road with the upstream end connecting to the v-notch weir at the discharge point for the Red Bud Storage Area. There is a headcut located approximately 150 LF downstream of the weir. The upper portion of the project is located on Town property; however, the lower portion of the stream is located between two (2) residential properties. An 8" sewer line parallels the stream on the right bank upstream, then crosses the stream and parallels on the left bank on the downstream end of the reach. The sewer ROW limits buffer enhancement possibilities where present. The project could be combined with the proposed Red Bud Storage Area and Honeysuckle Road culvert improvements to provide economies of scale of a larger project.

Picture 6-1: Sierra 3 looking upstream – RSC Opportunity

Stream Stabilization Project 2: Sedgefield 2

Sedgefield 2 has a large scour pool at the upstream end, just downstream of the culvert underneath Sedgefield Drive. The left bank at the outfall is steep and eroding. An attempt at stabilization was made by installing a retaining wall on the left bank, but it has failed. An 8" inch sewer line is located on the left bank also, further highlighting the need for a stabilization solution. This project also includes stream channel grade control. This reach is located on private property, and the presence of existing houses limits buffer enhancement to an extent. The project has good accessibility from Sedgefield Drive.

Picture 6-2: Sedgefield 2 looking upstream – Outfall/Bank Stabilization

Stream Stabilization Project 3: Booker 1

Booker 1 has a large scour pool at the upstream end, where the culvert discharges the creek under Honeysuckle Road. The banks in this scour pool area are eroding, and potentially threatening Honeysuckle Road. Farther downstream, there are areas where the steep stream banks are relatively stable, and others where they are not. Additionally, there are multiple driveway crossings of the creek that have perched culverts, which are evidence of channel scouring and incision, where grade control has been lost. These perched culverts also degrade aquatic habitat. The creek flows beside the road for most of this reach, so access is very good. The 8″ sewer line that parallels the road does not present apparent obstacles to the project, however the road and private property along the reach limit buffer enhancement to an extent.

Picture 6-3: Booker 1 looking upstream– Perched Culvert

Stream Stabilization Project 4: Booker 2

Booker 2 is located at the confluence of Booker Creek and an unnamed tributary. The stream is heavily incised, resulting in steep, eroding banks, and flow from the unnamed tributary is directed into an eroding bank on the mainstem during high flows. The steep, eroding banks and incised channel need stabilization. Also, altering the angle of the confluence through channel modification/relocation may lessen future erosion. The sanitary sewer easement for an existing 8″ inch line provides good access to this site on the left bank. Private property is on the right bank. Buffer enhancement opportunity is limited by the presence of the sewer easement.

Stream Stabilization Project 5: Foxwood 3

Foxwood 3 is located in between buildings at the Booker Creek Townhouse complex. It involves the removal of the concrete lining the channel between the buildings and replacing it with either stream channel restoration or RSC implementation. An 8″ sewer line parallels the channel on the right bank. This project is located entirely on private property, and in relatively close proximity to apartment buildings, so buffer enhancement may be limited. Accessibility to the channel from paved parking lots on either side is good.

Picture 6-4: Foxwood 3 looking upstream – RSC Opportunity

Stream Stabilization Project 6: Dobbins 1

Dobbins 1 located parallel to Fordham Boulevard, is a deeply incised channel with steep banks, resulting in erosion on the right bank that is threatening Fordham Boulevard in at least two (2) locations along the reach. Existing channel incision and erosion point out the need for bank stabilization, channel grade control and potentially raising the invert of the channel to decrease incision and enhance stability. RSC implementation is a consideration at this location. The presence of Fordham Boulevard precludes buffer enhancement on the right bank, and buffer currently is present on the left bank. The Town of Chapel Hill owns the property on the south side of the channel (left bank), enhancing site accessibility. There are no sewer utilities present along this reach.

Picture 6-5: Dobbins 1 looking upstream– RSC Opportunity

Stream Stabilization Project 7: Dobbins 3

Dobbins 3 is located just downstream from an existing dry pond SCM south of Turvey Court in an apartment complex. The channel here is incised, with eroding banks, and is a candidate site for either natural channel restoration or RSC implementation. There is existing buffer on both sides of the stream, but enhancement may be possible. Duke Energy owns the property where this site is located, and accessibility to the channel is good. There are limited sanitary constraints for this reach with the exception being the upstream portion near the dry pond.

Picture 6-6: Dobbins 3 looking upstream – RSC Opportunity

Stream Stabilization Project 8: Dobbins 5

Dobbins 5 is located parallel to Dobbins Drive between Erwin Road and Woodbridge Lane. Channel incision and eroding stream banks are threatening the Dobbins Drive roadbed infrastructure. A possible solution is the relocation and restoration of the stream channel away from the road. Dobbins Drive and existing buffer preclude buffer enhancement on a substantial portion of the left bank. This reach is entirely on private property, and there may be opportunities for buffer enhancement on the right bank. Access to the channel is fair to good. There are no sewer utilities along this reach.

Picture 6-7: Dobbins 5 looking downstream– Bank Stabilization

Stream Stabilization Project 9: Oxford 2

Oxford 2 is located south of Red Cedar Place. There is an existing head-cut that has created channel incision and eroding stream banks in the back yard of a private residence. Potential stabilization activities include repairing the head-cut and establishing channel grade control, repairing eroding stream banks, and buffer enhancement. There is an 8" sewer line nearby, but it is not visible, and does not appear to impair stabilization activities. Access to the channel is good.

Picture 6-8: Oxford 2 looking downstream – Stream Stabilization/Buffer Planting

Stream Stabilization Project 10: Velma 2

Velma 2 is located parallel to North Elliott Road, the upstream end begins at Velma Road, and the downstream end is a culvert under East Franklin Street at a fire station. There is a head-cut that has created steep, eroding banks. This site is a candidate for channel stabilization including repair of the head-cut and establishment of channel grade control, repair of the eroding banks, and buffer enhancement. An RSC design is possible here also. There is an 8" sewer line along the left bank and North Elliott Road, but its alignment does not appear to be a constraint on stabilization activities. This reach is located on private property and access to the channel is fair.

Picture 6-9: Velma 2 looking downstream – RSC Opportunity

6.2 SCM PROJECT IDENTIFICATION

6.2.1 OUTFALL OPPORTUNITIES

As described in Section 3.4 (See Table 3-13), sixty-eight (68) outfalls were assessed and prioritized for retrofit potential based on applying a desktop screening protocol that focused on ten (10) engineering feasibility factors. Outfalls were further evaluated to consider pairing outfall retrofits with identified stream stabilization and flood mitigation projects for holistic watershed solutions. For example, while an outfall opportunity by itself may not have ranked in the top tier, it might be located upstream of a proposed stream restoration reach which elevates its effectiveness and benefit as a retrofit. A final review of the sites eliminated sites LBC 0800, 0669, 0476 and 0514 due to future development plans or verification of site topography constraints. LBC sites 0280 and 0647 are included as the next highest-ranking sites. Through these final processes, ten (10) outfall retrofit opportunities were identified for water quality improvement in the Lower Booker Creek subwatershed (Table 6-2). Of the ten (10) sites identified, LBC0170 is entirely in the 100-year floodplain, and LBC0389 and LBC0411 are partially in the 100-year floodplain. In the Lower Booker Creek subwatershed, the benefit of treating runoff during much more frequent, lower intensity storm events was deemed a feasible tradeoff to the potential increased maintenance effort that location in the floodplain can require.

Table 6-2: Lower Booker Creek Outfall Opportunities

	Area (ac)	Location
LBC0170	0.29	Downstream Eastgate, combines with Elliott Storage
LBC0280	0.06	At corner of Velma Road and North Elliott Road
LBC0298	0.09	Southeast corner of Ephesus Church Road and Fordham
LBC0389	0.05	End of Wilder Place cul-de-sac
LBC0411	0.13	East of Oxford Hill Drive near intersection with Old Oxford Road
LBC0456	0.21	Triangle where Fordham splits near Franklin Street and north of Eastgate
LBC0597	0.06	Fordham ROW, west of intersection with Europa Drive
LBC0607	0.13	Fordham ROW, west of intersection with Europa Drive (across Eastbound land of Fordham Drive from LBC0597)
LBC0647	0.03	West of Scarlett Drive near intersection with Old Durham Rd
LBC0096	0.16	Fordham ROW, NW corner of intersection with Willow Drive

A more detailed description of the projects follows. In some instances, the figures illustrating the ten (10) outfall retrofit opportunities also show nearby outfall opportunities that did not rank as high. The outfall being described is labeled in yellow, and included in each figure title, respectively.

Project 1: LBC0170

Location: Downstream of Eastgate Crossing in the riparian corridor and floodplain (See Figure 6-4).

Description of Observed Problems/Opportunity: Untreated runoff from impervious surfaces (roofs and parking lots) leads to poor water quality, erosive velocities, and impaired habitat in the main stem of Booker Creek.

Proposed Retrofit: There is adequate room here to provide some level of water quality treatment for a large portion of the 17 acres of impervious area that drains to the outfall. The retrofit project is to construct a stormwater wetland in the vegetated riparian area.

Potential Constraints: There is the potential need for a flow splitter as well as the maintenance that would be needed after large events and the likelihood of inundation from being located in the floodplain.

Accessibility: Access should be adequate behind the southern retail building.

Comments: The project can be combined with the proposed Elliott Storage Area to provide economies of scale of a larger project and some added attenuation and water quality treatment for the smaller more frequent storms.

Outfall Assessment

Orange County

Chapel Hill, NC

Lower Booker Creek Watershed Plan

Outfall LBC0170

Figure 6-4

Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet

1 in = 100 ft

N

Biohabitats

April 2016

Project 2: LBC0280

Location: At corner of Velma Road and Elliott Road on private residential property (See Figure 6-5).

Description of Observed Problems/Opportunity: This site receives runoff from a single family residential area that is discharged without control or treatment to a wooded area and existing stream channel.

Proposed Retrofit: There is adequate room here to provide water quality treatment for a large portion of the 2.3 acres of impervious area that drains to the outfall. The retrofit project is to construct a bioretention or stormwater wetland.

Potential Constraints: Additional infrastructure is necessary to divert stormwater from the existing outfall on Wood Circle to the site. The project would require easements or purchase of what is currently undeveloped private property.

Accessibility: The project has good access from North Elliott Road or Velma Road. Some minor clearing may be necessary to provide sufficient outfall.

Project 3: LBC0298

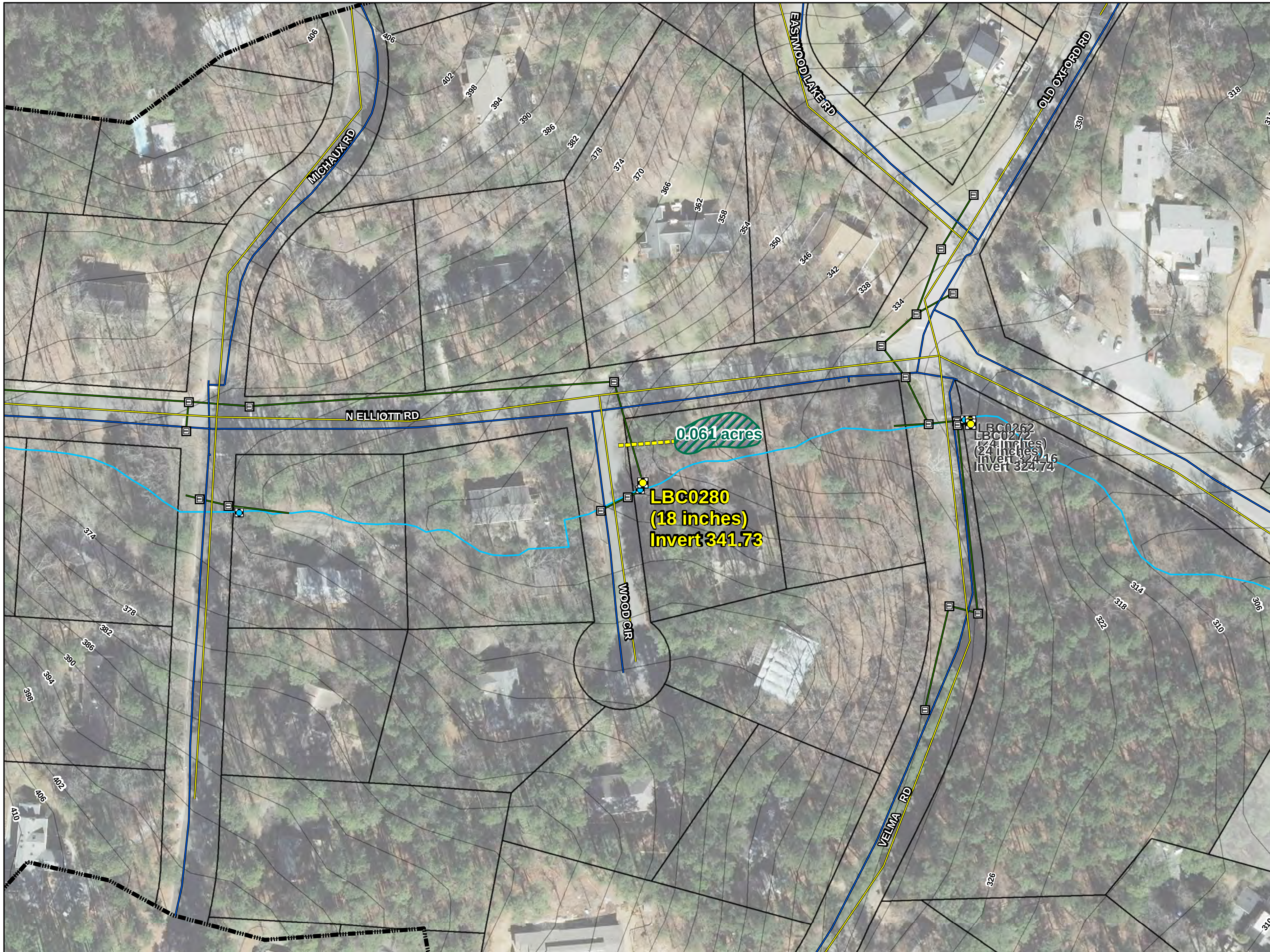
Location: Southeast corner of Ephesus Church Road and Fordham Boulevard (See Figure 6-6).

Description of Observed Problems/Opportunity: This site receives extensive commercial and ROW impervious area runoff and presents an opportunity to provide some water quality benefits as well as creating a more appealing aesthetic at this busy intersection.

Proposed Retrofit: This retrofit will require a flow splitter to divert smaller first flush flows to the proposed bioretention area. Larger flows will need to be by-passed so as not to overwhelm the SCM.

Potential Constraints: The biggest constraint is limited space given the size of the contributing watershed.

Accessibility: The project has good accessibility; however, traffic control may be an important element during certain construction phases.



Outfall Assessment

Orange County

Chapel Hill, NC

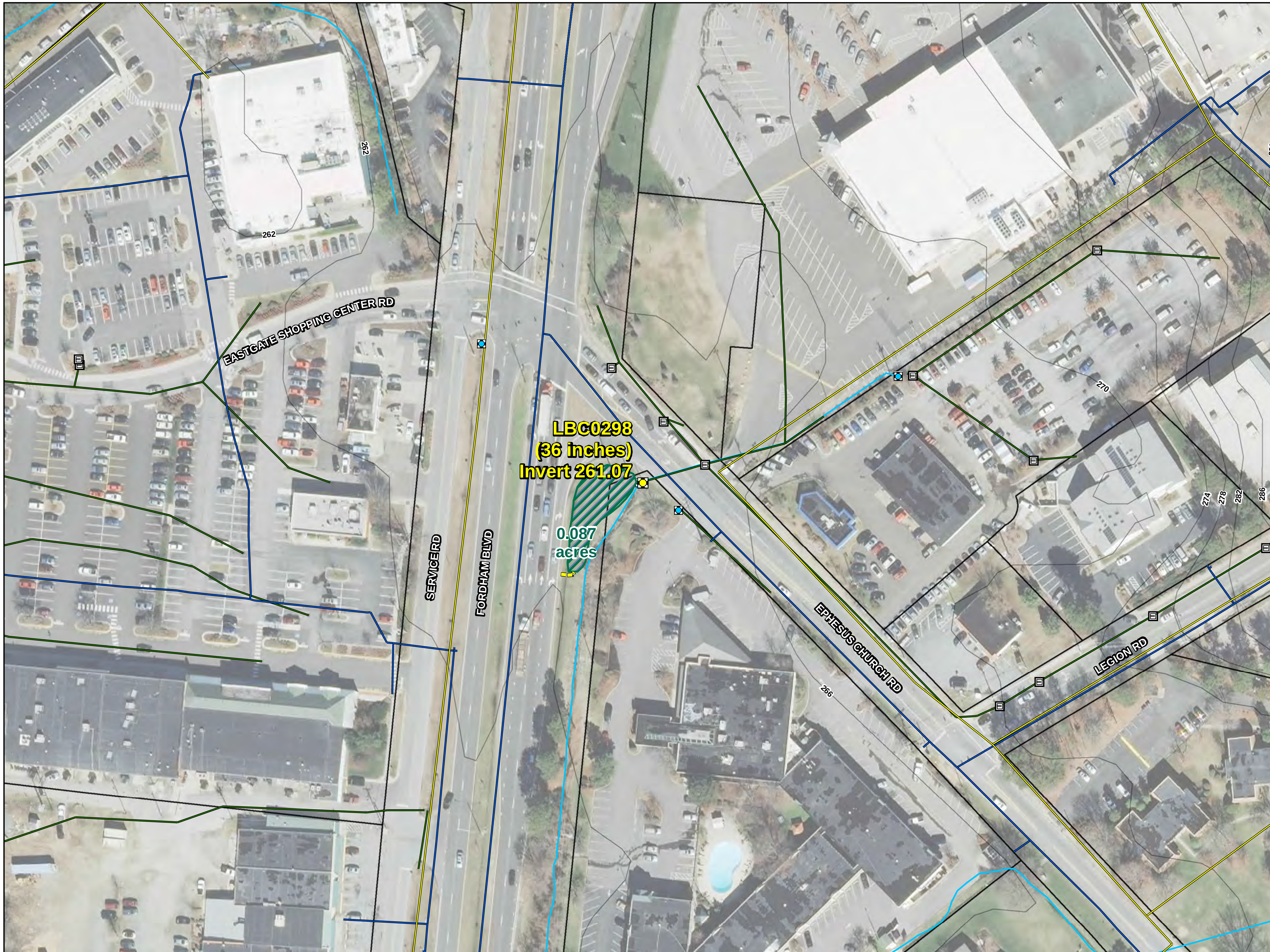
Lower Booker Creek Watershed Plan

Outfall LBC0280

Figure 6-5

Biohabitats

April 2016



Outfall Assessment
Orange County
Chapel Hill, NC

Lower Booker Creek Watershed Plan
Outfall LBC0298
Figure 6-6

Legend
- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet
1 in = 100 ft
N

Biohabitats
April 2016

Project 4: LBC0389

Location: End of Wilder Place cul-de-sac (See Figure 6-7).

Description of Observed Problems/Opportunity: This site receives runoff from a single family residential area that is discharged without control or treatment to a wooded area.

Proposed Retrofit: The proposed retrofit is a fairly simple regenerative stormwater conveyance system that would regulate flows to limit erosion and provide water quality treatment and shallow groundwater recharge benefits.

Potential Constraints: No significant constraints exist in the immediate vicinity of the proposed SCM but there is a sewer main down gradient that will need to be considered during design.

Accessibility: The project has good accessibility with a storm drain easement at the location of the outfall.

Project 5: LBC0411

Location: East of Oxford Hill Drive, near the intersection with Old Oxford Road (See Figure 6-8).

Description of Observed Problems/Opportunity: Runoff from a single family residential area is discharged to this site without control or treatment to a wooded riparian zone.

Proposed Retrofit: The proposed retrofit is a relatively simple regenerative stormwater conveyance system that would regulate flows to limit erosion and provide water quality treatment and shallow groundwater recharge benefits.

Potential Constraints: No significant constraints exist in the immediate vicinity of the proposed SCM but there is a sewer main down gradient that will need to be considered during design.

Accessibility: The project has good accessibility with a storm drain easement at the location of the outfall.

Project 6: LBC0456

Location: Triangular area bounded by Franklin Street, Fordham Boulevard, and a service road; the project site is north of Eastgate Crossing (See Figure 6-9).

Description of Observed Problems/Opportunity: This site receives runoff from commercial and ROW areas that have no controls or treatment.

Proposed Retrofit: The proposed retrofit is a constructed wetland that provides smaller storm attenuation and water quality treatment benefits.

Potential Constraints: Biggest constraints are tree loss to construct feature and associated habitat impacts. These ecological function losses can be offset with the new wetland ecology.

Accessibility: The project has good accessibility off Franklin Street but substantial traffic control will be necessary during construction.

Outfall Assessment
Orange County
Chapel Hill, NC

Lower Booker Creek Watershed Plan
Outfall LBC0389
Figure 6-7

Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet
1 in = 100 ft
N

Biohabitats
April 2016

Outfall Assessment

Orange County

Chapel Hill, NC

Lower Booker Creek Watershed Plan

Outfall LBC0411

Figure 6-8

Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet

1 in = 100 ft

N

Biohabitats

April 2016

Outfall Assessment

Orange County

Chapel Hill, NC

Lower Booker Creek Watershed Plan

Outfall LBC0456

Figure 6-9

Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet

1 in = 100 ft

N

Biohabitats

April 2016

Project 7: LBC0597

Location: Fordham Boulevard ROW, west of intersection with Europa Drive (See Figure 6-10).

Description of Observed Problems/Opportunity: This site runoff is from the commercial land use adjacent to the Fordham Boulevard ROW that is uncontrolled and untreated.

Proposed Retrofit: The proposed retrofit is a linear bioretention system that provides storm attenuation and water quality treatment benefits.

Potential Constraints: There do not appear to be any significant constraints.

Accessibility: The project has good accessibility off the service road adjacent to Fordham Boulevard.

Project 8: LBC0607

Location: Fordham Boulevard ROW (median between service road), west of intersection with Europa Drive (See Figure 6-11).

Description of Observed Problems/Opportunity: The runoff to this site is from Fordham Boulevard that is uncontrolled and untreated.

Proposed Retrofit: The proposed retrofit is to install a flow diversion in the existing storm drain network and create a bioretention in the median that provides stormwater attenuation and water quality treatment benefits.

Potential Constraints: The cost associated with the installation of the flow splitter is a potential constraint.

Accessibility: The project has fair accessibility off Fordham Boulevard.

Project 9 – LBC0647

Location: West of Scarlett Drive near intersection with Old Durham Road (See Figure 6-12).

Description of Observed Problems/Opportunity: This site receives runoff from the commercial land use adjacent to the Old Durham Road ROW that has no controls or treatment.

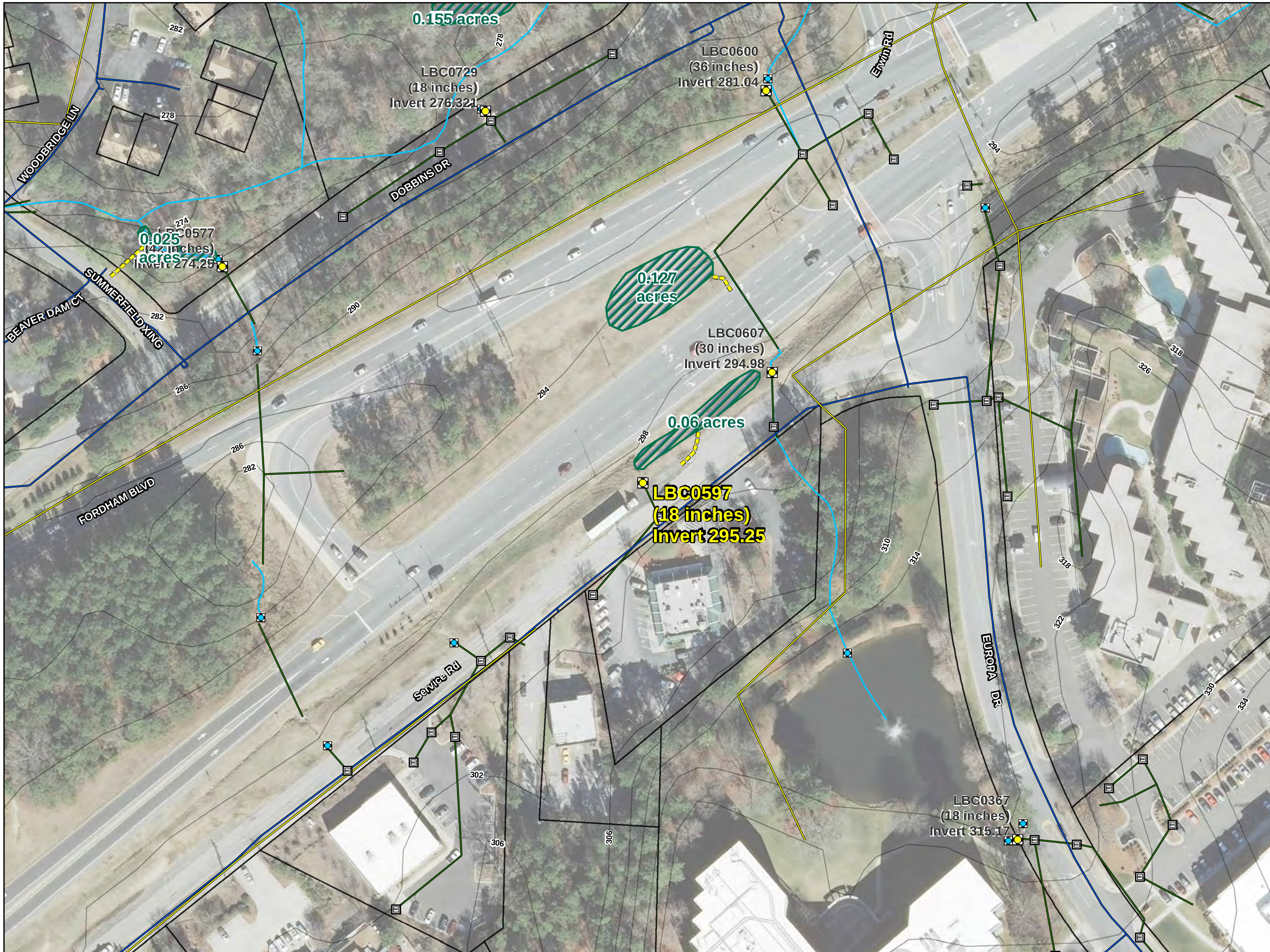
Proposed Retrofit: The proposed retrofit is a linear bioretention system that provides storm attenuation and water quality treatment benefits.

Potential Constraints: There do not appear to be any significant constraints, except temporary impacts to limited parking in the retail area. This project site is located in NCDOT right-of-way.

Accessibility: The project has good accessibility off the service road adjacent to the site.

Outfall Assessment
Orange County
Chapel Hill, NC

Lower Booker Creek Watershed Plan
Outfall LBC0597
Figure 6-10



Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet
1 in = 100 ft
N

Biohabitats

April 2016

Outfall Assessment

Orange County

Chapel Hill, NC

Lower Booker Creek Watershed Plan

Outfall LBC0607

Figure 6-11

Legend

- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet

1 in = 100 ft

N

Biohabitats

April 2016

Outfall Assessment
Orange County
Chapel Hill, NC

Lower Booker Creek Watershed Plan
Outfall LBC0647
Figure 6-12

Legend
- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet
1 in = 100 ft
N

Biohabitats
April 2016

Project 10 – LBC0096

Location: Fordham Boulevard ROW, NW corner of intersection with Willow Drive (See Figure 6-13).

Description of Observed Problems/Opportunity: This site receives runoff from commercial and ROW areas that have no controls or treatment.

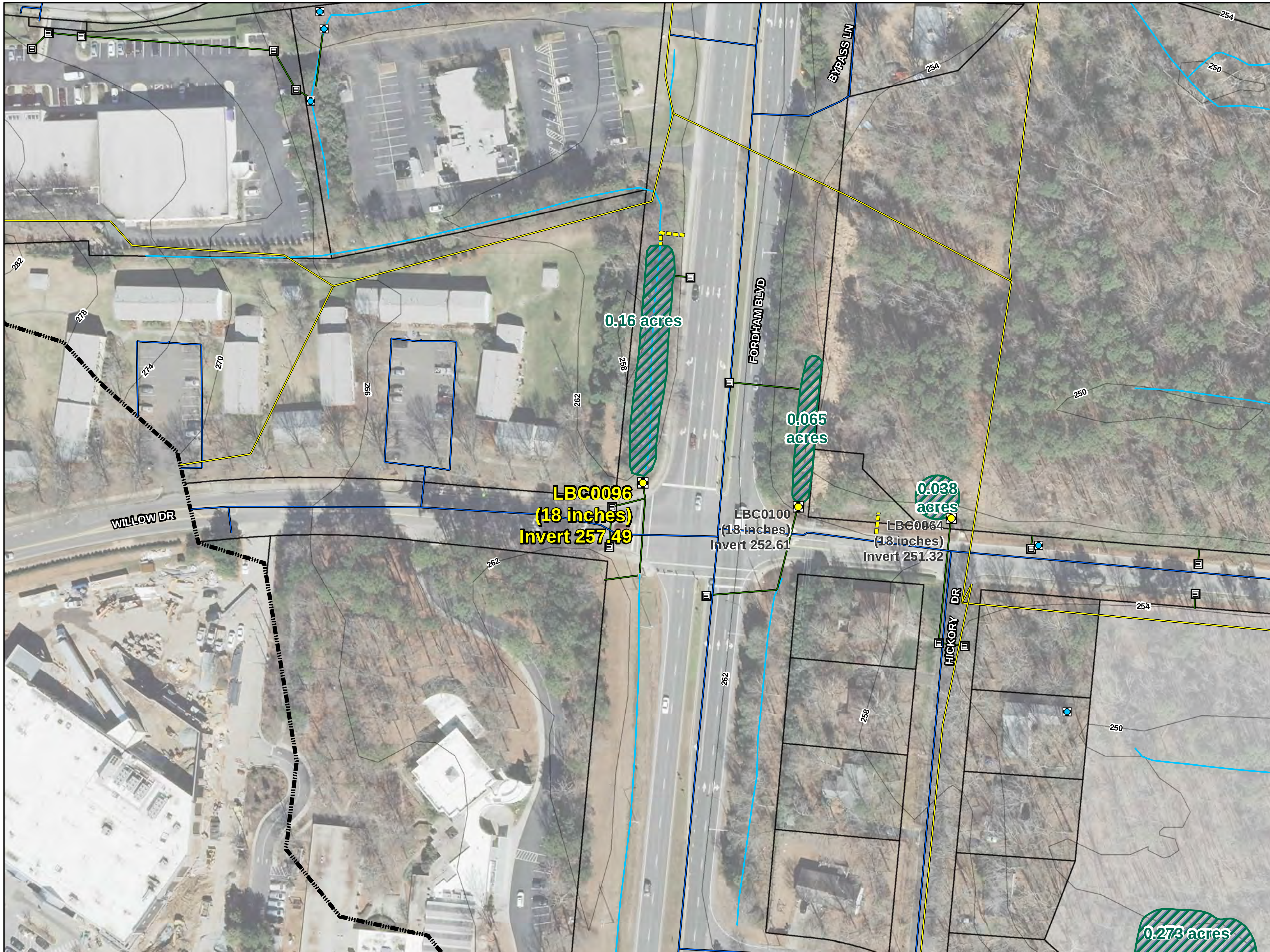
Proposed Retrofit: The proposed retrofit is a linear constructed wetland that provides smaller storm attenuation and water quality treatment benefits.

Potential Constraints: Biggest constraints are tree loss to construct feature and associated habitat impacts. These ecological function losses can be offset with the new wetland ecology. Other constraints might include on-line nature of wetland and ability to withstand flashy hydrology.

Accessibility: The project has good accessibility off Willow Drive but the traffic density around Fordham Boulevard will prove challenging.

Outfall Assessment
Orange County
Chapel Hill, NC

Lower Booker Creek Watershed Plan
Outfall LBC0096
Figure 6-13



Legend
- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Lower Booker Creek Watershed Boundary
- BMP Footprint

0 50 100 Feet
1 in = 100 ft
N

Biohabitats
April 2016

6.2.2 NEIGHBORHOOD OPPORTUNITIES

As described in Section 3.6, a desktop assessment was conducted on the entire Booker Creek watershed to evaluate neighborhoods for green infrastructure retrofitting potential. Eight (8) neighborhoods were identified through the GIS assessment as the top-ranking neighborhoods for retrofits such as vegetated swales (bioswales), rain gardens, permeable pavement/pavers, and bioretention cells. They are:

1. Northwood (Booker Headwaters subwatershed)
2. Timberlyne (Cedar Fork subwatershed)
3. Cedar Hills (Cedar Fork subwatershed)
4. Lake Forest (Cedar Fork subwatershed)
5. Lake Forest (Eastwood Lake subwatershed)
6. Lake Forest (Lower Booker Creek subwatershed)
7. Booker Creek (Lower Booker Creek subwatershed)
8. Ridgefield (Lower Booker Creek subwatershed)

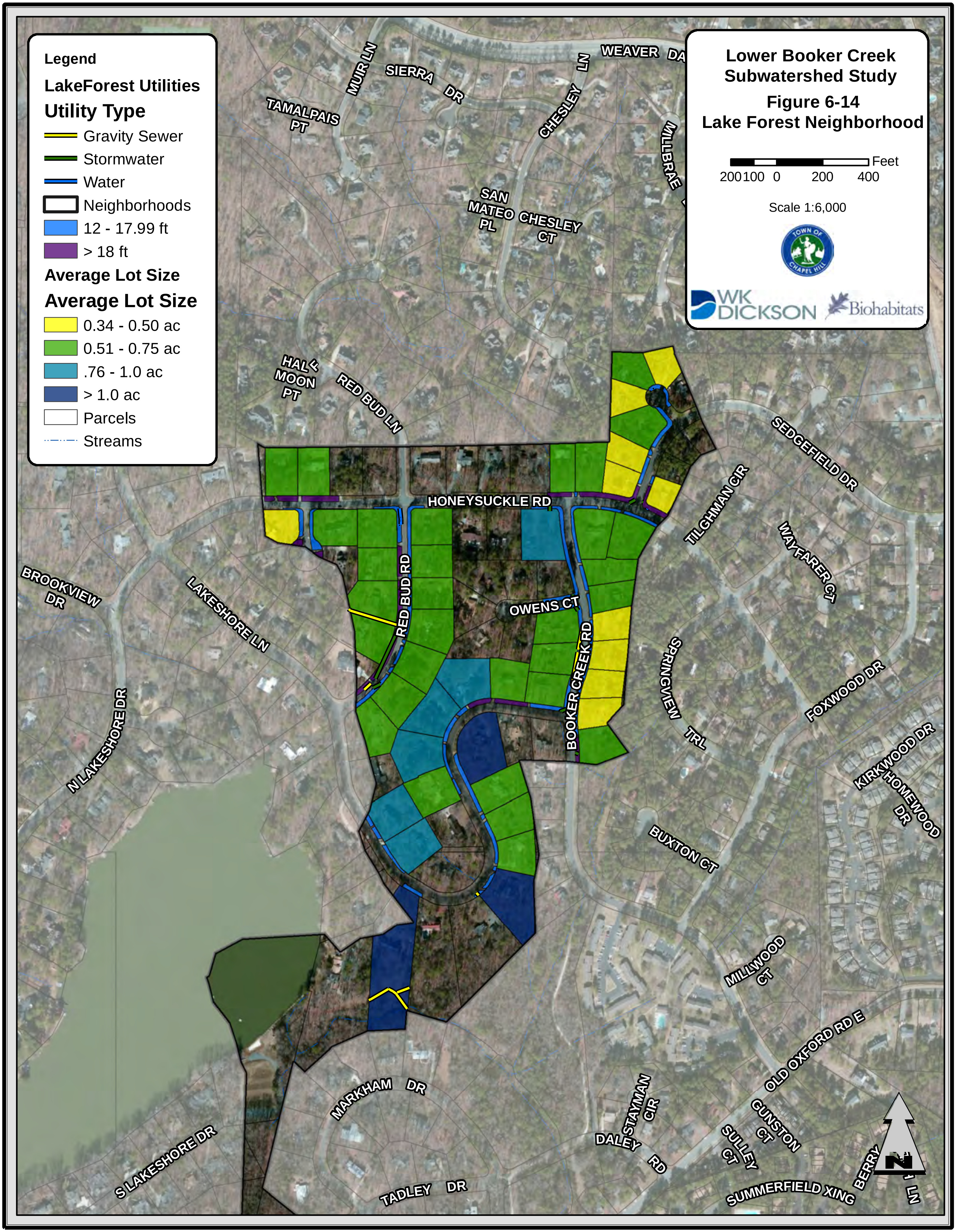
Three (3) of the neighborhoods are located in the Lower Booker Creek subwatershed - Lake Forest, Booker Creek and Ridgefield. These neighborhoods were selected as the top-ranking neighborhoods. They were further analyzed in GIS to determine specific areas in those neighborhoods where average lot size, road slope, road width, total road length and rights of-way length are conducive for the retrofit types mentioned above (See Figures 6-14 through 6-16).

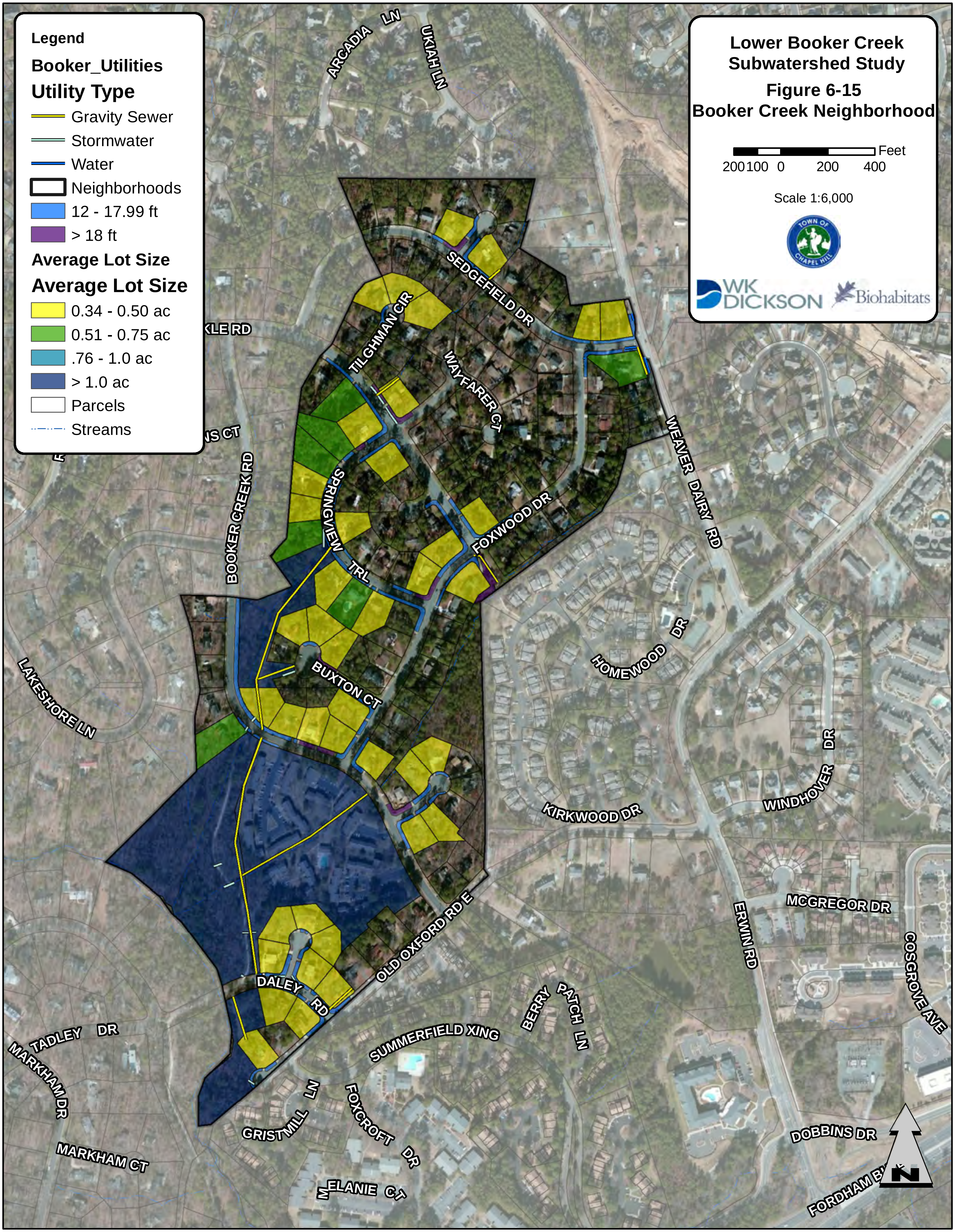
The acreages of each neighborhood are:

Lake Forest	100.2 ac
Booker Creek	99.1 ac
Ridgefield	102.4 ac

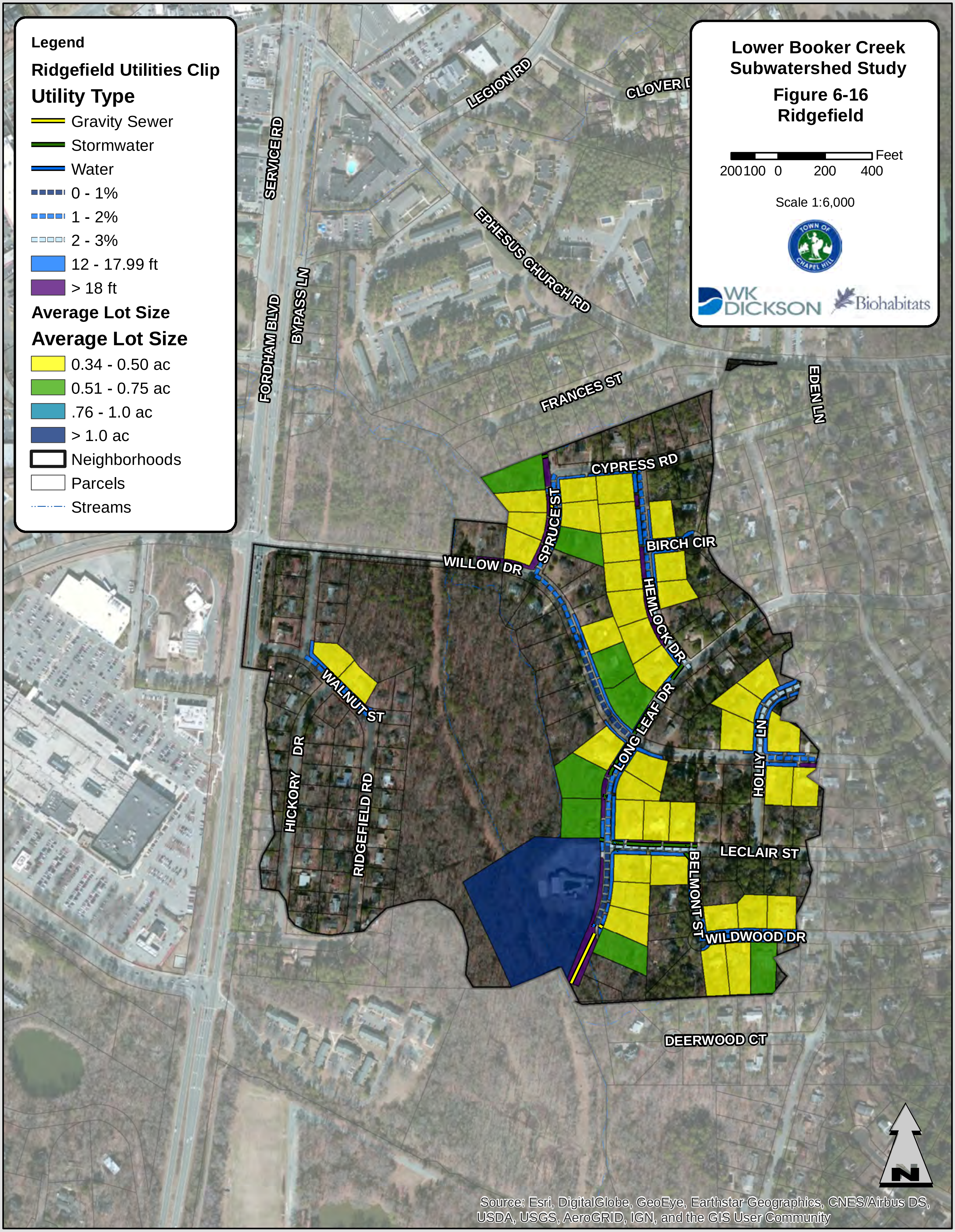
A range of stormwater control measures are available for greening these areas, with the focus being on publicly-owned areas such as the streets themselves and rights-of-way. Potential stormwater control measures that can be explored for implementation include: permeable paving for parking lanes, bioswales, rain gardens, impervious cover removal (road narrowing), and tree planting (to promote rainfall interception). Generally, utilities present the biggest constraint for these stormwater control measures.

This GIS analysis identified potential areas in each neighborhood where conditions appear to be favorable for water quality retrofits. Future follow-up field work will allow specific stormwater treatment options to be identified. This analysis does not recommend specific water quality stormwater control measures at any particular location, just that the existing conditions are favorable to implement one or more potential stormwater control measures. Water quality modeling information in Section 6.3 below will help to identify specific areas for further investigation and field work.


Legend
LakeForest Utilities
Utility Type
Gravity Sewer
Stormwater
Water
Neighborhoods
12 - 17.99 ft
> 18 ft
Average Lot Size
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
Lower Booker Creek Subwatershed Study
Figure 6-14
Lake Forest Neighborhood
Feet
200 100 0 200 400
Scale 1:6,000
WK DICKSON
Biohabitats
WEAVER DA
SIERRA DR
MUIR LN
TAMALPAIS PT
CHESLEY LN
MILLBRAE
SAN MATEO PL
CHESLEY CT
HALF MOON PT
RED BUD LN
HONEYSUCKLE RD
SEDGEFIELD DR
TILGHMAN CIR
WAYFARER CT
BROOKVIEW DR
LAKESHORE LN
RED BUD RD
OWENS CT
BOOKER CREEK RD
SPRINGVIEW TRL
FOXWOOD DR
N LAKESHORE DR
KIRKWOOD DR
HOMEWOOD DR
BUXTON CT
MILLWOOD CT
OLD OXFORD RD E
MARKHAM DR
STAYMAN CIR
GUNSTON CT
SULLEY CT
DALEY RD
S LAKESHORE DR
TADLEY DR
SUMMERFIELD XING
BERRY
N



Legend
Booker_Utilities
Utility Type
Gravity Sewer
Stormwater
Water
Neighborhoods
12 - 17.99 ft
> 18 ft
Average Lot Size
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
Lower Booker Creek
Subwatershed Study
Figure 6-15
Booker Creek Neighborhood
Feet
200 100 0 200 400
Scale 1:6,000
TOWN OF CHAPEL HILL
WK DICKSON
Biohabitats
ARCADIA LN
UKIAH LN
SEDGEFIELD DR
TILGHMAN CIR
WAYFARER CT
WEAVER DAIRY RD
SPRINGVIEW TRL
FOXWOOD DR
BOOKER CREEK RD
BUXTON CT
HOMEWOOD DR
LAKESHORE LN
WINDHOVER DR
KIRKWOOD DR
OLD OXFORD RD E
MCGREGOR DR
ERWIN RD
COSGROVE AVE
DALEY RD
BERRY PATCH LN
SUMMERFIELD XING
TADLEY DR
MARKHAM DR
GRISTMILL LN
FOXCROFT DR
DOBBINS DR
MARKHAM CT
MELANIE CT
FORDHAM BL
N


Legend
Ridgefield Utilities Clip
Utility Type
Gravity Sewer
Stormwater
Water
0 - 1%
1 - 2%
2 - 3%
12 - 17.99 ft
> 18 ft
Average Lot Size
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Neighborhoods
Parcels
Streams
Lower Booker Creek Subwatershed Study
Figure 6-16
Ridgefield
Feet
200 100 0 200 400
Scale 1:6,000
TOWN OF CHAPEL HILL
WK DICKSON
Biohabitats
LEGION RD
CLOVER D
SERVICE RD
BYPASS LN
FORDHAM BLVD
EPHESUS CHURCH RD
FRANCES ST
EDEN LN
CYPRESS RD
SPRUCE ST
BIRCH CIR
WILLOW DR
HEMLOCK DR
WALNUT ST
LONG LEAF DR
HOLLY LN
HICKORY DR
RIDGEFIELD RD
LECLAIR ST
BELMONT ST
WILDWOOD DR
DEERWOOD CT
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

6.3 WATER QUALITY MODELING

Water quality modeling was performed using the Watershed Treatment Model (2013), which was developed by the Center for Watershed Protection, a Maryland-based non-profit that is a leader in the development of watershed management techniques.

The Watershed Treatment Model (WTM), is a simple spreadsheet-based model that calculates pollutant loads from a wide range of sources, and incorporates the full suite of watershed treatment options. In addition, the model allows the watershed manager to adjust these loads based on the level of effort put forth for implementation. Although the simple algorithms in this model are no substitute for more detailed watershed information, and model assumptions may be modified as the watershed plan is implemented, the WTM acts as an empirically-based tool which can be used by watershed managers to evaluate multiple alternatives for watershed treatment.

The WTM can predict annual rates of total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and runoff volume. It computes loading based on four (4) major components:

- Sources;
- Practices (existing);
- Practices (future); and
- New development

The WTM determines pollutant loads for one (1) drainage area at a time, using one (1) annual rainfall total. It is strictly a pollutant load model and does not model flow.

Existing Primary Sources Baseline Pollutant Loads

Primary pollutant sources are determined using five (5) major land use/cover categories- Residential, Commercial, Industrial, Forest, and Rural. To determine existing TN, TP and TSS loadings in the watershed, land use/land cover information obtained from the Town of Chapel Hill was entered into the model as summarized in Section 2.

Based on the land use acreages assigned, the existing loadings are as follows:

Table 6-3: Existing Surface Water Loadings Based on Current Land Uses in the Watershed

TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
10,237.1	2,009.7	503,172.2

It is important that the Town of Chapel Hill identify existing pollutant sources and calculate the pollutant loads. Chapel Hill is subject to the set of regulations known as the "Jordan Rules," which went into effect in 2009. One of the rules focuses on pollutant loads, specifically nitrogen and phosphorus, from existing development. Based on monitoring performed by the North Carolina Division of Water Resources (Division), the Town may be required to implement a Stage 2 adaptive management program to address nutrient loads from existing development. The Division has established an eight percent reduction for nitrogen and a five percent reduction for phosphorus. More information about the Jordan Existing Development Rule may be found at http:portal.ncdenr.org/web/jordanlake/read-the-rules.

To comply with the Stage 2 Load Goals using the estimated existing surface water loadings calculated by the WTM (Table 6.3), N has to be reduced by 819 pounds (8%) and TP has to be reduced by 100.5 pounds (5%).

Identified Outfalls Load Reductions

The priority outfall retrofits identified in Section 6.2 were entered into the WTM to estimate the load reduction achieved by those retrofits. The model required the drainage area and percent impervious cover data, which were calculated for each location. The retrofits were classified by the SCM type as follows in Table 6-4.

Table 6-4: Identified Outfalls Modeled in WTM and Their Associated SCM Types

	ID	Approximate Location	Practice Type
1	LBC0170	Near Eastgate Shopping Center	Wetland
2	LBC0280	At corner of Velma Road and North Elliott Road	Bioretention
3	LBC0298	Southeast corner of Ephesus Church Road and Fordham	Bioretention
4	LBC0389	End of Wilder Place cul-de-sac	Bioretention/RSC
5	LBC0411	East of Oxford Hill Dr, near intersection with Old Oxford Road	Bioretention/RSC
6	LBC0456	Triangle where Fordham splits near Franklin Street and north of Eastgate	Wetland
7	LBC0597	Fordham ROW, NW corner of intersection with Willow Drive	Bioretention
8	LBC0607	Fordham ROW, west of intersection with Europa Drive (across Eastbound land of Fordham Drive from LBC0597	Bioretention
9	LBC0647	West of Scarlett Drive, near intersection with Old Durham Road	Bioretention
10	LBC0067	West of Scarlett Drive near intersection with Old Durham Road	Wetland

The modeling results of the pollutant load reductions for the outfalls listed in Table 6-4 are included below in Table 6-5.

Table 6-5: Surface Water Loadings Based on Modeled Identified Outfalls Loading Reductions

	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Existing	10,237.1	2,009.7	503,172.2
Modeled	9,894.1	1,933.27	492,153.99
Pounds Reduced	343	76.5	11,018.4
Percent Reduction	3.4	3.8	2.2

Based on the WTM calculations listed in Table 6-5, TN is reduced by 343 lb/yr, a 3.4% reduction, which is 42.5% of the 8% reduction needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 76.5 lb/yr, a 3.8% reduction, which is 76% of the 5% amount needed to comply with the Jordan Lake Stage 2 requirement. Total suspended solids were also reduced by over 11,000 lb/yr, which is a 2.2% reduction.

Neighborhoods Analysis Load Reductions

The three top ranked neighborhoods in the Lower Booker Creek subwatershed - Lake Forest (Lower Booker Creek subwatershed), Booker Creek, and Ridgefield were modeled using the WTM. These neighborhoods were analyzed in GIS to determine specific areas where average lot size, road slope, road width, total road length, and rights-of-way width are feasible for the types of retrofits mentioned above.

The acreages of each neighborhood are:

Lake Forest 100.2 ac
Booker Creek 99.1 ac
Ridgefield 102.4 ac

Based on the GIS analysis, the percent area of each neighborhood where retrofits were feasible was estimated. Those percentages and the resultant acreages used in the analysis are listed below in Table 6-6.

Table 6-6: Acreages Used in the Neighborhoods WTM Analysis

Neighborhood	Acreage	Percent Area for Retrofits	Area Used for Analysis in WTM
Lake Forest	100.2	50	50.1
Booker Creek	99.1	45	44.6
Ridgefield	102.4	33	33.8
	301.7		128.5

To estimate the reduction in pollutant concentrations from the 128.5 acres identified for the proposed retrofits, the land use categories and baseline nutrient event mean concentrations (EMC) in the WTM were revised by creating a new land use category – 'Low Nutrient Input MDR.' The event mean concentrations for TN and TP for this new category were revised to reflect the lower mean runoff concentrations resulting from the proposed retrofits. The Medium Density Residential acreage (MDR 1 – 4 dwelling units per acre) in the baseline WTM was reduced by 128.5 acres.

The revised, lower EMCs were obtained from the National Stormwater Quality Database (NSQD) Version 3 (2003). The NSQD lists statistically-based concentration values for different land use types. A range of EMCs for TN and TP is listed in the NSQD for residential land use - a low concentration, an average concentration, and a high concentration. The low EMC values were selected to replace the baseline EMC values in the WTM. The baseline EMCs in the WTM are 2.1

mg/l for TN and 0.31 mg/l for TP. The EMC values for the new MDR category used in the post-retrofit WTM were 1.5 mg/l for TN and 0.2 mg/l for TP, a 28.5% reduction and 35.5% reduction from the WTM baselines, respectively.

Table 6-7: Surface Water Loadings Based on Modeled Neighborhood Retrofit Reductions

	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Existing	10,237.1	2,009.7	503,172.2
Modeled (Post- Retrofit)	9,981.9	1,979.5	502,111.7
Pounds Reduced	255.2	30.2	1,060.5
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	819	N/A	N/A
TP – 5% Reduction	N/A	100.5	N/A
Jordan Stage 2 Target Percent Reduction	31.1%	30.0%	N/A

Based on the WTM calculations in Table 6-7, TN is reduced by 255.2 lb/yr, TN is reduced by 255.2 lb/yr, which is 31% of the amount needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 30.2 lb/yr, which is 30% of the amount needed to comply with the Jordan Lake Stage 2 requirement. Total suspended solids were also reduced by over 1,060.5 lb/yr, which is a 0.2% reduction.

Stream Restoration/Stabilization Load Reductions

The WTM was not used to estimate load reductions from proposed stream restoration projects. Rather, load reductions for TN, TP and TSS were taken from Table 3 of the *Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects* (2014), and applied to the identified stream projects in Section 6. The load reductions are as follows: TN- 0.075 lb/ft/yr; TP- 0.068 lb/ft/yr; and TSS- 44.88 lb/ft/year. Load reductions were applied to the estimated project lengths listed in Table 6-8.

Table 6-8: Estimated Stream Restoration Loading Reductions

Reach Name	Project Type	Approx. Project Length (lf)	TN Removal (lb/ft/yr)	TP Removal (lb/ft/yr)	TSS Removal (lb/ft/yr)
Sierra 3	Stabilize large head-cut, stream banks, enhance buffer	400	30	27	17,952
Sedgefield 2	Repair retaining wall/stabilize bank, stream channel grade control	200	15	14	8,976
Booker 1	Repair perched culverts, stabilize steep banks	600	45	41	26,928
Booker 2	Stabilize steep banks and channel grade control at confluence	70	5	5	3,142
Foxwood 3	Restore concrete channel to stream or RSC	408	31	28	18,311
Dobbins 1	Stabilize steep banks, channel grade control, or RSC, protect road	601	45	41	26,973
Dobbins 3	Bank stabilization, channel grade control	394	30	27	17,683
Dobbins 5	Stabilize banks/relocate channel, channel grade control, protect road	790	59	54	35,455
Oxford 2	Bank stabilization, buffer enhancement	300	23	20	13,464
Velma 2	Stabilize banks, stabilize head-cut, or RSC	483	36	33	21,677
Summerfield Crossing	Undersized channel	0	0	0	-
	TOTALS (lb/yr)	4,246	318	289	190,560

Using the lb/ft/yr values described above, a surface water loading reduction summary is presented in Table 6-9.

Table 6-9: Surface Water Loadings Based on Estimated Stream Restoration Reductions

	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Existing	10,237.1	2,009.7	503,172.2
Modeled (Post- Retrofit)	9,981.9	1,979.5	502,111.7
Pounds Reduced	255.2	30.2	1,060.5
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	819	N/A	N/A
TP – 5% Reduction	N/A	100.5	N/A
Jordan Stage 2 Target Percent Reduction	39%	14.4%	N/A

Based on the load reductions in the *Expert Panel Recommendations* paper and the results from Tables 6-8 and 6-9, TN is reduced by 318 lb/yr, which is approximately 39% of the amount needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 289 lb/yr, a 14.4% reduction, which is more than the amount needed to comply with the Jordan Lake Stage 2 requirement. Total suspended solids were also reduced by almost 38%.

Storage Areas Load Reduction

Six (6) potential flood storage areas in the Booker Creek watershed were identified for modeling analysis, and are listed below:

- Elliott - Upstream of Elliott Road, just south of Eastgate Shopping Center
- Red Bud - Upstream of Honeysuckle Drive at an existing V-notch weir
- Daley - Town-owned property downstream of Booker Creek Road
- Parkside - Upstream of New Parkside Drive
- MLK - East of MLK Boulevard, partially on Orange United Methodist Church property
- Piney Mountain - Upstream of Piney Mountain Road on privately-owned property

The strategy for estimating load reductions in the WTM consisted of modeling these flood storage areas as dry detention basins, using the input data summarized in Table 6-10 below.

Table 6-10: Summary of Storage Area Data Used in the WTM to Estimate Load Reductions

Storage Area	Footprint Area (ac)	Drainage Area (ac)	Impervious Area (ac)	% Impervious
Elliott	5.4	3,724.7	790.1	21
Redbud	2	62.3	10.9	18
Daley	8	318.8	78.4	25
Parkside	7.5	138.1	32.8	24
MLK	2.5	706.7	150.6	21
Piney Mountain	5.7	1,473.3	273.5	19

Using input data from Table 6-10, the WTM estimated reductions for the flood storage areas are summarized in Table 6-11 below.

Table 6-11: Surface Water Loadings Based on Estimated Storage Reductions

	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Existing	10,237.1	2,009.7	503,172.2
Modeled (Post- Retrofit)	10,035.5	1,917.1	493,196.4
Pounds Reduced	201.6	92.6	9,975.8
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	819	N/A	N/A
TP – 5% Reduction	N/A	100.5	N/A
Jordan Stage 2 Target Percent Reduction	24.6%	92.1%	N/A

Table 6-12 summarizes estimated load reduction results with respect to achieving the Jordan Lake Stage 2 load reduction requirements, based on the identified outfalls, neighborhoods and stream restoration modeling/estimates presented in this section.

Table 6-12: Summary of Load Reduction Estimates

	TN	% of Jordan Lake Stage 2 TN Requirement	TP	% of Jordan Lake Stage 2 TP Requirement
Jordan Lake Stage 2 Loading Reduction Requirement	8%		5%	
Identified Outfall Reduction	3.8%	47.5%	4.4%	88%
Neighborhood Retrofit Reduction	2.5%	31.0%	1.5%	30%
Stream Restoration Reduction	3.1%	39.0%	14.4%	288%
Storage Area Reduction	2.0%	25.0%	4.6%	92%
TOTALS	11.4%	142.5%	24.9%	498%

Table 6-12 illustrates that outfall retrofits are most effective in reducing TN loads, and very effective in reducing TP loading also. The neighborhood retrofits can provide approximately 30% of the load reduction needed to comply with the Stage 2 requirements. Stream restoration provides effective TN reduction, and very effective TP reduction. Storage can be very effective in TP reduction. The results indicate that an assortment of choices is available with respect to effective nutrient load reductions in the Lower Booker Creek subwatershed.

ANTICIPATED PERMITTING

The proposed improvements described in Sections 4 and 6 may require local, State, and/or Federal permits or approvals prior to the onset of construction. Based on the types of projects identified in the LBC subwatershed, permits or approvals may be required for any of the following reasons:

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

The permitting matrix in Table 7-1 shows the different types of permits that are anticipated for each of the proposed projects. The proposed SCMs may require erosion control permits if the land disturbance area is greater than 1.0 acre, but permits or agreements from NCDEQ, USACE, FEMA, and NCDOT are not anticipated for these projects. Riparian buffer requirements may apply to projects located within fifty (50) feet of a streambank. Coordination with NCDEQ is recommended to determine if buffer impacts are exempt or allowable with mitigation.

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

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

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

NWP#3 – Maintenance

This permit authorizes the repair, replacement, or rehabilitation of any previously permitted or currently serviceable structure. A PCN is not required for minor deviations in the structure's configuration or filled area that occur as a result of changes in materials, construction techniques, or safety standards necessary to make repair or replacement, provided environmental impacts are minimal. A PCN to the USACE is required if a significant amount of sediment is excavated/filled within the channel. NC Division of Water Quality (DWQ) does not typically require a PCN for NWP #3 but usually receives one as a courtesy.

Other provisions imposed by the State of North Carolina require that culvert inverts must be buried a minimum of 1-foot below the streambed for culverts greater than or equal to 48 inches in diameter to allow low flow passage of water and aquatic life. Culverts less than 48 inches in diameter should be buried to a depth of 20% or greater of the culvert's diameter.

NWP #13 – Bank Stabilization

This permit authorizes the reshaping of channel banks or bank stabilization activities that are necessary for erosion prevention. The placement of material is prohibited in any special aquatic site in a manner that may impede surface water flow into or out of a wetland area, or in a manner that will be eroded during normal or high flows. The activity must be part of a single and complete project and cannot exceed 1 cubic yard per running foot placed below the high-water mark line. If stabilization activities exceed 500 linear feet, then a PCN is required for both the USACE and DWQ. DWQ must also be notified should fill be placed within the streambed.

NWP #27 – Stream and Wetland Restoration Activities

This permit authorizes stream enhancement, stream restoration, and channel relocation for restoration purposes that provide gains in aquatic functions. Stream channelization and the conversion of streams to other aquatic uses such as impoundments or waterfowl habitat are not authorized. A PCN to the USACE is required for any restoration activities occurring on private or public lands. DWQ requires a PCN if impacts are proposed for greater than 500 feet of stream bank or if in-stream structures are used.

Impacts proposed to the streams may need evaluation under the State Environmental Policy Act (SEPA). An Environmental Assessment (EA) is required under SEPA if greater than 500 linear feet of perennial stream is disturbed and stream restoration or enhancement is not performed. Channel disturbances are defined as activities that remove or degrade stream uses such as channelization, culvert placement, riprap, and other hard structures.

A list of some other conditions that should be followed under regulations provided by the USACE and DWQ are as follows:

- Soil erosion and sediment controls must be used and maintained in effective operating conditions during construction, and all exposed soil and fills should be stabilized at the earliest possible date.
- No activity is authorized under any NWP that is likely to jeopardize the existence of a threatened or endangered species, or which will destroy or adversely modify the habitat of such species.
- No activity is authorized that may affect historic properties listed or eligible for listing in

the National Register of Historic Places.

- More than one NWP used for a single and complete project is prohibited.
- Impacts to waters of the US should be avoided and minimized to the greatest extent practicable.
- Mitigation in all its forms will be required to the extent necessary to ensure that the adverse effects to the aquatic environment are minimal.
- Hardening techniques should be avoided and minimized to the greatest practicable extent.

7.2 INDIVIDUAL PERMITS

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

7.3 FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Streams with a drainage area greater than one (1) square mile are typically modelled and mapped by FEMA for flood insurance purposes. The 100-year floodway and floodplain have been mapped for the entire reach of Booker Creek within the LBC subwatershed study area. Any proposed projects that will include grading within a FEMA defined floodway will require a Conditional Letter of Map Revision (CLOMR) submitted to FEMA for pre-approval purposes and a Letter of Map Revision (LOMR) upon completion of construction. Table 7-1 identifies projects where FEMA permitting is expected.

7.4 EROSION AND SEDIMENTATION CONTROL

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

Table 7-1: Permitting Matrix for Proposed Projects

	FEMA	NCDEQ /NPDES	404/401 (NWP)	404/401 (IP)	NCDOT
OVERALL BOOKER CREEK WATERSHED					
New Parkside Drive Storage Area		X	X		
Martin Luther King, Jr. Boulevard Storage Area	X	X	X		
Piney Mountain Road Storage Area	X	X	X		
LBC NORTH					
Red Bud Storage Area		X	X		
Honeysuckle Road		X	X		
Booker Creek Road – U/S		X	X		
Daley Road Storage Area	X	X	X		
Chesley Road Closed System		X			
Booker Creek Road/Lakeshore Lane System		X			
Old Oxford Road/ Booker Creek Road System		X			
LBC SOUTH					
Elliott Storage Area/Passive Green Space	X	X	X		
Willow Drive	X	X	X		
Ephesus Church Road System		X			X
LBC WEST					
Old Oxford Road System		X			
Markham Drive/Old Oxford Road Closed System		X			
Wood Circle/Velma Road System		X			
LBC EAST					
Dobbins Drive		X	X		X
Foxcroft Drive		X	X		
Summerfield Crossing System		X			

COST ESTIMATES

The cost estimates provided as part of the Lower Booker Creek Subwatershed Study were prepared to assist Town staff in making planning level decisions and prioritizing improvements. These cost estimates are not final design cost estimates. The preliminary project cost estimates in Table 8-1 were developed using recent bid tabulations from other communities and NCDOT projects within North Carolina. They include easement acquisitions, surveying, engineering, legal, and administrative costs. A detailed breakdown of the costs for the projects listed below in Table 8-1 is included in Appendix G. Projects are not listed based on priority. See Section 9 for a prioritization list. The cost estimates are approximate and are subject to change due to local costs, materials, delivery, construction, and other factors.

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

Table 8-1: Preliminary Project Cost Estimates

PROJECTS	PRELIMINARY PROJECT COST
Overall Booker Creek Watershed	
New Parkside Drive Storage Area	$2,786,000
Martin Luther King, Jr. Boulevard Storage Area	$3,789,000
Piney Mountain Road Storage Area	$1,906,000
LBC North	
Red Bud Storage Area	$914,000
Honeysuckle Road	$336,000
Booker Creek Road – U/S	$1,285,000
Daley Road Storage Area	$3,140,000
Chesley Road Closed System	$146,000
Booker Creek Road/Lakeshore Lane System	$263,000
Old Oxford Road/ Booker Creek Road System	$634,000
LBC South	
Elliott Storage Area/Passive Green Space	$1,140,000
Willow Drive	$4,010,000
Ephesus Church Road System	$1,045,000
LBC West	
Old Oxford Road System	$295,000
Markham Drive/Old Oxford Road Closed System	$451,000
Wood Circle/Velma Road System	$170,000
LBC East	
Dobbins Drive	$200,000
Foxcroft Drive	$660,000
Summerfield Crossing System	$97,000

Stream Stabilization Cost Estimates
To estimate the cost of stream restoration, a low and high cost per linear foot of construction were derived from local bid tab sources and best professional judgement. The strategy for determining the cost range per linear foot, and the low, medium, and high price points begins by noting the NCDEQ Division of Mitigation Services' fees for stream mitigation in highly developed or urban watersheds, which is currently $394 per foot (April 2018).

Many factors influence stream restoration costs in developed or urbanized areas. Those that tend to increase costs include the presence of utilities near the channel; presence of infrastructure such as stormwater outfalls, roads and buildings; constrained work areas that make excavation/building material movement logistics difficult; higher land costs; and short restored reach lengths which can reduce the economy of scale for construction. A convergence of multiple factors such as these can add hundreds of dollars to the per-foot construction cost.

For the purposes of this cost estimate, $400/linear foot is taken as a conservative low construction cost estimate, $550/linear foot is taken as a medium construction cost estimate, and $700/linear foot is assumed as a high construction cost estimate. Design, easement acquisition, surveying, legal, and administrative costs can add up to 30% to the implementation process increasing the total project costs as follows:

Low cost estimate: $520/LF

Medium cost estimate: $715/LF

High cost estimate: $910/LF

Using these estimates of design plus construction costs for stream stabilization or restoration, the costs of the identified stream restoration projects are estimated in Table 8-2.

In addition, a cost estimate range per linear foot for regenerative stormwater conveyances in urban settings, based on professional experience, is $600 to $900 per linear foot. The midpoint of this range is $750/LF. Estimated RSC project costs using this medium cost estimate are included on reaches where an RSC is identified as a potential alternative to stream restoration in Table 8-2.

Table 8-2: Summary of Stream Project Cost Estimates

Reach Name	Approx. Project Length (LF)	Restoration Costs Based on Low, Medium and High Cost/LF Estimates			RSC Costs Based on Medium Cost/LF Estimate
		Low $520/LF	Med $715/LF	High $910/LF	Med $750/LF
Sierra 3	400	$208,000	$286,000	$364,000	
Sedgefield 2	200	$104,000	$143,000	$182,000	
Booker 1	600	$312,000	$429,000	$546,000	
Booker 2	70	$36,400	$50,050	$63,700	
Foxwood 3	408	$212,160	$291,720	$371,280	$306,000
Dobbins 1	601	$312,520	$429,715	$546,910	$450,750
Dobbins 3	394	$204,880	$281,710	$358,540	
Dobbins 5	790	$410,800	$564,850	$718,900	
Oxford 2	540	$280,800	$386,100	$491,400	
Velma 2	483	$251,160	$345,345	$439,530	$362,250
TOTALS	4,246	$2,332,720	$3,207,490	$4,082,260	$1,119,000

Based on Table 8-2, the cost of constructing the identified stream restoration projects ranges from approximately $2.3 million dollars to $4.1 million dollars. The costs associated with RSC implementation fall in between the medium and high stream restoration costs.

__Outfall Retrofit Cost Estimates__

To estimate the cost of outfall retrofit opportunities a range of cost sources was considered depending on the proposed practice type. For constructed wetlands and bioretention, King and Hagen (2011) was used as the primary source. In this report, costs are determined based on acres of impervious cover treated as the unit cost factor. Costs include design, permitting, and construction. Bioretention costs were separated into two categories, low and high. The low-cost category was for installations in a suburban setting (less constraints and lower unit cost), and the higher cost range was for urban retrofits (more constraints and higher unit costs). The lower bioretention cost factor ($50,000) was used for all the identified practices except the LBC 0298 site, where the more expensive cost factor ($186,750) was employed, but then discounted ($118,500) to reflect targeted treatment for only a portion of the total drainage area due to lack of available treatment area. For RSC opportunities, a linear foot unit cost was employed based on recent design and construction experience in the mid-Atlantic and North Carolina. The lower end ($700/LF) of typical ranges of $600-$900 per linear foot was selected for the two (2) proposed RSC sites as they are fairly easy to access and have few site constraints other than tree loss. Land and/or easement acquisition costs are not included in the outfall retrofit cost estimates.

Table 8-3: Summary of Outfall Retrofit Project Cost Estimates

Outfall ID	Practice Area (acres)	Drainage Area (acres)	Impervious Area (acres)	Practice Type	Length (ft)	Total Cost	Unit Cost $/IA
LBC0170	0.29	32.23	17.3	Wetland		$ 1,141,800	$ 66,000
LBC0280	0.09		2.3	Bioretention			
LBC0298	0.09	21.24	14.34	Bioretention		$ 169,929	$ 118,500
LBC0389	0.05	0.34	0.19	RSC	100.0	$ 70,000	$ 700
LBC0411	0.13	3.92	1.09	RSC	110.0	$ 77,000	$ 700
LBC0456	0.21	6.19	3.04	Wetland		$ 200,640	$ 66,000
LBC0597	0.06	3.75	1.28	Bioretention		$ 64,000	$ 50,000
LBC0607	0.13			Bioretention			
LBC0647	0.03	2.29	1.26	Bioretention		$ 3,000	$ 50,000
LBC0096	0.16	10.26	4.31	Wetland		$ 284,460	$ 66,000
					TOTAL	$ 2,396,749	
LBC0298 assumed to only be providing partial treatment to full drainage area							

PRIORITIZATION AND RECOMMENDATIONS

After completing all the assessments and modeling described throughout the report, WK Dickson developed conceptual solutions for a wide variety of capital projects to fulfill the LBC Subwatershed Study's goals of addressing stormwater quantity; addressing stormwater quality; and protecting and restoring natural stream corridors.

The recommended solutions begin with projects that reduce flooding, which was identified as priority for residents who provided input via the project survey, website, and public information meetings. These flood reduction projects were categorized as either flood storage/primary system projects or secondary system projects. Success criteria used to measure the proposed flood reduction projects included:

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

The two (2) lists of flood reduction projects were then prioritized separately. The prioritization factors used were:

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

In some instances, project prioritization will be impacted by the required sequencing of projects to provide the highest possible flood reduction benefits and to reduce or negate any downstream impacts from the proposed projects. Table 9-1 shows the proposed prioritization of the Flood Storage/Primary System Projects. The Town should re-visit the prioritization lists annually to determine if the priorities should change.

Table 9-1: Flood Reduction Prioritization – Flood Storage/Primary System Projects

Priority	Project
1	Elliott Storage
2	Red Bud Storage
3	Piney Mountain Road
4	Booker Creek Road U/S
5	Honeysuckle Road
6	Dobbins
7	Willow Drive
8	New Parkside Drive
9	Daley Storage
10	Martin Luther King Jr. Storage
11	Foxcroft Drive

As noted in Section 4, the Elliott Storage project can have the largest impact on the Eastgate shopping area by lowering the tailwater on the Eastgate culvert and allowing it to convey water more efficiently. Projects 2 through 4 are all located in Lower Booker North. The Honeysuckle Road project initially ranked higher than the Booker Creek Road U/S project; however, the Booker Creek Road project should be constructed first since it is downstream of Honeysuckle Road. The Piney Mountain Road Storage Area is one of the most cost-effective detention possibilities located outside of the LBC subwatershed, and the proposed project would have the added benefit of improving the level of service at Piney Mountain Road. Projects 7-10 are flood storage projects requiring significant amounts of excavation; therefore, the costs are higher resulting in lower rankings for those projects.

Table 9-2 below lists the Secondary Systems prioritization. Projects 7 and 8 are dependent on other developments that will impact their implementation.

Table 9-2: Flood Reduction Prioritization – Secondary System Projects

Priority	Project
1	Old Oxford Road/Booker Creek Road System
2	Markham Drive/Old Oxford Road System
3	Chesley Lane System
4	Booker Creek Road/Lakeshore Lane System
5	Old Oxford Road System
6	Wood Circle/Velma Road System
7	Ephesus Church Road System
8	Summerfield Crossing System

Stream stabilization projects, neighborhood retrofits, and outfall retrofits are not separately prioritized. Some of these project types will be reflected as prioritization factors represented by "water quality – SCM" and "open channel – erosion control" as shown on Page 9-1.

Neighborhood retrofits and stream stabilization projects on private property will be heavily dependent on community acceptance and willingness to participate.

Outfall retrofit priorities will likely change with project opportunities such as grant funding or availability of property.

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