WK DICKSON
community infrastructure consultants

TOWN OF CHAPEL HILL

Town of Chapel Hill
Eastwood Lake Subwatershed Study

Volume I : Report



June 2020

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Eastwood Lake Subwatershed Study Volume I: Report

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LIST OF ABBREVIATIONS

CCTV	Closed-Circuit Television
CLOMR	Conditional Letter of Map Revision
CMP	Corrugated Metal Pipe
DCIA	Directly Connected Impervious Area
DEMLR	Division of Energy, Mineral, and Land Resources
DEQ	Department of Environmental Quality
DIP	Ductile Iron Pipe
D/S	Downstream
DWR	Division of Water Resources
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
RCN	Runoff Curve Number
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 Eastwood Lake 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 Eastwood Lake subwatershed is approximately 700 acres (~1.1 square miles) and is located in the north central portion of Chapel Hill. The subwatershed is the middle part of the overall Booker Creek watershed (~6.3 square miles), which includes the Booker Headwaters, Crow Branch, Lower Booker Creek, and Cedar Fork subwatersheds in addition to Eastwood Lake. 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 Lower Booker Creek is highly commercialized including the Blue Hill District (formerly Ephesus Fordham).

The Eastwood Lake Subwatershed Study includes a process to assess how stormwater is currently managed within the subwatershed, to 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 500 drainage structures and five (5) miles of pipes within the Eastwood Lake subwatershed. Additionally, the WK Dickson team evaluated 34,000 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 some instances the existing infrastructure does not provide the desired level of service. Within the Eastwood Lake 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 Figure 3-1) based on the current land use and hydrologic parameters within the watershed. 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 the Booker Creek watershed. 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 about proper pet waste disposal, fertilizer applications, and riparian buffer management will be critical for the success of any water quality program. The Eastwood Lake 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 Eastwood Lake 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 three (3) geographic focus areas. The Eastwood Lake subwatershed is divided into East and West focus areas and the third area is for the portion of the Booker Creek watershed outside of the Eastwood Lake subwatershed. While the focus of this study is to improve infrastructure within the Eastwood Lake subwatershed, over 75% of the drainage area contributing to the overall watershed is outside of the Eastwood Lake 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 impacts peak flows in the downstream in the Eastwood Lake subwatershed.

Overall Booker Creek Watershed

The New Parkside Drive, Martin Luther King Jr. Boulevard, and Piney Mountain Road flood storage projects were recommended as part of the Lower Booker Creek Subwatershed Study dated September 2018. Summaries of those (3) projects are also included in this Study because they will impact flows and water surface elevations in the Eastwood Lake subwatershed.

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 would 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 Eastwood Lake subwatershed. The Town could also consider providing connectivity between the proposed project and Homestead Park along with 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 7% at North Lakeshore Drive and would result in greater downstream flow reductions if constructed in combination with the other proposed flood storage areas.

Piney Mountain Road
The proposed 5.5-acre project is located on Town-owned property upstream of Piney Mountain Road approximately 0.5 miles east of Martin Luther King Jr. Boulevard. It is located within the Eastwood Lake subwatershed. Significant excavation would be required to provide temporary storage upstream of Piney Mountain Road during storm events. Passive recreational amenities could be added to the project if desired to enhance pedestrian connectivity in the community. The drainage area for 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 providing significant peak reduction at the site.

The combined impact of the three (3) storage areas listed above results in an 11% reduction in the 25-year peak flow immediately downstream of the Eastwood Lake dam and a corresponding 0.4-foot reduction in the 25-year peak water surface elevation at that location.

Eastwood Lake West

The Eastwood Lake West portion of the study consists of the area immediately downstream of the confluence between Crow Branch and Booker Creek (Lake Ellen outlet) to just downstream of Piney Mountain Road. The infrastructure in the area consists predominantly of open systems with culvert crossings that drain to Booker Creek and eventually to Eastwood Lake. A variety of projects are proposed in this area including floodplain culverts, secondary system improvements, stream stabilization, and neighborhood retrofits.

Piney Mountain Road
The existing bridge at Piney Mountain Road is in good condition but it is overtopped during the 10-year event. Since the bridge has no known structural issues, it is recommended that it be left in place and a floodplain culvert be installed to increase the level of service. Installing a 7′ x 5′ reinforced concrete box floodplain culvert would provide a 25-year level of service based on future built-out conditions assuming New Parkside Drive, Martin Luther King Jr. Boulevard, and Piney Mountain Road storage areas are constructed as well.

Secondary Drainage Improvements
In addition to the primary system improvement at Piney Mountain Road, secondary drainage system improvements are recommended downstream of Woodshire Lane behind Huntington Road as well as improvement of a secondary culvert under Piney Mountain Road. Proposed improvements include replacing existing culverts with larger capacity pipes and spot streambank stabilization. Utility conflicts will need to be resolved during design and implementation of these projects particularly for the culvert project under Piney Mountain Road.

Water Quality Projects
Multiple opportunities exist in the subwatershed to improve the water quality, which will aid the Town in complying with the Jordan Lake Rules. Stream stabilization projects are recommended downstream of Lake Ellen Drive (Project 3 – Lake Ellen 1) and adjacent to Piney Mountain Road and Huntington Drive (Project 1 – Woodshire 2 and Project 2 – Woodshire 3).

Portions of the Eastwood Road – Johnson Farm, Coker Woods West, and Forest Lake 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.

Eastwood Lake East

The Eastwood Lake East portion of the study consists of the area between Piney Mountain Road and the outlet of Eastwood Lake which includes portions of the Coker Hills, Coker Woods West, and Lake Forest subdivisions. Most of the drainage infrastructure in this portion of the subwatershed consists of open channels with culvert crossings that drain directly to Eastwood Lake. The open channels typically enter the lake around the perimeter downstream of the Eastwood Lake forebay. Some closed infrastructure does exist in this portion of the subwatershed, typically for street drainage. There are no proposed primary system improvements in this portion of the subwatershed.

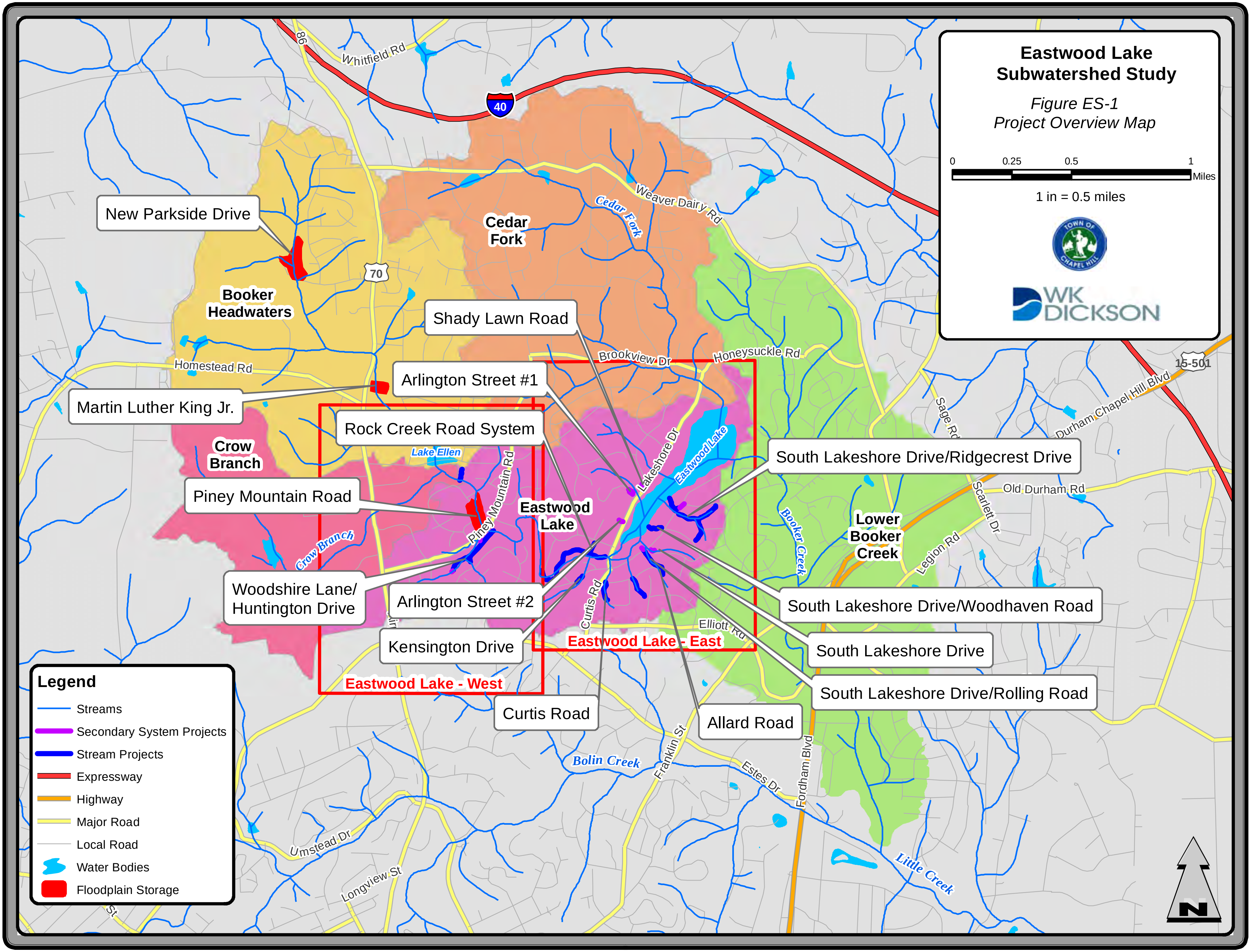
Secondary Drainage Improvements
Secondary drainage improvements are recommended at the following locations:

- Shady Lawn Road near its intersection with North Lakeshore Drive;
- Arlington Street near its intersection with North Lakeshore Drive;
- Ridgecrest Drive at intersection with South Lakeshore Drive;
- Rolling Road just upstream of South Lakeshore Drive; and
- South Lakeshore Drive between Rolling Road and Curtis Road.

Each of the recommended projects was based on feedback from residents and Town staff that flooding has repetitively occurred in these locations. 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
Stream stabilization projects are recommended for the channel sections along Kensington Drive, adjacent to Rock Creek Road, between Curtis Road and Lyons Road, adjacent to Allard Road, downstream of Woodhaven Road, adjacent to Rolling Road, and between Ridgecrest and Woodhaven Road. The Ridgecrest Road, Rolling Road, and Allard Road stabilization projects should be combined with the proposed secondary system drainage improvements listed above.

Portions of the Coker Woods West, Lake Forest, and Coker Hills 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 HOAs for high ranking neighborhoods to determine if interest exists for pilot green infrastructure retrofits.



Eastwood Lake Subwatershed Study
Figure ES-1
Project Overview Map
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0.25
0.5
1
Miles
1 in = 0.5 miles
WK DICKSON
Legend
Streams
Secondary System Projects
Stream Projects
Expressway
Highway
Major Road
Local Road
Water Bodies
Floodplain Storage
New Parkside Drive
Shady Lawn Road
Arlington Street #1
Martin Luther King Jr.
Rock Creek Road System
Piney Mountain Road
Woodshire Lane/ Huntington Drive
Arlington Street #2
Kensington Drive
Curtis Road
Allard Road
South Lakeshore Drive/Ridgecrest Drive
South Lakeshore Drive/Woodhaven Road
South Lakeshore Drive
South Lakeshore Drive/Rolling Road
Eastwood Lake - West
Eastwood Lake - East
Booker Headwaters
Cedar Fork
Crow Branch
Eastwood Lake
Lower Booker Creek
Lake Ellen
Crow Branch
Cedar Fork
Booker Creek
Bolin Creek
Little Creek
Whitfield Rd
Weaver Dairy Rd
Homestead Rd
Brookview Dr
Honeysuckle Rd
Durham Chapel Hill Blvd
Old Durham Rd
Sage Rd
Scarlett Dr
Legion Rd
Piney Mountain Rd
Lakeshore Dr
Curtis Rd
Elliott Rd
Franklin St
Estes Dr
Fordham Blvd
Umstead Dr
Longview St
40
70
86
15-501

Prioritization and Recommendations

To appropriately allocate Town resources, the flood reduction 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

Costs for the proposed floodplain storage areas identified in the Lower Booker Creek Subwatershed Study are included in the capital project list in that Study regardless of where they are located in the overall Booker Creek watershed. Table ES-1 shows the proposed prioritizations for the Primary Flood Reduction Improvements. The total cost for all the recommended primary and secondary system capital improvements in the Eastwood Lake subwatershed is approximately $1,561,900.

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. 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 Reduction Project Prioritization – Primary Systems

Prioritization	Project	Cost
1	Piney Mountain Road Culvert	$456,800
	Total	$456,800

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

Prioritization	Project	Cost
1	South Lakeshore Drive/Ridgecrest Drive System	$125,200
2	South Lakeshore Drive/Rolling Road System	$216,800
3	Arlington Street #1 System	$104,400
4	Woodshire Lane/Huntington Road	$372,300
5	Shady Lawn Road System	$153,300
6	Arlington Street #2 System	$133,100
	Total	$1,105,100

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 reduction projects should be scheduled with those projects. The anticipated cost range for stream stabilization projects is $3.5 million to $6.2 million depending on the required measures and design specifics. The anticipated total cost for outfall retrofits is $750,000 based on literature values for similar projects. The stream stabilization and water quality projects will add approximately $5.7 million to the total costs ($1,561,900) 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 be adjusted with project opportunities such as grant funding or availability of property.

INTRODUCTION

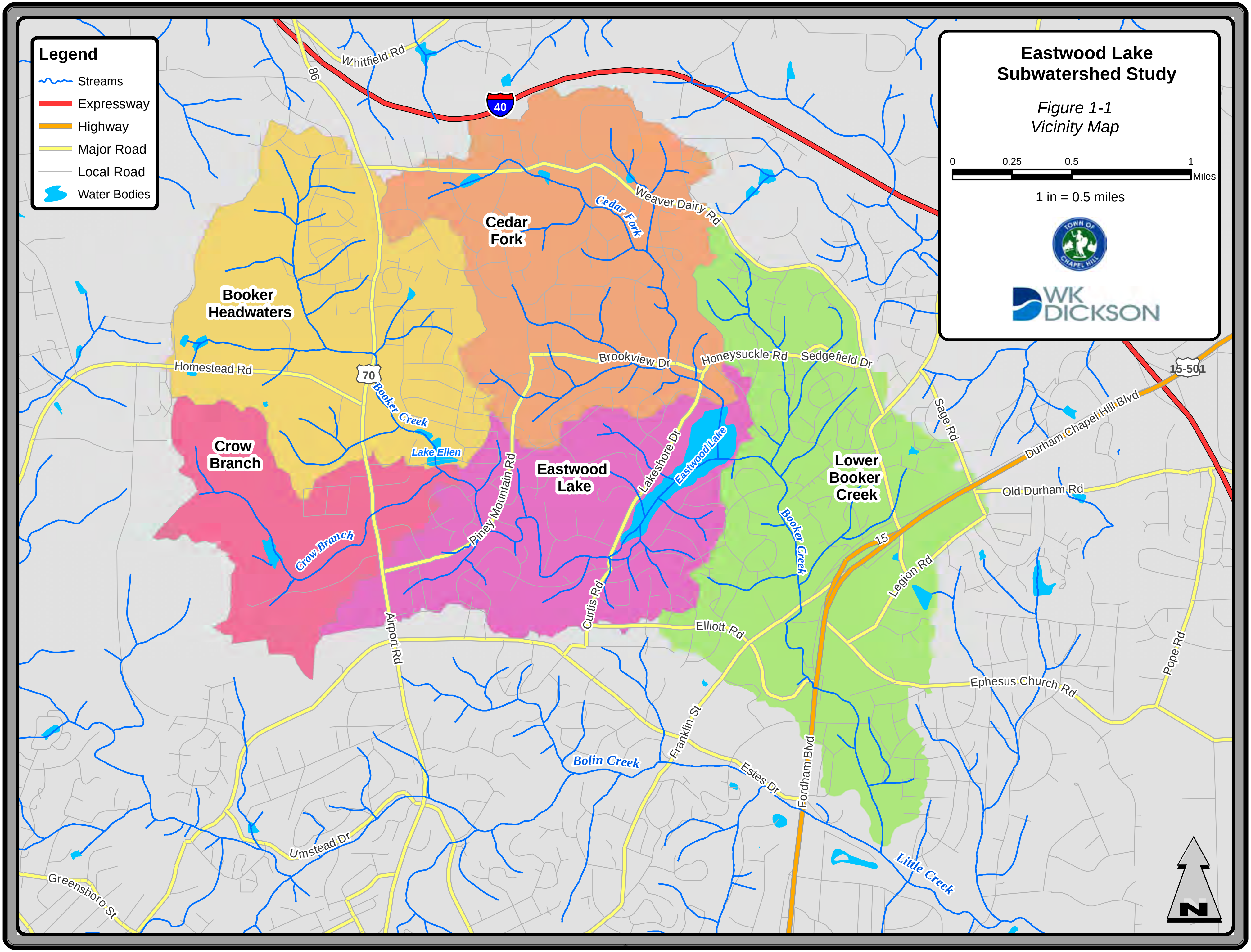
1.1 PROJECT DESCRIPTION

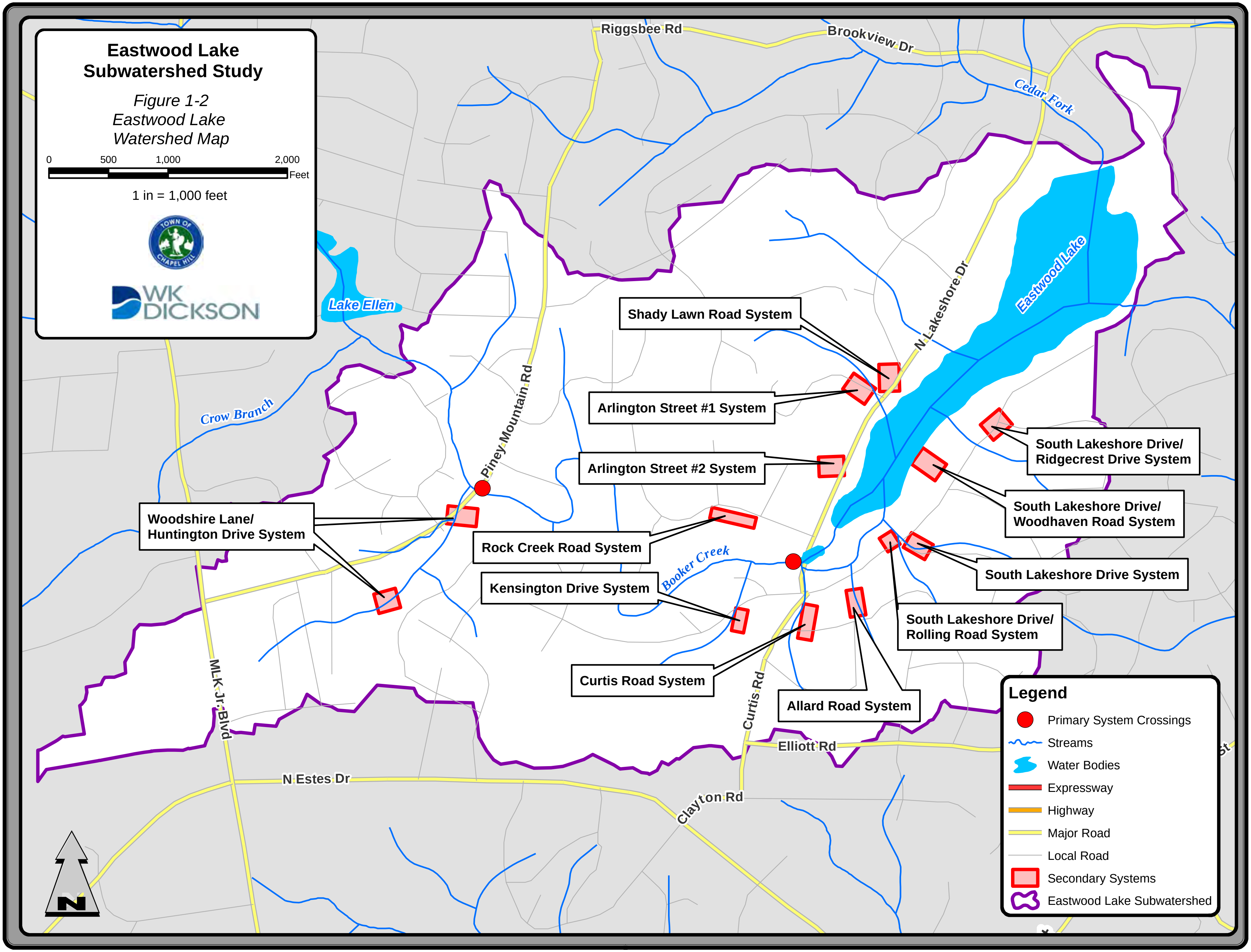
The Town of Chapel Hill retained WK Dickson to complete a Subwatershed Study and Plan for the Eastwood Lake subwatershed. As shown in Figure 1-1, the Eastwood Lake subwatershed is located in the north central portion of Chapel Hill and generally drains west to east through Eastwood Lake. The 1.1 square mile Eastwood Lake subwatershed is located within the 6.3 square mile Booker Creek watershed, upstream of the Lower Booker Creek subwatershed. As noted in the Executive Summary, the continued development of Subwatershed Studies is a strategic initiative as part of the Town's Stormwater Program Master Plan Goals (2) addressing stormwater quantity, (3) addressing stormwater quality, and (4) protecting and restoring natural stream corridors. To assist in achieving these goals, WK Dickson completed a stormwater inventory of both infrastructure and natural features within the Eastwood Lake subwatershed.

The Subwatershed Study includes an evaluation of the segment of Booker Creek from the Eastwood Lake dam at the downstream end to its confluence with Crow Branch at the upstream end. Additionally, twelve (12) conveyance systems that drain to the main creek were evaluated. For the purposes of this report, Booker Creek will be noted as the primary system and the conveyance systems will be noted as secondary systems. A project area map showing the Eastwood Lake 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
    - North Lakeshore Drive Bridge
    - Piney Mountain Road Bridge

- Secondary Systems
    - Shady Lawn Road System
    - Arlington Street #1 System
    - Arlington Street #2 System
    - Rock Creek Road Closed System
    - South Lakeshore Drive/Ridgecrest Drive System
    - South Lakeshore Drive/Woodhaven Road System
    - South Lakeshore Drive/Rolling Road System
    - South Lakeshore Drive System
    - Allard Road System
    - Curtis Road System
    - Woodshire Lane/Huntington Drive System
    - Kensington Drive System


Legend
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
Eastwood Lake
Subwatershed Study
Figure 1-1
Vicinity Map
0
0.25
0.5
1
Miles
1 in = 0.5 miles
WK DICKSON
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
Sage Rd
15-501
Durham Chapel Hill Blvd
Old Durham Rd
Piney Mountain Rd
Lakeshore Dr
Eastwood Lake
Crow Branch
Curtis Rd
Airport Rd
Elliott Rd
15
Legion Rd
Booker Creek
Ephesus Church Rd
Pope Rd
Bolin Creek
Franklin St
Estes Dr
Fordham Blvd
Umstead Dr
Little Creek
Greensboro St
N



Eastwood Lake
Subwatershed Study
Figure 1-2
Eastwood Lake
Watershed Map
0
500
1,000
2,000
Feet
1 in = 1,000 feet
WK DICKSON
Riggsbee Rd
Brookview Dr
Cedar Fork
Lake Ellen
Crow Branch
Eastwood Lake
N Lakeshore Dr
Piney Mountain Rd
Booker Creek
MLK Jr Blvd
Curtis Rd
Elliott Rd
N Estes Dr
Clayton Rd
Shady Lawn Road System
Arlington Street #1 System
Arlington Street #2 System
South Lakeshore Drive/
Ridgecrest Drive System
South Lakeshore Drive/
Woodhaven Road System
Woodshire Lane/
Huntington Drive System
Rock Creek Road System
Kensington Drive System
South Lakeshore Drive System
South Lakeshore Drive/
Rolling Road System
Curtis Road System
Allard Road System
Legend
Primary System Crossings
Streams
Water Bodies
Expressway
Highway
Major Road
Local Road
Secondary Systems
Eastwood Lake Subwatershed
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 conveyance 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 Conveyance Systems Local Roadway Crossings	10	• Woodshire Lane/Huntington Drive • Shady Lawn Road • Arlington Street #1 and #2 • Rock Creek Road • Kensington Drive • Curtis Road • Allard Road • South Lakeshore Drive/Rolling Road • South Lakeshore Drive • South Lakeshore Drive/Woodhaven Road • South Lakeshore Drive/Ridgecrest Drive
Minor Thoroughfare (Collector and Arterial Roadway) Crossings	25	• None
Regulatory Floodway	100	• North Lakeshore Drive (Booker Creek) • Piney Mountain Road (Booker Creek)

EXISTING WATERSHED CONDITIONS

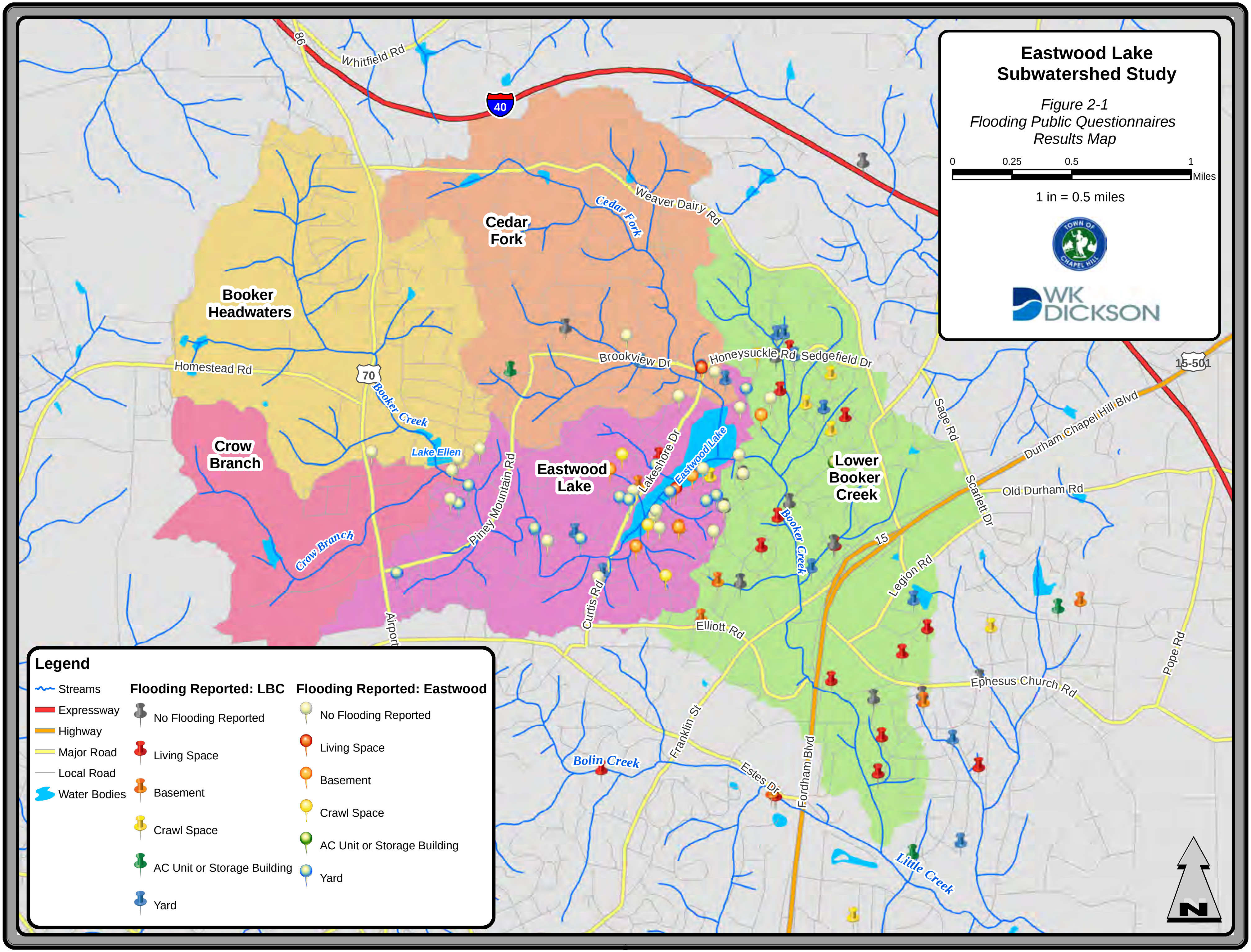
2.1 CITIZEN INPUT

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 May 2017, WK Dickson distributed questionnaires to property owners in the Eastwood Lake subwatershed requesting feedback on erosion and flooding.

Fifty-four (54) total responses were received for consideration. Thirty-three (33) of the fifty-four (54) respondents were located within the Eastwood Lake subwatershed. Half of the total respondents (27) indicated experiencing some type of flooding at least once a year. In addition to the responses received as part of the Eastwood Lake subwatershed, nine (9) completed questionnaires were received from residents within the Eastwood Lake subwatershed during the previously completed Lower Booker Creek Subwatershed Study. Six (6) of those nine (9) responses indicated some level of property flooding. The questionnaire results were georeferenced using the address of the questionnaire respondent. Figures 2-1 and 2-2 show response locations from both the Lower Booker Creek Subwatershed Study and the Eastwood Lake Subwatershed Study. 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 Eastwood Lake public meeting was held on June 1, 2017 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 December 7, 2017 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.



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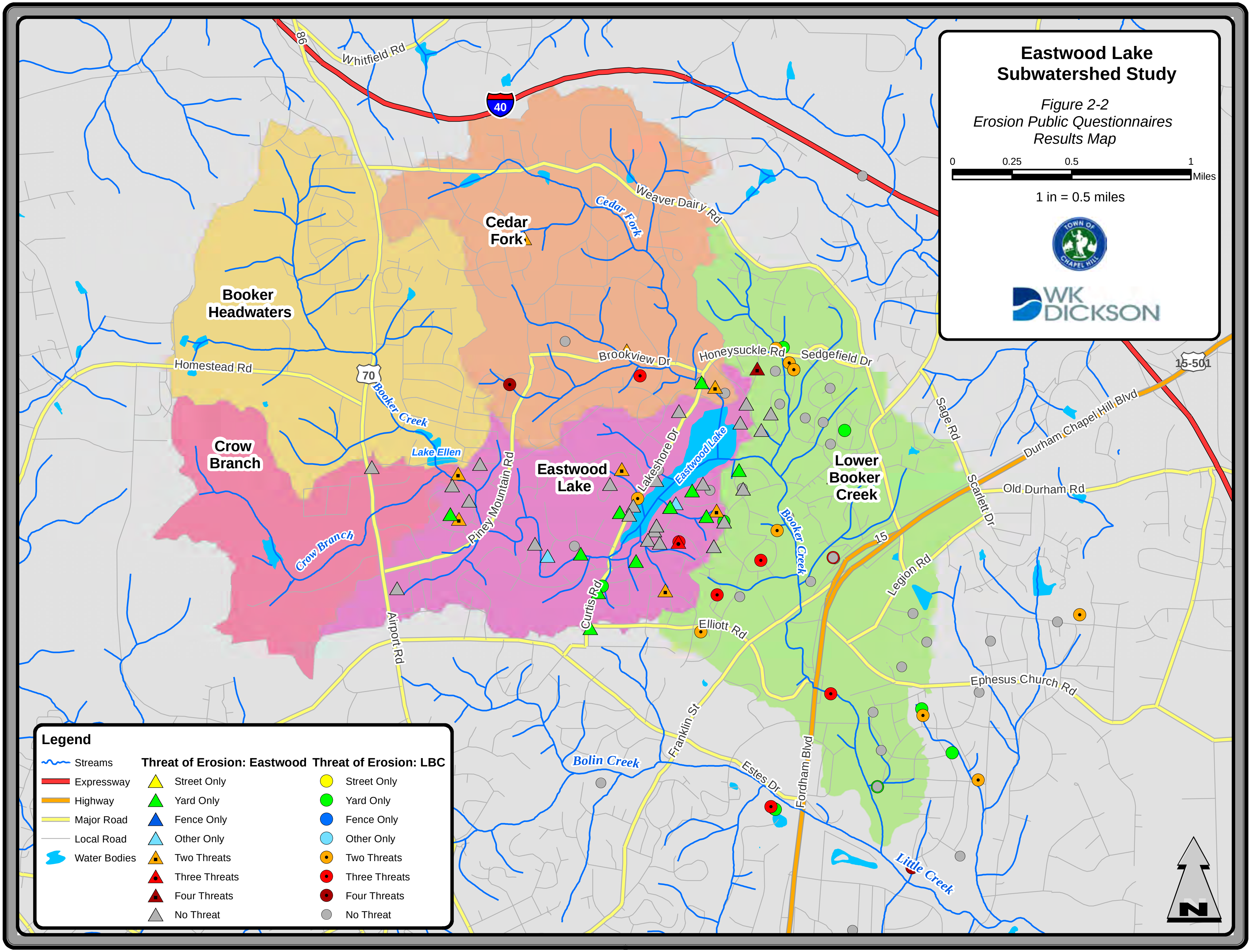
15
40
70
86
N


Eastwood Lake
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Results Map
0
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TOWN OF CHAPEL HILL
WK DICKSON
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
Piney Mountain Rd
Lakeshore Dr
Eastwood Lake
Crow Branch
Scarlett Dr
Old Durham Rd
15
Legion Rd
Curtis Rd
Airport Rd
Elliott Rd
Ephesus Church Rd
Franklin St
Bolin Creek
Estes Dr
Fordham Blvd
Little Creek
N
Legend
Streams
Expressway
Highway
Major Road
Local Road
Water Bodies
Threat of Erosion: Eastwood
Street Only
Yard Only
Fence Only
Other Only
Two Threats
Three Threats
Four Threats
No Threat
Threat of Erosion: LBC
Street Only
Yard Only
Fence Only
Other Only
Two Threats
Three Threats
Four Threats
No Threat

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 Eastwood Lake subwatershed is approximately 700 acres (1.1 square miles). As shown in Figure 1-2, the downstream boundary of the subwatershed is the outlet of the Eastwood Lake dam and the upstream boundary condition is just east of the confluence between Booker Creek and Crow Branch (south of the Lake Ellen outlet). Land in the Eastwood Lake 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 Eastwood Lake subwatershed, is primarily residential (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 Blue Hill District (formerly Ephesus-Fordham area) and Northern Area Task Force focus area. It should be noted that the existing land use for the Blue Hill District (formerly 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: Eastwood Lake Subwatershed Existing Land Use

Land Use Category	Area (acres)
Office/Institutional/Mixed Used	46
High Density Residential	34
Medium Density Residential	14
Low Density Residential	598
Parks/Open Space	6
Right-of-Way	7

Table 2-4: Eastwood Lake Subwatershed Future Land Use

Land Use Category	Area (acres)
Office/Institutional/Mixed Used	28
High Density Residential	34
Medium Density Residential	14
Low Density Residential	598
Right-of-Way	7
University	24

The soils within the Booker Creek watershed are predominately NRCS hydrologic groups B (52%) and D (27%); similarly, in the Eastwood Lake subwatershed 54% of the soils are NRCS hydrologic group B and 20% 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

Stormwater utility infrastructure throughout the subwatershed 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 NAD 1983 and vertical datum NAVD 1988. A total of 504 closed system structures and 26,904 linear feet of pipe was collected as part of the inventory. Tables 2-5 and 2-6 summarize the inventory collected in the Eastwood Lake subwatershed.

Table 2-5: Inventory Summary – Closed System Structures

Structure Type	Number Surveyed
Drop Inlet	34
Junction Box	32
Pipe End	180
Pond Structure	3
Slab Top Inlet	15
Catch Basin	213
Underground Pipe Junction	3
Difficult Access	24

Table 2-6: Inventory Summary – Pipes*

Size	Length (Linear Feet)
12″ Diameter	428
15″ Diameter	12,295
18″ Diameter	4,136
24″ Diameter	4,127
30″ Diameter	796
36″ Diameter	1,291
42″ Diameter	416
48″ Diameter	207
'Other' Diameter	2,571

*Lengths provided do not include 'mismatched' pipe ends (637 linear feet). Mismatched pipe ends are those where the measured upstream end of the pipe differs from the downstream end.

Data were obtained for those open channels required to complete connectivity for modeling purposes. Attributes such as shape, lining type, bed type, flow, bottom width, top width, and bank heights were collected for 102 open channel sections totaling 6.5 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 bank, bottom of bank, and channel centerline, were obtained at twenty-one (21) cross sections throughout the Eastwood Lake 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 Eastwood Lake subwatershed. However, to estimate floods in the Eastwood Lake subwatershed, 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 Eastwood Lake 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)
ADD-CB-BH	Confluence of Crow Branch and Booker Creek	21577	505	1,018	1,318	1,600	1,837
Piney Mountain Rd – Booker Ck	Piney Mountain Road	20223	566	1,022	1,373	1,661	1,899
ADD-EL-50	Upstream of Eastwood Lake	16524	603	1,059	1,419	1,714	1,950
N Lakeshore Dr – Booker Ck	North Lakeshore Drive	15024	615	1,070	1,431	1,728	1,964
Eastwood Lake	Downstream of Eastwood Lake	11352	668	1,641	2,217	2,614	2,850

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 Eastwood Lake 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 Eastwood Lake HEC-RAS model were determined based on values calculated in the models prepared for the Lower Booker Creek Subwatershed Study.

Hydraulic Performance

Two (2) roadway crossings were analyzed for flooding potential of the primary system. Descriptions of the existing primary system crossings analyzed are summarized in Table 3-2. Pictures 3-1 and 3-2 of this report provide visual images of the primary system bridge crossings.

Table 3-2: Existing Condition of Primary System Crossings

Location	Size/Material	Condition
North Lakeshore Drive	Bridge	Good
Piney Mountain Road	Bridge	Good

Picture 3-1: North Lakeshore Drive Bridge

Picture 3-2: Piney Mount Road bridge

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. The two (2) bridges in the Eastwood Lake subwatershed are not meeting the desired 100-year level of service. North Lakeshore Drive and Piney Mountain

Road are both operating at a 10-year level of service. Both crossings were reconstructed in 2001 following storm damage in late 2000.

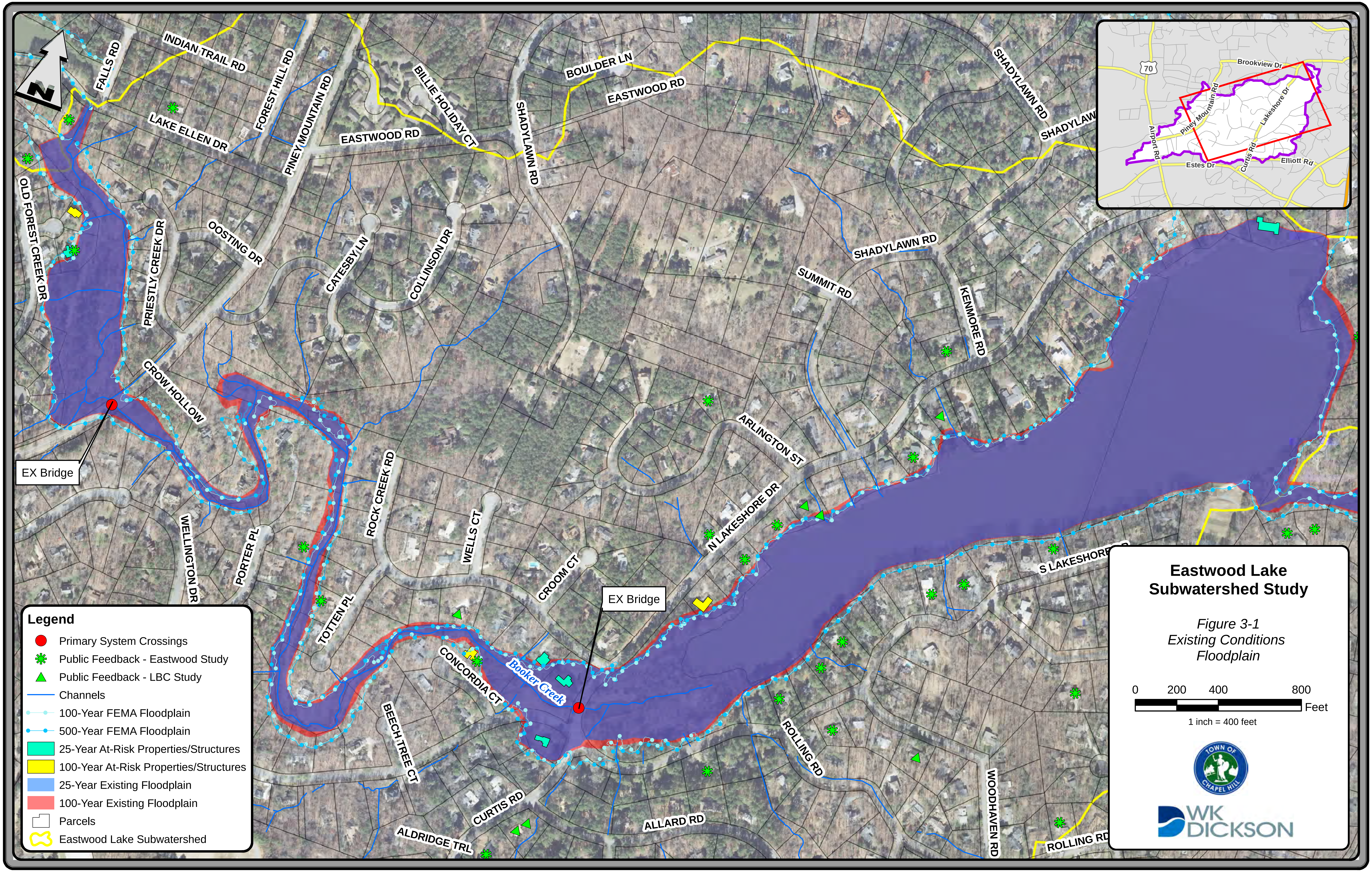
Table 3-3: Hydraulic Performance for Existing Conditions Roadway Flooding

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							
North Lakeshore Drive	301.63	100	298.73	301.06	**302.31**	**302.52**	**302.61**
Piney Mountain Road	385.66	100	378.56	383.64	**386.70**	**387.32**	**387.72**

*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 stream 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 Figure 3-1. The mapped floodplains are based on HEC-RAS 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 buildings 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, six (6) structures along Booker Creek were identified for being at risk of flooding in the 25-year storm event and an additional two (2) structures 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.


Eastwood Lake
Subwatershed Study
Figure 3-1
Existing Conditions
Floodplain
0 200 400 800
Feet
1 inch = 400 feet
WK DICKSON
Legend
Primary System Crossings
Public Feedback - Eastwood Study
Public Feedback - LBC Study
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
Eastwood Lake Subwatershed
EX Bridge
EX Bridge
Booker Creek
INDIAN TRAIL RD
FALLS RD
FOREST HILL RD
PINEY MOUNTAIN RD
EASTWOOD RD
BILLIE HOLIDAY CT
SHADYLAWN RD
BOULDER LN
LAKE ELLEN DR
OLD FOREST CREEK DR
PRIESTLY CREEK DR
OOSTING DR
CATESBY LN
COLLINSON DR
SHADYLAWN RD
SUMMIT RD
KENMORE RD
CROW HOLLOW
ARLINGTON ST
N LAKESHORE DR
ROCK CREEK RD
WELLS CT
CROOM CT
WELLINGTON DR
PORTER PL
TOTTEN PL
CONCORDIA CT
BEECH TREE CT
CURTIS RD
ALDRIDGE TRL
ALLARD RD
ROLLING RD
WOODHAVEN RD
S LAKESHORE DR
ROLLING RD
Brookview Dr
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Curtis Rd
Elliott Rd
70

3.2 SECONDARY SYSTEM HYDROLOGIC AND HYDRAULIC ANALYSES

While Booker Creek is the primary source of flooding within the watershed, undersized systems can also lead to building and roadway flooding. Based on the questionnaire responses, public meetings, and feedback from Town staff, eleven (11) secondary systems were identified for further evaluation. The secondary systems evaluated are:

- Shady Lawn Road System;
- Arlington Street #1 System;
- Arlington Street #2 System;
- Rock Creek Road Closed System;
- South Lakeshore Drive/Ridgecrest Drive System;
- South Lakeshore Drive/Woodhaven Road System;
- South Lakeshore Drive/Rolling Road System;
- South Lakeshore Drive System;
- Allard Road System;
- Curtis Road System; and
- Woodshire Lane/Huntington Drive System.

3.2.1 HYDROLOGY

Two (2) models were used in the hydrologic evaluation of the secondary systems: EPA Storm Water Management Model (SWMM) and Hydraflow Storm Sewers. For the larger more complex secondary systems (Shady Lawn Road, Arlington #1, Arlington #2, South Lakeshore Drive/Ridgecrest Drive, South Lakeshore Drive/Woodhaven Road, South Lakeshore Drive/Rolling Road, South Lakeshore Drive, Allard Road, Curtis Road, and Woodshire Lane/Huntington Drive), SWMM was selected as the hydrologic and hydraulic model. Smaller systems that were completely closed systems including Rock Creek Road were modeled using Rational flow calculations within Hydraflow Storm Sewers. 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

Shady Lawn Road System

The Shady Lawn Road system collects drainage from approximately 16 acres including a portion of the Lake Forest subdivision. The system consists of two (2) parallel systems that run along each side of Shady Lawn Road. The system along the eastern side of the road consists of 15″ and 18″ RCPs. The 18″ RCP outlets to a roadside ditch with a 1-foot high bank, a 2-foot bottom width, and a 2.5-foot top width. The eastern system (15″ RCP) crosses North Lakeshore Drive before discharging to a channel section between 2000 and 2004 North Lakeshore Drive that enters Eastwood Lake.

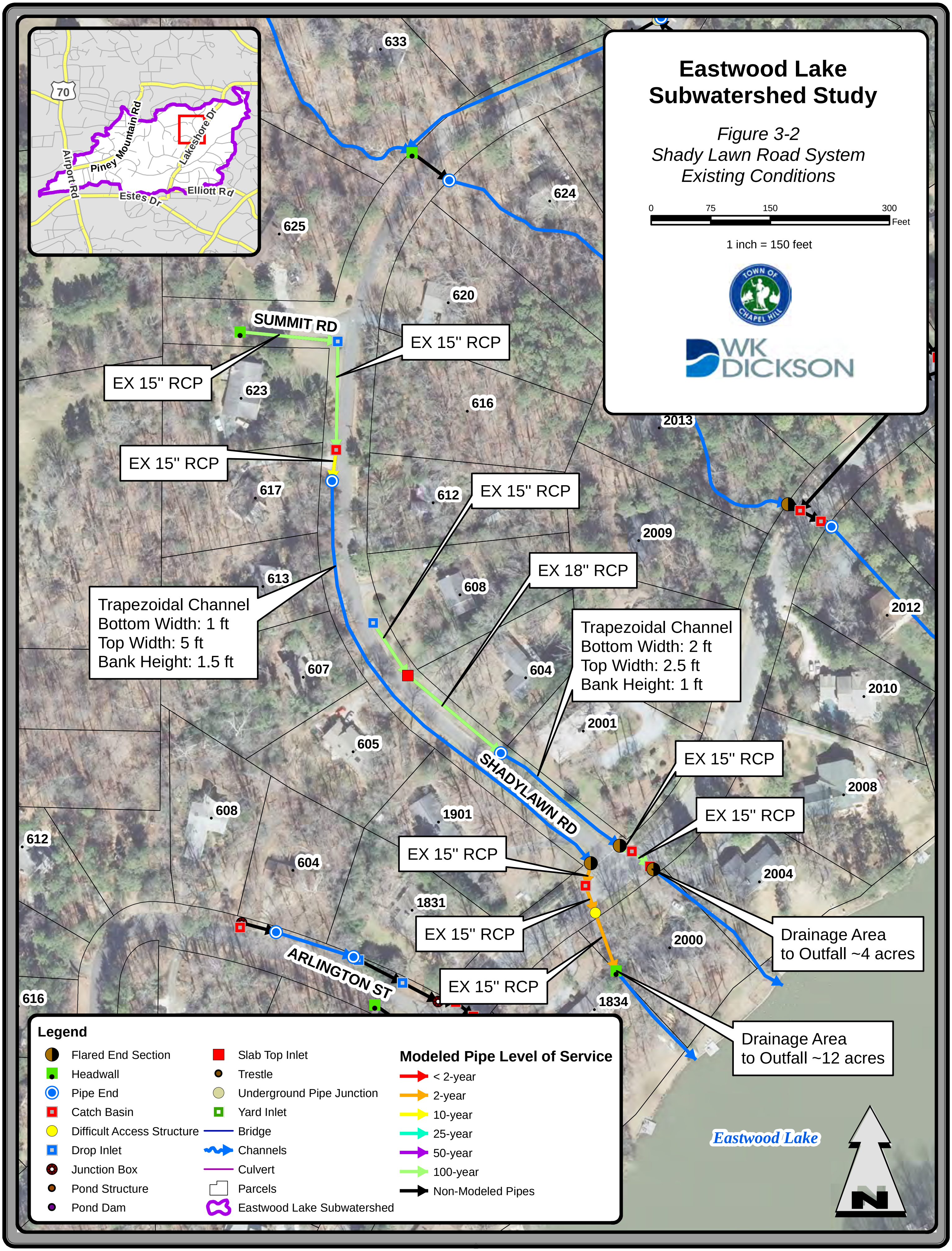
The conveyance system along the western side of the road starts further north along Summit Road prior to its intersection with Shady Lawn Road. The closed segment of the system is comprised of 15″ RCPs connected by a roadside ditch with a 1.5-foot high bank, a 1-foot bottom width, and a 5-foot top width. Similar to the western system, the eastern system crosses North Lakeshore Drive, discharges to a channel section and outlets to Eastwood Lake. There is one (1) report of flooding adjacent to the Shady Lawn Road system. The resident at 2008 North Lakeshore Drive has reported experiencing yard flooding approximately once a year.

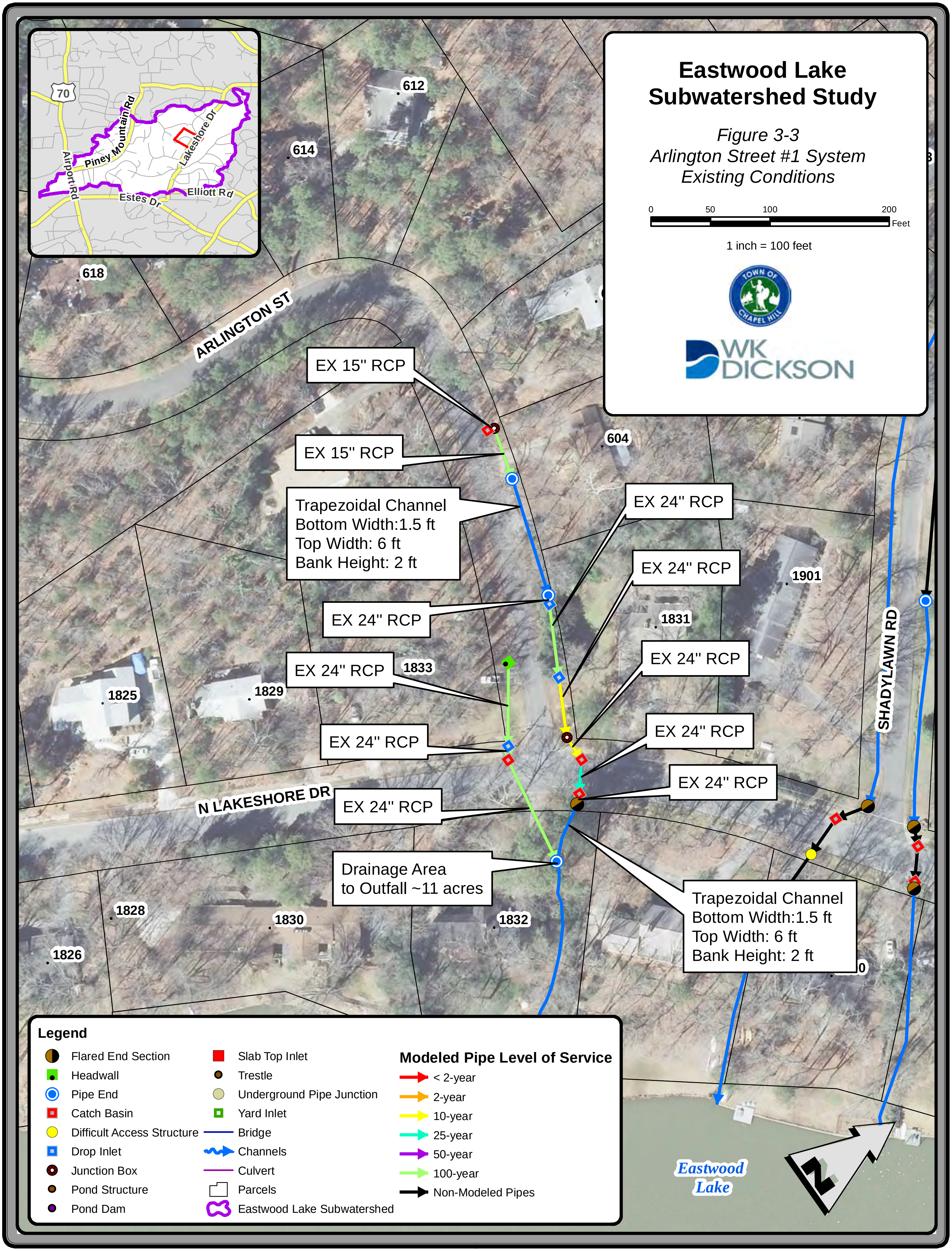
Figure 3-2 shows the level of service being provided by the existing closed system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are not connected to the Shady Lawn Road System. The model results show most of the existing system is operating above the desired 10-year level of service. The entire system along the eastern side of the road is meeting a 10-year level of service while the lower portion of the western system including the 15″ RCP crossing North Lakeshore Drive is operating at or 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.

Arlington Street #1 System

The Arlington Street #1 System collects drainage from 10.5 acres in the Pine Knob and Lake Forest subdivisions. It discharges to a channel section that outlets to Eastwood Lake. The conveyance system is comprised of 15″ and 24″ RCPs. Based on data collected during the inventory, the pipes are in good condition. The closed system (24″ RCP) crosses North Lakeshore Drive in two (2) locations.

Figure 3-3 shows the level of service being provided by the existing closed system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are not connected to the Arlington Street #1 System. The model results show that the existing system is operating above the desired 10-year level of service. There are three (3) reports of flooding adjacent to this system. The resident at 1832 North Lakeshore Drive has reported experiencing yard and basement flooding two to three times a year. The resident attributed this to the pipe becoming clogged with leaves and debris. Consequently, the property owner had a special grate installed to mitigate the flooding. The resident at 1831 North Lakeshore Drive reported significant yard flooding during storm events. A small channel conveys runoff behind the house to Arlington Street; however, when the runoff volume exceeds the channel capacity, the overflow inundates the front yard of the property. The resident at 612 Arlington Street has also reported yard, basement, and crawl space flooding two to three times a year. The property is located at the bottom of the hill with no infrastructure in place to capture the runoff.


Eastwood Lake Subwatershed Study
Figure 3-2
Shady Lawn Road System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Mountain Rd
Lakeshore Dr
Piney
Airport Rd
Estes Dr
Elliott Rd
SUMMIT RD
SHADYLAWN RD
ARLINGTON ST
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 18" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
Trapezoidal Channel
Bottom Width: 1 ft
Top Width: 5 ft
Bank Height: 1.5 ft
Trapezoidal Channel
Bottom Width: 2 ft
Top Width: 2.5 ft
Bank Height: 1 ft
Drainage Area
to Outfall ~4 acres
Drainage Area
to Outfall ~12 acres
633
624
625
620
623
616
617
612
613
608
607
604
605
608
612
604
616
1901
1831
1834
2013
2009
2012
2010
2001
2008
2004
2000
Eastwood Lake
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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N


Eastwood Lake
Subwatershed Study
Figure 3-3
Arlington Street #1 System
Existing Conditions
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
612
614
618
604
1901
1831
1833
1829
1825
1828
1830
1832
1826
ARLINGTON ST
N LAKESHORE DR
SHADYLAWN RD
EX 15" RCP
EX 15" RCP
Trapezoidal Channel
Bottom Width:1.5 ft
Top Width: 6 ft
Bank Height: 2 ft
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
EX 24" RCP
Drainage Area
to Outfall ~11 acres
Trapezoidal Channel
Bottom Width:1.5 ft
Top Width: 6 ft
Bank Height: 2 ft
Eastwood Lake
N
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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes

Arlington Street #2 System

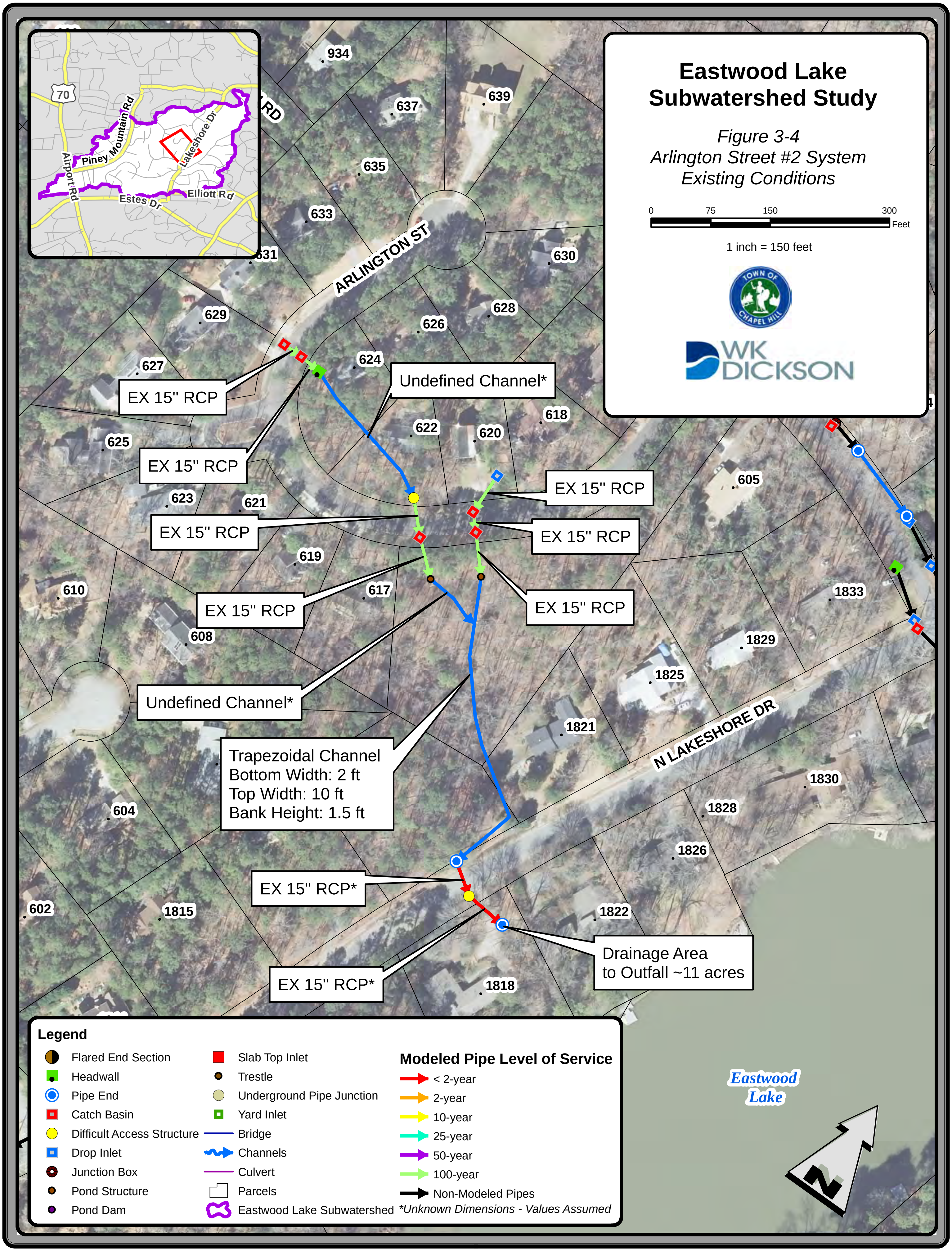
The Arlington Street #2 System collects drainage from approximately 11 acres in the Pine Knob, Lake Forest, and Cooker Woods West subdivisions. The conveyance system is comprised of 15" RCPs connected by small channel sections. The upper portion of the system carries drainage from the Arlington Road cul-de-sac through a series of yards before carrying drainage across Arlington Road. The lower portion of the system is composed of open channel on the upstream and downstream side of North Lakeshore Drive crossing. There are two (2) reports of flooding adjacent to this system. The resident at 1821 North Lakeshore Drive has reported experiencing yard flooding two to three times a year while the resident at 1826 North Lakeshore Drive reports less frequent yard flooding, less than once a year.

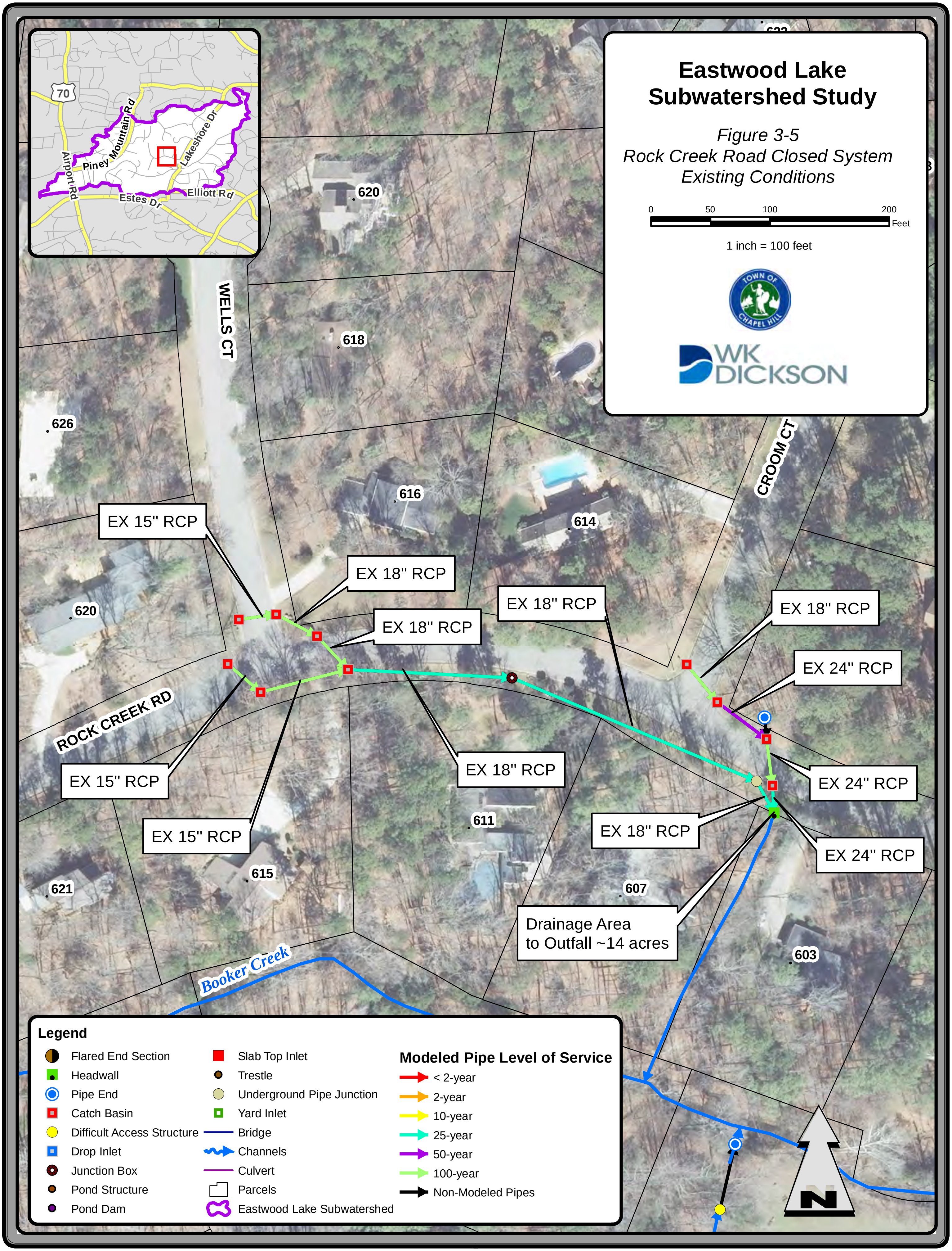
Figure 3-4 shows the level of service being provided by the existing closed system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are not connected to the Arlington Street #2 System. The model results show the majority of the existing system is exceeding the desired 10-year level of service. The existing 15" RCP segments that cross North Lakeshore Drive are operating below a 2-year level of service, assuming full capacity in the pipe. In addition to being undersized the pipes were half buried when visited during the field inventory. The majority of the upstream Pine Knob subdivision drain to a channel that outlets to the 15" RCP at North Lakeshore Drive.

Rock Creek Road Closed System

The Rock Creek Road System collects drainage from approximately 14 acres in the Coker Woods West subdivision and adjacent residential parcels. It discharges to an open channel section located between 603 and 607 Rock Creek Road with a 2.5-foot high bank, a 4-foot bottom width, and a 4.5-foot top width before discharging to Booker Creek. 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, with the exception of the cracked endwall at the outfall. The outfall pipes are also significantly perched. The resident located at 615 Rock Creek Road has observed yard and street flooding several times per year as well as intersection flooding at North Lakeshore Drive and Rock Creek Road.

Figure 3-5 shows the level of service being provided by the existing closed system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are outside of the modeling limits for the Rock Creek Road System. The model results show 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. The terrain is steep in this area and the properties south of Rock Creek Road are lower in elevation than the street, so if water overtops the curb or flows into a driveway, properties are at risk of flooding. No infrastructure exists between Wells Court and Totten Place, which also could contribute to the reported flooding.


Eastwood Lake Subwatershed Study
Figure 3-4
Arlington Street #2 System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Airport Rd
Lakeshore Dr
Estes Dr
Elliott Rd
ARLINGTON ST
N LAKESHORE DR
934
637
639
635
633
631
630
629
628
626
627
624
625
622
620
618
623
621
605
619
617
610
608
1833
1829
1825
1821
604
1830
1828
1826
602
1815
1822
1818
EX 15" RCP
EX 15" RCP
Undefined Channel*
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" RCP
Undefined Channel*
Trapezoidal Channel
Bottom Width: 2 ft
Top Width: 10 ft
Bank Height: 1.5 ft
EX 15" RCP*
EX 15" RCP*
Drainage Area
to Outfall ~11 acres
Eastwood Lake
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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
*Unknown Dimensions - Values Assumed
N


Eastwood Lake
Subwatershed Study
Figure 3-5
Rock Creek Road Closed System
Existing Conditions
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
WELLS CT
CROOM CT
ROCK CREEK RD
Booker Creek
620
618
626
616
614
620
611
615
621
607
603
EX 15" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 24" RCP
EX 15" RCP
EX 18" RCP
EX 24" RCP
EX 15" RCP
EX 18" RCP
EX 24" RCP
Drainage Area
to Outfall ~14 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
Parcels
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

South Lakeshore Drive/Ridgecrest Drive System

The South Lakeshore Drive/Ridgecrest Drive System collects drainage from approximately 23 acres from the Lake Forest subdivision. It discharges to Eastwood Lake between the properties located at 1917 and 1921 South Lakeshore Drive. The conveyance system is comprised of a 24" RCP that crosses South Lakeshore Drive and a 15" RCP that crosses the intersection of Ridgecrest Drive and South Lakeshore Drive. These culverts are connected by open channel sections that have a 3-foot high bank, a 3-foot bottom width, and a 7-foot top width. A section of the channel connecting the system is undefined, it is a shallow path that is not clearly defined but it has been included for model connectivity. Based on data collected during the inventory, the pipes are in good condition. The stream has significant bank erosion and a limited buffer resulting in sediment loads to Eastwood Lake.

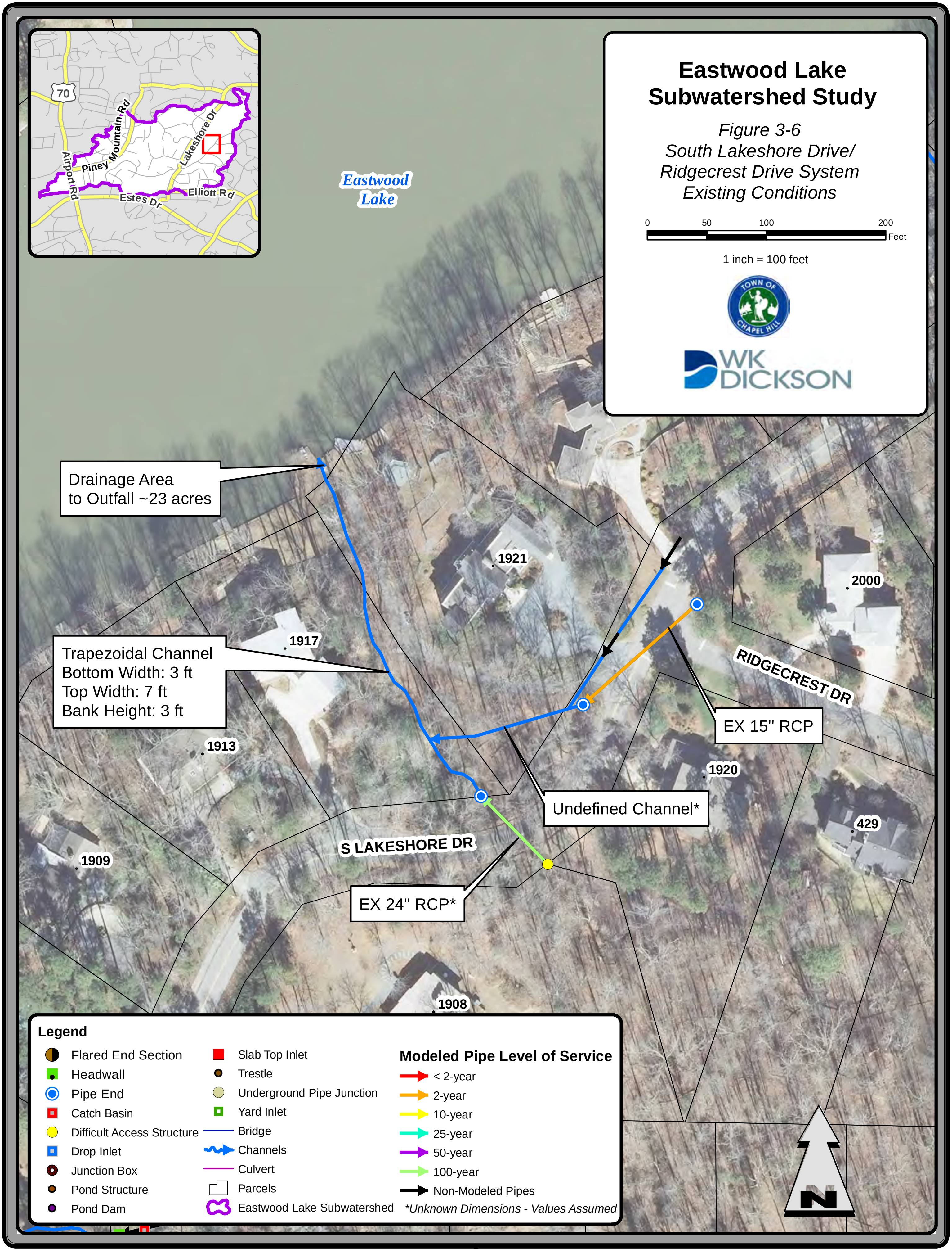
Figure 3-6 shows the level of service being provided by the existing closed system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are outside of the modeling limits for the South Lakeshore Drive/Ridgecrest Drive System. The model results show that while the majority of the existing system is operating above the desired 10-year level of service, the segment of 15" RCP is only performing at a 2-year level of service. The upstream end of the 24" RCP was covered in debris during the field collection and will require cleaning and maintenance to provide the intended level of service. The neighboring residents at 1917 and 1921 South Lakeshore Drive both report experiencing yard flooding 2 to 3 times per year.

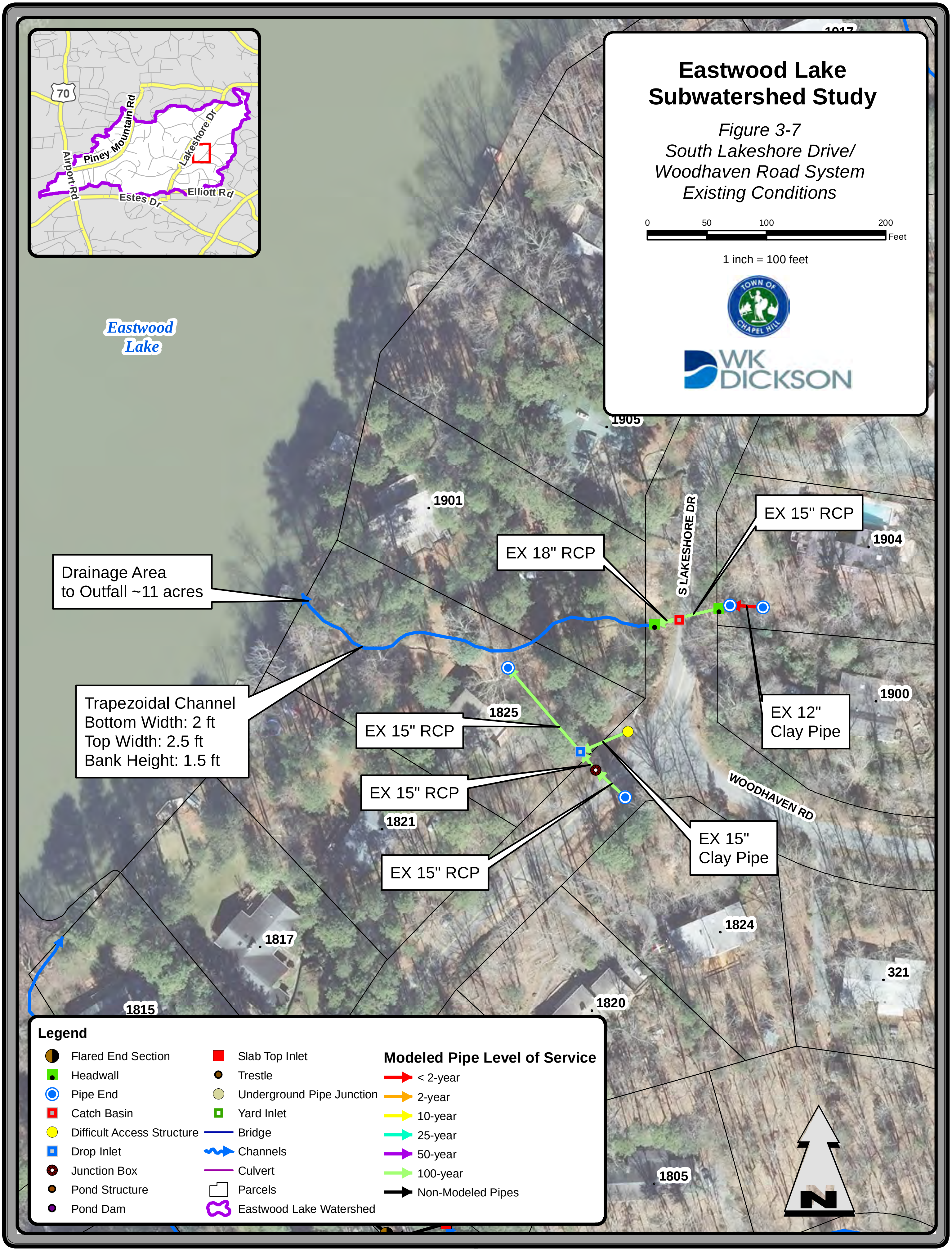
South Lakeshore Drive/Woodhaven Road System

The South Lakeshore Drive/Woodhaven Road System collects drainage from approximately 11 acres in the Lake Forest subdivision. It discharges to a channel section located between 1825 and 1901 South Lakeshore Drive before it outlets to Eastwood Lake. The conveyance system is comprised of clay pipe and RCPs ranging in size from 12- to 18-inches. The closed system (15" RCP) crosses South Lakeshore Drive at two (2) locations. The channel located between 1825 and 1901 South Lakeshore Drive has significant bank erosion and a limited buffer resulting in sediment loads to Eastwood Lake.

Figure 3-7 shows the level of service being provided by the existing closed system. The model results show that there is only one (1) segment of the existing system operating below the desired 10-year level of service. The remainder of the existing conveyance system including the sections that cross South Lakeshore Drive are exceeding the 10-year level of service.

There is one (1) report of flooding adjacent to this system. The resident at 1825 South Lakeshore Drive has reported experiencing yard flooding at 2 to 3 times a year. This occurs during heavy rainfalls when the water runs down Woodhaven Road into the driveway and yard at base of the roadway. Previously, the resident at 1901 South Lakeshore Drive experienced similar yard flooding. A section of curb and gutter was installed along the front of the property to convey the runoff.


Eastwood Lake
Subwatershed Study
Figure 3-6
South Lakeshore Drive/
Ridgecrest Drive System
Existing Conditions
0 50 100 200 Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Airport Rd
Lakeshore Dr
Estes Dr
Elliott Rd
Eastwood Lake
Drainage Area to Outfall ~23 acres
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 7 ft
Bank Height: 3 ft
1921
1917
1913
1909
1908
2000
1920
429
RIDGECREST DR
S LAKESHORE DR
EX 15" RCP
Undefined Channel*
EX 24" 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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
*Unknown Dimensions - Values Assumed
N


Eastwood Lake
Subwatershed Study
Figure 3-7
South Lakeshore Drive/
Woodhaven Road System
Existing Conditions
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Eastwood Lake
Drainage Area to Outfall ~11 acres
Trapezoidal Channel
Bottom Width: 2 ft
Top Width: 2.5 ft
Bank Height: 1.5 ft
EX 18" RCP
EX 15" RCP
EX 12" Clay Pipe
EX 15" RCP
EX 15" RCP
EX 15" RCP
EX 15" Clay Pipe
S LAKESHORE DR
WOODHAVEN RD
1905
1901
1904
1900
1825
1821
1817
1815
1824
1820
321
1805
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
Eastwood Lake Watershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

South Lakeshore Drive/Rolling Road System

The South Lakeshore Drive/Rolling Road System collects drainage from approximately 38 acres from sections of the Lake Forest, Vernon Hills, and Coker Hills subdivision. It discharges to an open channel section before it outlets to Eastwood Lake. The conveyance system is comprised of 24″ RCPs crossing Rolling Road and South Lakeshore Drive. Based on data collected during the inventory, the pipes are in good condition. These pipes are connected by open channel sections that have bank heights ranging from 1 to 3.5 feet with bottom widths ranging from 2.5 to 4 feet and top widths ranging from 3.8 to 8 feet. The channel upstream of the 24″ crossing at South Lakeshore Drive has significant bank erosion.

Figure 3-8 shows the level of service being provided by the existing system. Nearby non-modeled pipes are shown on the figure; however, they were not included in the model because they are not connected to the South Lakeshore Drive/Rolling Road System. The model results show that the existing system is operating below a 2-year level of service, which is less than the desired 10-year level of service. The residents at 1817 and 1820 South Lakeshore Drive both reported flooding. The resident at 1817 South Lakeshore Drive experiences yard, crawl space, and storage building/shed flooding less than once a year. The property owner installed a French drain to alleviate the flooding. The resident at 1820 South Lakeshore Drive reported street flooding.

South Lakeshore Drive System

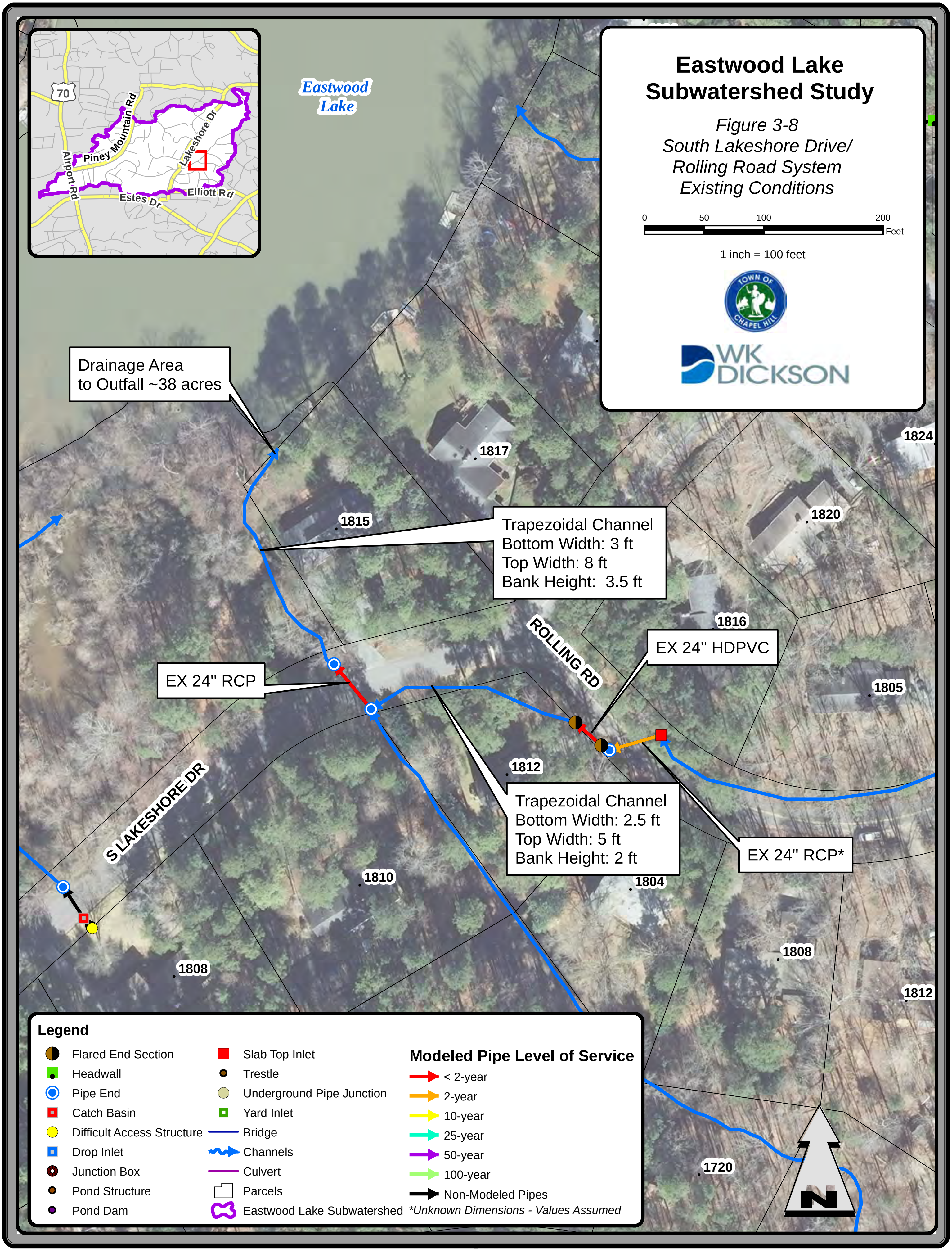
The South Lakeshore Drive System collects drainage from approximately 2 acres from a section of the Coker Hills subdivision. It is a small system that begins in front of 1808 South Lakeshore Drive and consists of an 18″ RCP. The system terminates at an open channel section that has a 1.5-foot high bank, a 6-foot bottom width, and an 8-foot top width. The resident at 1808 South Lakeshore Drive reports experiencing basement flooding less than once a year and yard flooding more than three times per year. In the back yard, the water comes down from Allard Road. Occasionally, the front yard will also flood from the runoff coming from the Rolling Road/South Lakeshore Drive intersection.

Figure 3-9 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.

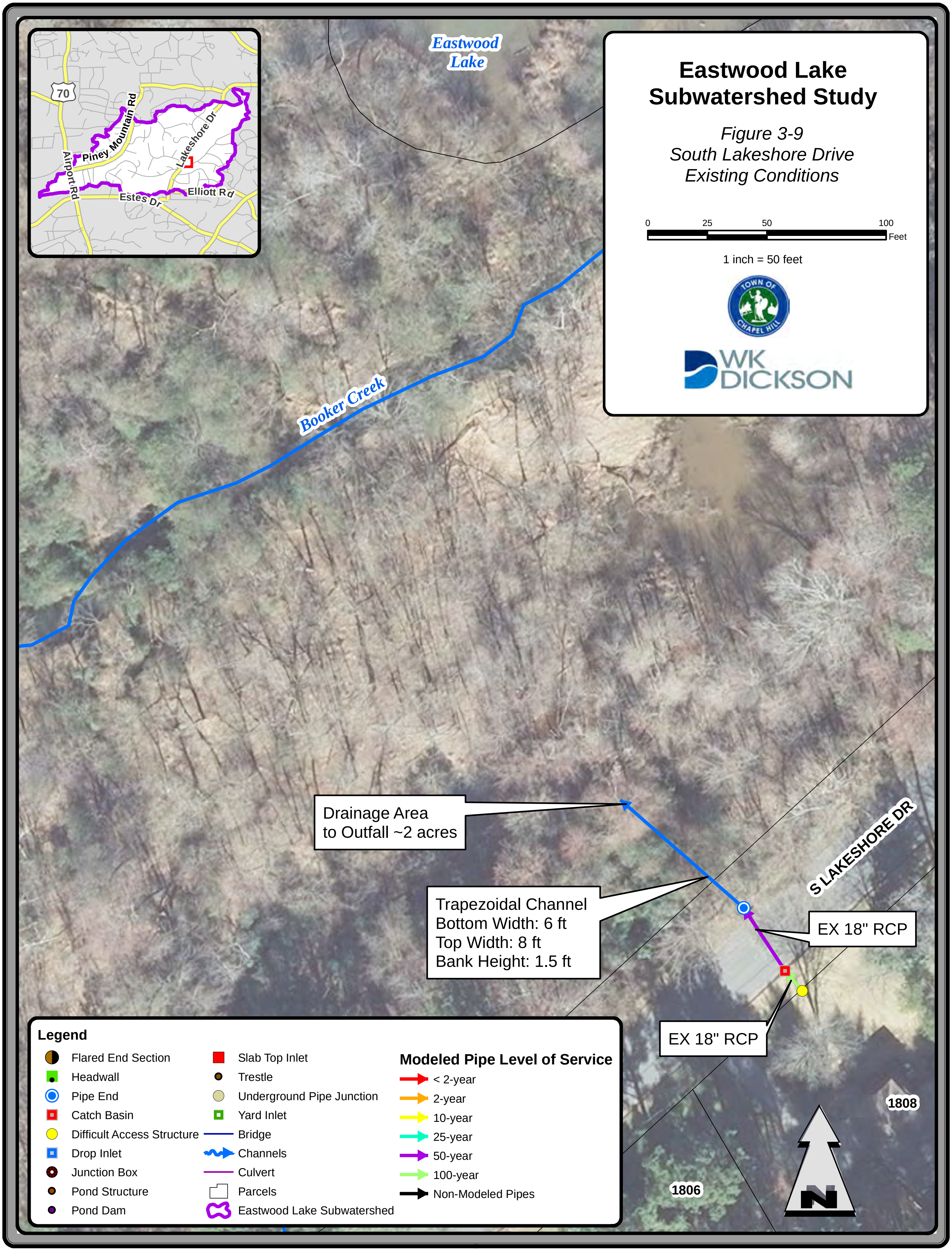
Allard Road System

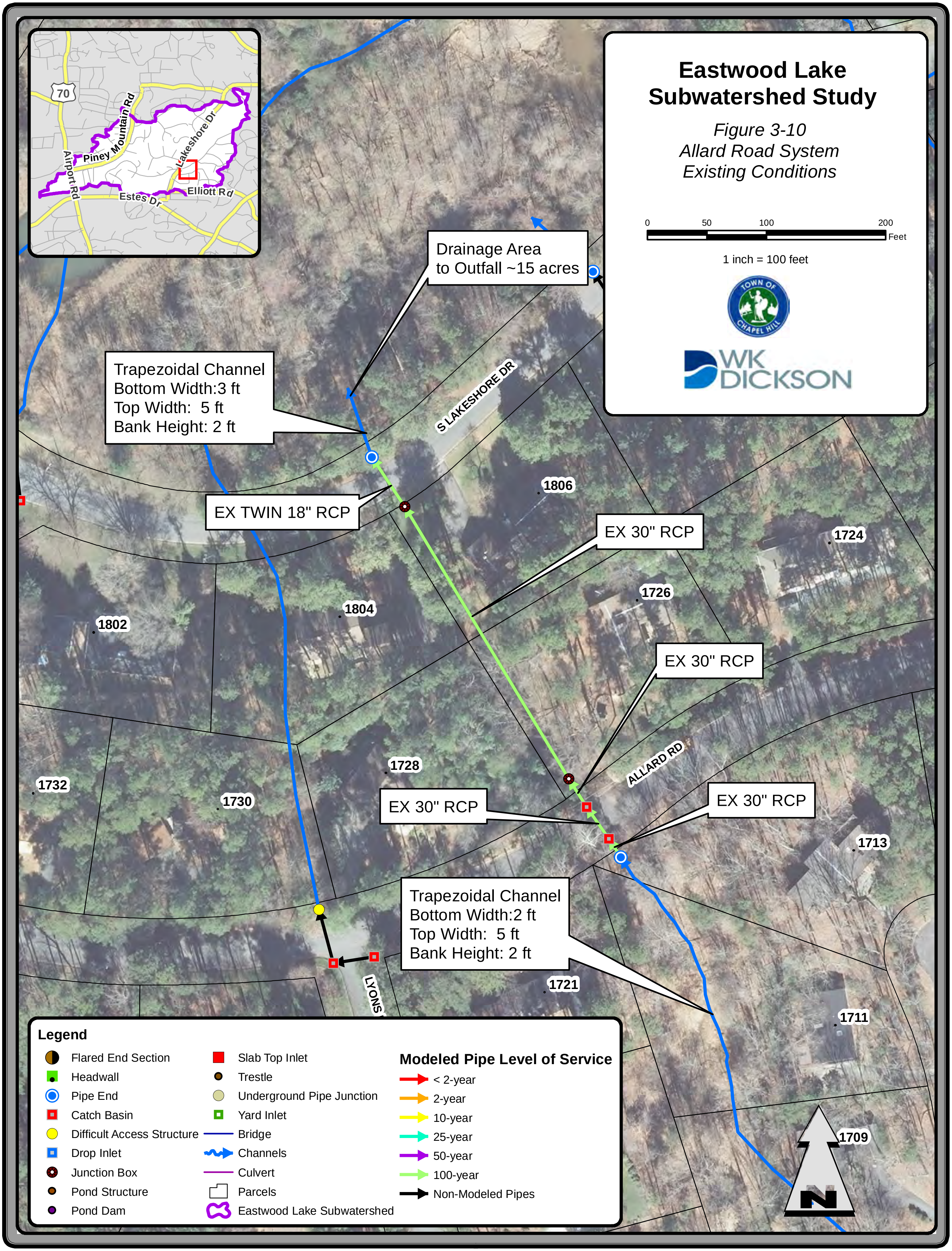
The Allard Road System collects drainage from approximately 15 acres of the Coker Hills subdivision. It is comprised of 18″ and 30″ RCPs. The portion of the system being analyzed begins on the upstream side of the Allard Road crossing adjacent to 1713 Allard Road. The conveyance system continues through private properties, 1726 Allard Road and 1806 South Lakeshore Drive, before traversing South Lakeshore Drive (twin 18″ RCPs). The system outfalls to an open channel section that discharges to Booker Creek. The open channel upstream of the 30″ pipes has streambank erosion.

Figure 3-10 shows the level of service being provided by the existing closed system. The model results show that the existing system is exceeding the desired 10-year level of service.



Eastwood Lake
Subwatershed Study
Figure 3-8
South Lakeshore Drive/
Rolling Road System
Existing Conditions
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Eastwood Lake
Drainage Area
to Outfall ~38 acres
1817
1815
1824
1820
1816
1805
1812
1810
1804
1808
1808
1812
1720
Trapezoidal Channel
Bottom Width: 3 ft
Top Width: 8 ft
Bank Height: 3.5 ft
ROLLING RD
EX 24" HDPVC
EX 24" RCP
S LAKESHORE DR
Trapezoidal Channel
Bottom Width: 2.5 ft
Top Width: 5 ft
Bank Height: 2 ft
EX 24" 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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
*Unknown Dimensions - Values Assumed
N


Eastwood Lake Subwatershed Study
Figure 3-9
South Lakeshore Drive
Existing Conditions
0
25
50
100
Feet
1 inch = 50 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Eastwood Lake
Booker Creek
Drainage Area to Outfall ~2 acres
Trapezoidal Channel
Bottom Width: 6 ft
Top Width: 8 ft
Bank Height: 1.5 ft
EX 18" RCP
EX 18" RCP
S LAKESHORE DR
1808
1806
N
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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes



Eastwood Lake Subwatershed Study
Figure 3-10
Allard Road System
Existing Conditions
0 50 100 200 Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
Drainage Area to Outfall ~15 acres
Trapezoidal Channel Bottom Width:3 ft Top Width: 5 ft Bank Height: 2 ft
EX TWIN 18" RCP
EX 30" RCP
EX 30" RCP
EX 30" RCP
EX 30" RCP
Trapezoidal Channel Bottom Width:2 ft Top Width: 5 ft Bank Height: 2 ft
S LAKESHORE DR
ALLARD RD
LYONS
1806
1724
1726
1804
1802
1728
1732
1730
1713
1721
1711
1709
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott 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
Parcels
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

Curtis Road System

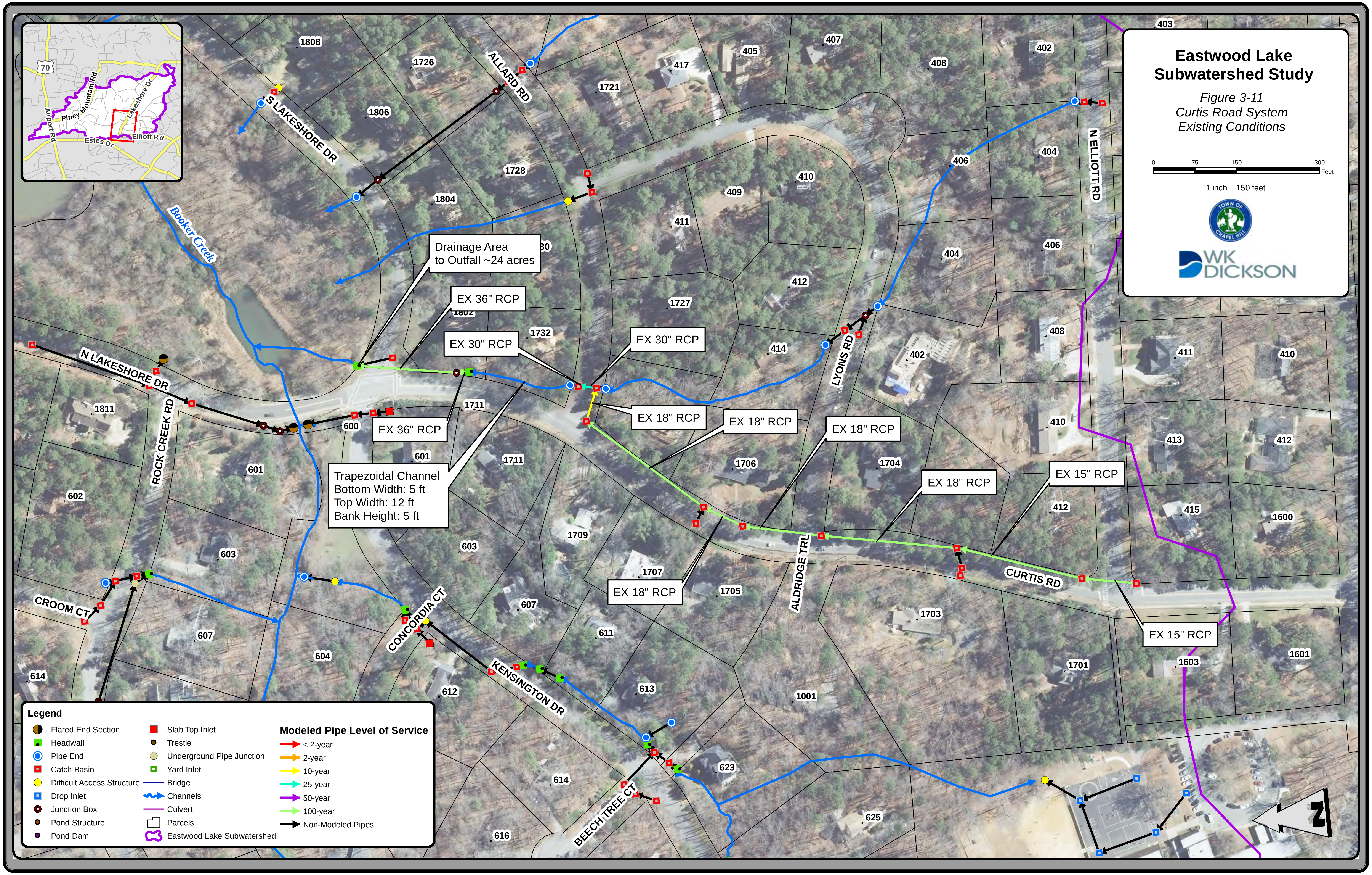
The Curtis Road System collects drainage from approximately 24 acres including a portion of the Lake Forest, Coker Woods West, and Coker Hills subdivisions. The system starts at the intersection of North Elliott Road and Curtis Road. It continues along the Curtis Road ROW crossing Lyons Road, Allard Road, and South Lakeshore Drive. The conveyance system outfalls to an open channel system with a 2-foot high bank, a 3-foot bottom width, and a 6-foot top width. The open channel downstream of Allard Drive has streambank erosion. Ultimately, the Curtis Road System outlets to Booker Creek just upstream of the North Lakeshore Drive bridge. The closed system ranges in size from 15” to 36” RCPs.

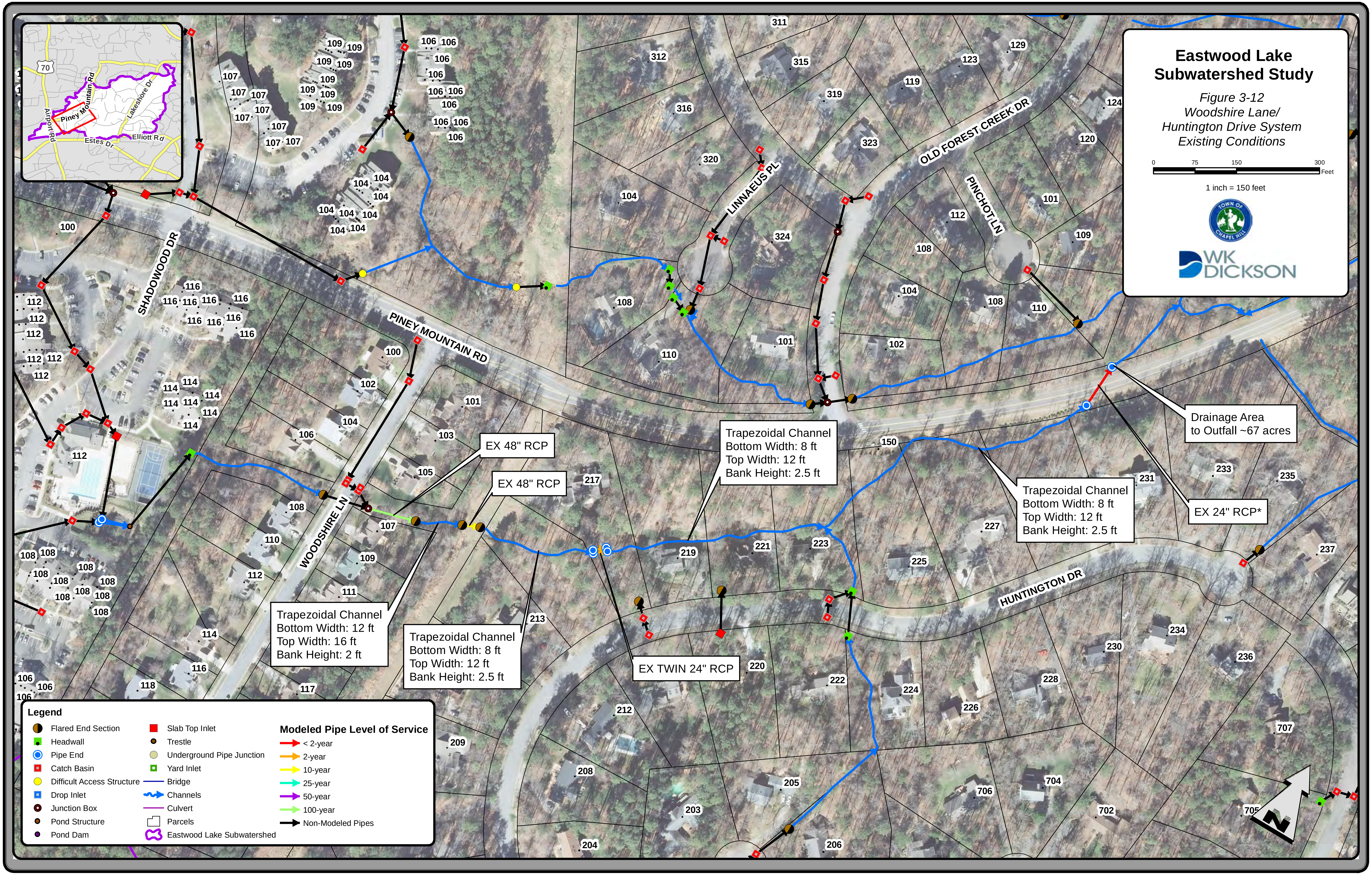
Figure 3-11 shows the level of service being provided by the existing closed system. Non-modeled pipes are shown on the figure; however, they were not included in the model because they are outside of the modeling limits for the Curtis Road System. The model results show most of the existing system is operating at or above the desired 10-year level of service. Street flooding at the intersection of South Lakeshore Drive/Curtis Road/Kensington Drive/North Lakeshore Drive has been reported by several residents in the Eastwood Lake subwatershed.

Woodshire Lane/Huntington Drive System

The Woodshire Lane/Huntington Drive System collects drainage from approximately 67 acres including Shadowood Apartments, a portion of Timber Hollow Apartments, Coker Woods West, and Coker Woods subdivisions. The portion of the system being analyzed is comprised of 24” and 48” RCPs. It begins on the upstream side of the Woodshire Lane crossing between 105 and 107 Woodshire Lane. The system alternates between open channel and closed pipe through a common area of Coker Woods, a transmission line easement, and private property along Huntington Drive. The final segment (24” RCP) of the Woodshire Lane/Huntington Drive system crosses Piney Mountain Road before discharging to an open channel section. Ultimately, the system outlets to Booker Creek just upstream of the Piney Mountain Road bridge. The open channel is predominantly located in back yards with limited buffer resulting in streambank erosion along the stream.

Figure 3-12 shows the level of service being provided by the existing closed system. Non-modeled pipes are shown on the figure; however, they were not included in the model because they are outside of the modeling limits for the Woodshire Lane/Huntington Drive System. The model results show the upstream 48” RCPs are performing at the desired 10-year level of service. The lower section of the system, including the Piney Mountain Road crossing is operating at or below a 2-year level of service. The 24” RCP crossing under Piney Mountain Road is significantly smaller than the upstream 48” diameter pipes.


Eastwood Lake Subwatershed Study
Figure 3-11
Curtis Road System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
WK DICKSON
Drainage Area to Outfall ~24 acres
EX 36" RCP
EX 30" RCP
EX 30" RCP
EX 36" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 18" RCP
EX 15" RCP
EX 18" RCP
EX 15" RCP
Trapezoidal Channel
Bottom Width: 5 ft
Top Width: 12 ft
Bank Height: 5 ft
S LAKESHORE DR
ALLARD RD
N LAKESHORE DR
ROCK CREEK RD
LYONS RD
N ELLIOTT RD
CURTIS RD
ALDRIDGE TRL
CROOM CT
CONCORDIA CT
KENSINGTON DR
BEECH TREE CT
Booker Creek
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott 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
Parcels
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes


Eastwood Lake Subwatershed Study
Figure 3-12
Woodshire Lane/
Huntington Drive System
Existing Conditions
0 75 150 300 Feet
1 inch = 150 feet
WK DICKSON
EX 48" RCP
EX 48" RCP
Trapezoidal Channel
Bottom Width: 8 ft
Top Width: 12 ft
Bank Height: 2.5 ft
Trapezoidal Channel
Bottom Width: 8 ft
Top Width: 12 ft
Bank Height: 2.5 ft
Drainage Area
to Outfall ~67 acres
EX 24" RCP*
Trapezoidal Channel
Bottom Width: 12 ft
Top Width: 16 ft
Bank Height: 2 ft
Trapezoidal Channel
Bottom Width: 8 ft
Top Width: 12 ft
Bank Height: 2.5 ft
EX TWIN 24" RCP
PINEY MOUNTAIN RD
SHADOWOOD DR
WOODSHIRE LN
LINNAEUS PL
OLD FOREST CREEK DR
PINCHOT LN
HUNTINGTON DR
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
70
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
Eastwood Lake Subwatershed
Modeled Pipe Level of Service
< 2-year
2-year
10-year
25-year
50-year
100-year
Non-Modeled Pipes
N

3.3 STREAM STABILITY FIELD ASSESSMENTS

The following overview and description of the Little Creek watershed, of which the Eastwood Lake sub-basin is tributary, 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).

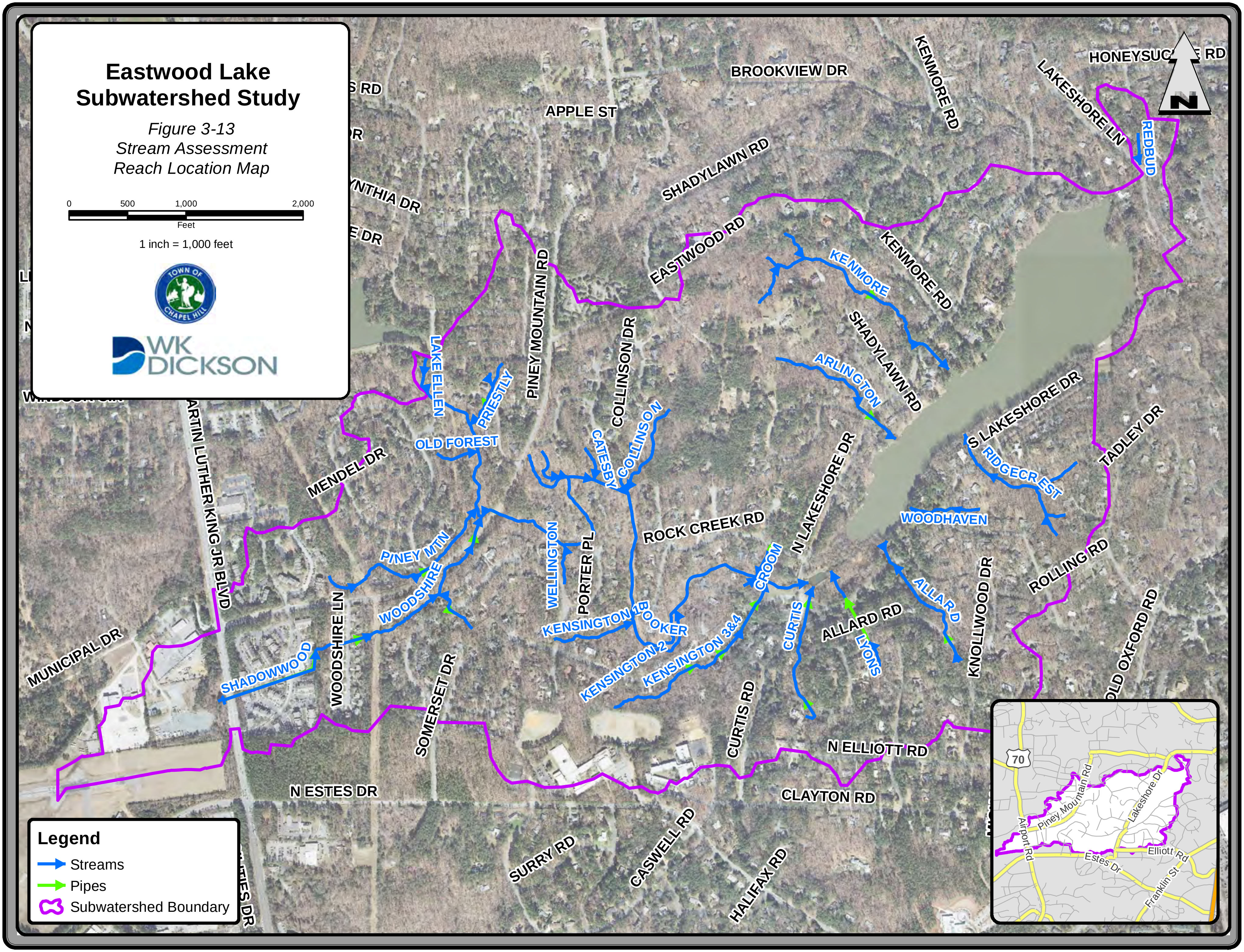
Located in Orange and Durham Counties, Little Creek flows into the New Hope arm of B. Everett Jordan Lake, draining a 24.6-square mile area in subbasin 03-06-06 of the Cape Fear River basin. Two (2) major tributaries, Booker Creek and Bolin Creek, drain the majority of the Little Creek catchment. The 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). As of 1999, impervious areas such as road and buildings covered approximately 15 percent of the study area. 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 Orange Water and Sewer Authority(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 (2) 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

The extent of intermittent and perennial streams was estimated in the Eastwood Lake subwatershed using U.S. Geological Survey (USGS) 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 Eastwood Lake 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 nearly 32,000 linear feet, or approximately 6 miles (See Figure 3-13).


Eastwood Lake
Subwatershed Study
Figure 3-13
Stream Assessment
Reach Location Map
0
500
1,000
2,000
Feet
1 inch = 1,000 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Pipes
Subwatershed Boundary
BROOKVIEW DR
APPLE ST
KENMORE RD
HONEYSUCKLE RD
LAKESHORE LN
REDBUD
SHADYLAWN RD
EASTWOOD RD
KENMORE
KENMORE RD
SHADYLAWN RD
ARLINGTON
S LAKESHORE DR
TADLEY DR
RIDGECREST
WOODHAVEN
PINEY MOUNTAIN RD
COLLINSON DR
LAKE ELLEN
PRIESTLY
OLD FOREST
CATESBY
COLLINSON
MENDEL DR
MARTIN LUTHER KING JR BLVD
ROCK CREEK RD
N LAKESHORE DR
PINEY MTN
WOODSHIRE
WELLINGTON
PORTER PL
CROOM
ALLARD
KNOLLWOOD DR
ROLLING RD
OLD OXFORD RD
MUNICIPAL DR
SHADOWWOOD
WOODSHIRE LN
SOMERSET DR
KENSINGTON 1
BOOKER
KENSINGTON 2
KENSINGTON 3&4
CURTIS
ALLARD RD
LYONS
CURTIS RD
N ELLIOTT RD
N ESTES DR
CLAYTON RD
SURRY RD
CASWELL RD
HALIFAX RD
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Franklin St

As with the Lower Booker Creek subwatershed, 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 electronic tablets.

3.3.3 UNIFIED STREAM ASSESSMENT (USA)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 surrounding land use, size of dominant channel substrate, stream shading, and approximate bank heights. It also included numerical rating scores, ranging from 0-10 points for each bank, and 0-20 points for overall stream condition 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 separate forms (Forms 1 – 5) for each occurrence when 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 pipe and 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 discharge severity, from 0-5 points, that described the outfall discharge or flow 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 Eastwood Lake subwatershed assessment also applied the Habitat Assessment and Physicochemical Parameters data collection methodology, from the EPA Rapid Bioassessment Protocol. The form for high gradient streams (mountain or piedmont regions) was used (Appendix K). 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 Eastwood Lake subwatershed was divided into forty-seven (47) 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.

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

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 126-148 points, which encompasses the upper scores in the Suboptimal category, through the Optimal range.

The stability scores recorded in the field in the Eastwood Lake subwatershed ranged from 39-138 points, with a mean of 94.5 points. A summary of stream stability score statistics is included in Table 3-4.

Table 3-4: Statistical Summary of USA Stream Stability Scores

Mean	94.5
Standard Error	3.6
Median	91
Standard Deviation	25
Range	99
Minimum	39
Maximum	138
Number of Reaches	47

The average score of 94 points falls in the lower range of the suboptimal category, which in a highly developed watershed, is not unexpected. The wide range of scores, 39-138, indicates that there are streams in poor condition, but that there are also reaches that are in relatively stable and good condition.

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

Group	Range	Number of Reaches in Range	Total Length (ft)
Low	39-76	13 reaches	6,346
Medium	77-100	15 reaches	11,915
High	101-138	19 reaches	13,719
			Total: 31,980

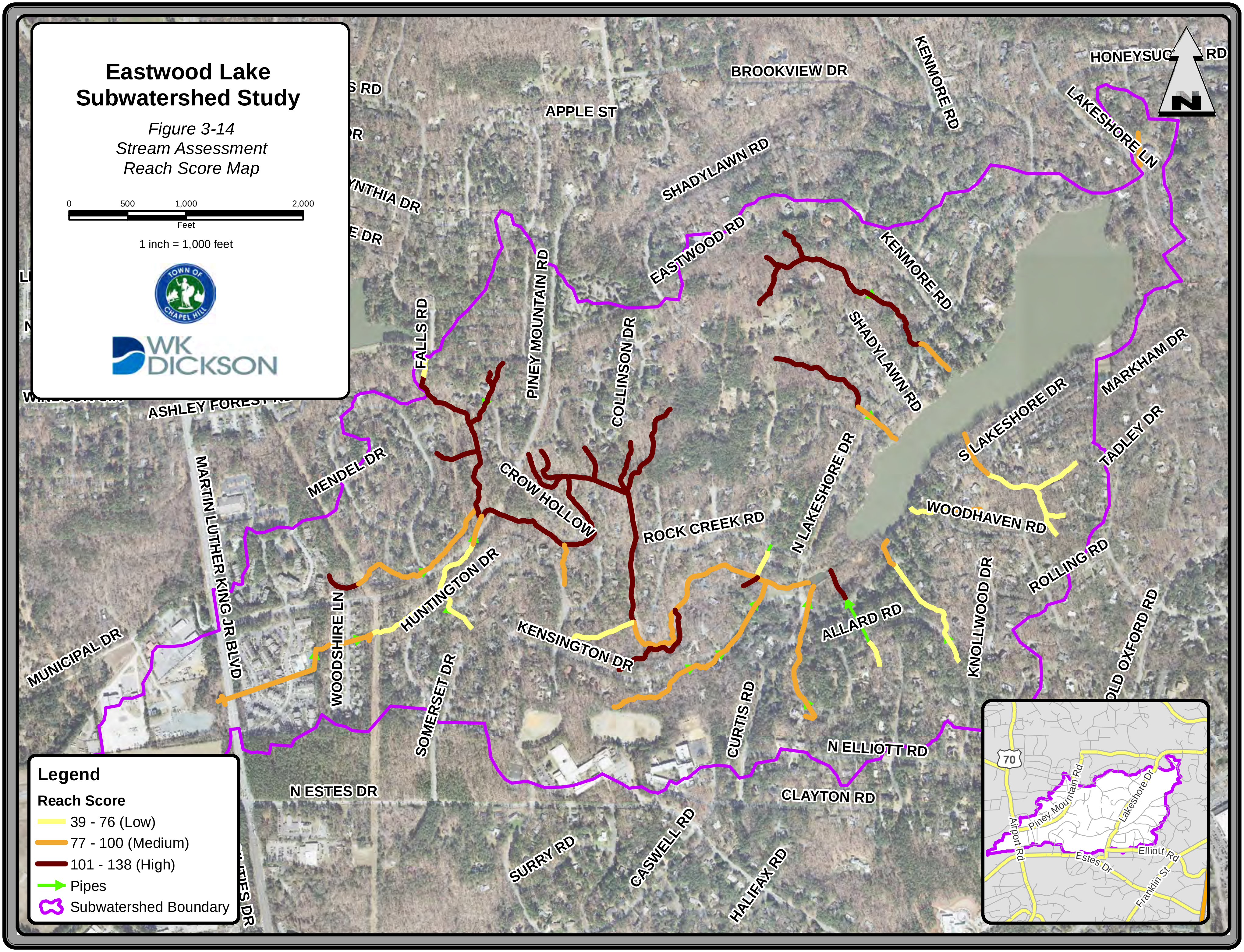
The reaches, color-coded by group, are illustrated in Figure 3-14. Approximately 20% of the total subwatershed stream length are in the Low group, approximately 37% are in the Medium group, and approximately 43% are in the High group.

From Figure 3-14, the distribution of low, medium and high scoring reaches is spread relatively evenly across the subwatershed, with no apparent pattern for any of the groups, except for the similarity in distribution of ratings with the habitat scores. The similarities in habitat and stability ratings for the streams indicate the close association aquatic habitat has with stream stability.

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, fourteen (14) reaches or sections of stream in the Eastwood Lake subwatershed were identified as candidates for stabilization, restoration, buffer improvements or a combination of these. These sites are at the field-identification stage, with design specifics evolving with future onsite analysis. Although not a part of this analysis, the low stability reach locations may be cross-referenced with parcel data to determine where low stability reaches intersect with HOA property to identify possible riparian buffer restoration projects.

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


Eastwood Lake
Subwatershed Study
Figure 3-14
Stream Assessment
Reach Score Map
0
500
1,000
2,000
Feet
1 inch = 1,000 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Reach Score
39 - 76 (Low)
77 - 100 (Medium)
101 - 138 (High)
Pipes
Subwatershed Boundary
BROOKVIEW DR
APPLE ST
KENMORE RD
HONEYSUC RD
LAKESHORE LN
SHADYLAWN RD
EASTWOOD RD
PINEY MOUNTAIN RD
COLLINSON DR
FALLS RD
ASHLEY FOREST RD
MENDEL DR
MARTIN LUTHER KING JR BLVD
CROW HOLLOW
ROCK CREEK RD
N LAKESHORE DR
S LAKESHORE DR
MARKHAM DR
TADLEY DR
WOODHAVEN RD
ROLLING RD
HUNTINGTON DR
WOODSHIRE LN
KENSINGTON DR
ALLARD RD
KNOLLWOOD DR
OLD OXFORD RD
MUNICIPAL DR
SOMERSET DR
CURTIS RD
N ELLIOTT RD
N ESTES DR
CLAYTON RD
SURRY RD
CASWELL RD
HALIFAX RD
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Franklin St

EPA Habitat Assessment Scores

The EPA Habitat Assessment and Physiochemical Parameters methodology protocol utilized does not require comparison of scores to a reference reach score range. Alternatively, there are four "Condition" categories for each parameter assessed in the protocol; 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 stability scores recorded in the field in the Eastwood Lake subwatershed ranged from 48-169 points, with a mean of 113.3 points. A summary of stream stability score statistics is included in Table 3-5.

Table 3-5: Statistical Summary of EPA Habitat Assessment Scores

Mean	113.3
Standard Error	34.1
Median	117
Standard Deviation	27.9
Range	121
Minimum	48
Maximum	169
Number of Reaches	47

The average score of 113 points falls is just above the mid-point of the total point scale and falls within the lower 25% of the suboptimal category, reflecting the high level of development present in the subwatershed. The wide range of scores, 48-169, indicates that there are streams in poor condition, but that there are also areas that are stable and in good condition, as were documented with the reach stability scores.

It is important to note that piped sections of stream in the Shadowwood (approximately 850 feet) and Lyons (approximately 250 feet) reaches were not included in the Jenks-Natural Breaks categorization procedure. This was because, based on the protocol, it was determined that their habitat scores were essentially zero. If these reaches are included in the habitat analysis, they skew the resulting grouping values downward substantially and bias the assessment of the majority of the subwatershed's channel length, which is not piped.

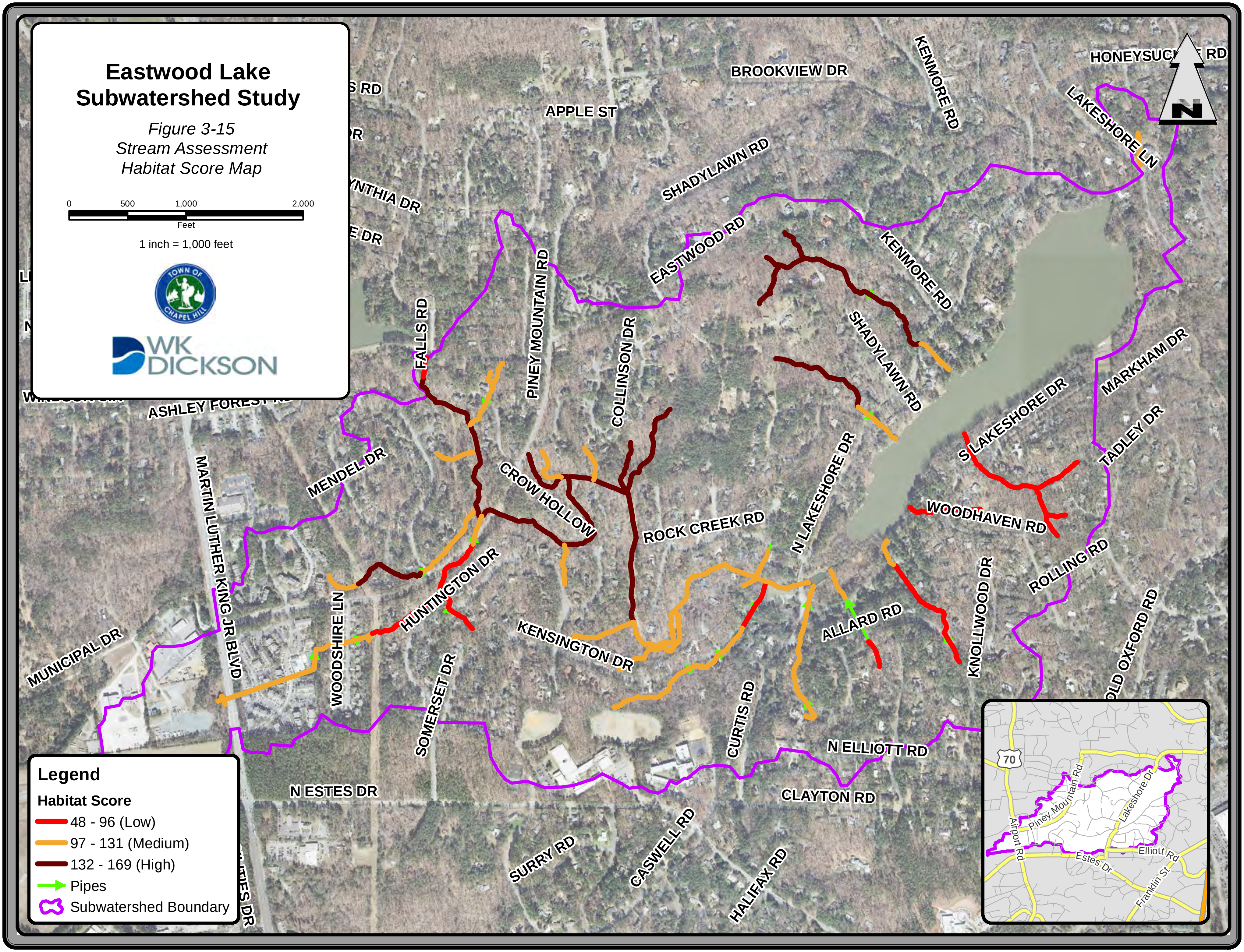
The ranges for habitat scores generated by the Jenks-Natural Breaks algorithm were:

Group	Range	Number of Reaches in Range	Total Length (ft)
Low	48 – 96	14 reaches	6,471*
Medium	97 – 131	22 reaches	14,637
High	132 – 169	11 reaches	10,872
			Total: 31,980

*Piped stream sections not include in length.

The reaches, color-coded by group, are illustrated in Figure 3-15.

From Figure 3-15, no distinct patterns are evident in the distribution of Low, Medium and High scoring reaches across the subwatershed. However, based on the scores, the large impervious surface area associated with the apartment complex on Martin Luther King, Jr. Boulevard apparently has affected the aquatic habitat in the unnamed tributary flowing from the Carolina North property to Booker Creek. The low scores associated with the tributaries to the west of Eastwood Lake, that flow down very steep slopes, suggest that they are impacted by the combination of stormwater runoff generated by development and the steep topography. There is a long section of Booker Creek channel in the upper part of the subwatershed that is rated High, and downstream of it the largest group of Medium rated channel occurs, upstream of Eastwood Lake. There is a relatively short but very incised and eroded section of channel located upstream of this High-rated reach, just downstream of Lake Ellen. There is a continuing source of a large amount of sediment from the high, collapsing stream banks that have developed from erosion in this location.



Eastwood Lake Subwatershed Study
Figure 3-15
Stream Assessment
Habitat Score Map
0
500
1,000
2,000
Feet
1 inch = 1,000 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Habitat Score
48 - 96 (Low)
97 - 131 (Medium)
132 - 169 (High)
Pipes
Subwatershed Boundary
BROOKVIEW DR
APPLE ST
KENMORE RD
HONEYSUCKLE RD
LAKESHORE LN
SHADYLAWN RD
EASTWOOD RD
PINEY MOUNTAIN RD
COLLINSON DR
FALLS RD
ASHLEY FOREST RD
MENDEL DR
MARTIN LUTHER KING JR BLVD
CROW HOLLOW
ROCK CREEK RD
N LAKESHORE DR
S LAKESHORE DR
MARKHAM DR
TADLEY DR
WOODHAVEN RD
ROLLING RD
KNOLLWOOD DR
OLD OXFORD RD
ALLARD RD
HUNTINGTON DR
KENSINGTON DR
WOODSHIRE LN
SOMERSET DR
CURTIS RD
N ELLIOTT RD
CLAYTON RD
N ESTES DR
MUNICIPAL DR
SURRY RD
CASWELL RD
HALIFAX RD
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Franklin St

3.4 OUTFALL ANALYSIS

A desktop assessment was conducted for the Eastwood Lake subwatershed to evaluate stormwater outfalls for retrofit potential. The assessment involved automated processes performed with GIS, as well as application of engineering judgment 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. Field work and public input identified two (2) additional sites that were added to the outfalls prioritized list. The final step was to produce summary profiles for the top ten (10) scoring outfalls and the two (2) added opportunities.

To ensure quality assurance and verify the scoring process, over ten percent of the outfalls analyzed were independently verified. Further, the outfall opportunities comprising the top quartile of ranked sites were field verified.

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 outfalls identified by this process.

Dataset of Outfalls for Analysis

GIS data documenting the location of storm sewer system pipes and outfalls were collected as part of the stormwater inventory. The initial dataset containing 204 pipe ends was sorted to include only pipe ends designated as "outgoing" or "ingoing." "Ingoing" outfalls were not explicitly included in the analysis; however, in specific instances retrofits were investigated or sited at "ingoing" outfall. The resulting 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 along the same stream line, and stream order combined with pipe diameter.

Stream order is the commonly used classification system of stream channels, where the uppermost perennial streams in a watershed are classified as first order. When two first order streams flow together, the stream classification becomes second order, and when two second order streams flow together the classification becomes third order, etc. For pass-through outfalls along first order streams, the outfalls were included in the analysis. All pass-through outfalls along second order streams were excluded. The final dataset analyzed included 141 "outgoing" and "ingoing" 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
- SCM 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 3-6.

Table 3-6: Factor Description and Evaluation

Hydraulic Feasibility Hydraulic feasibility looks at whether diversion or redirection of flow to an outfall retrofit is possible/practical. Hydraulic feasibility is evaluated by engineering judgment 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 SCM 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 SCM 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 judgment and divided into three categories: None, Possible, and Expected. An outfall is designated as having Expected utility impacts when the SCM 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 judgment 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 look 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 judgment 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 assess 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 SCM 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 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 SCM).
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 SCM footprint
- Pipe 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 two (2) points maximum. The total points possible is 100. Factors and the point system are shown in Table 3-7 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 3-7: 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**		

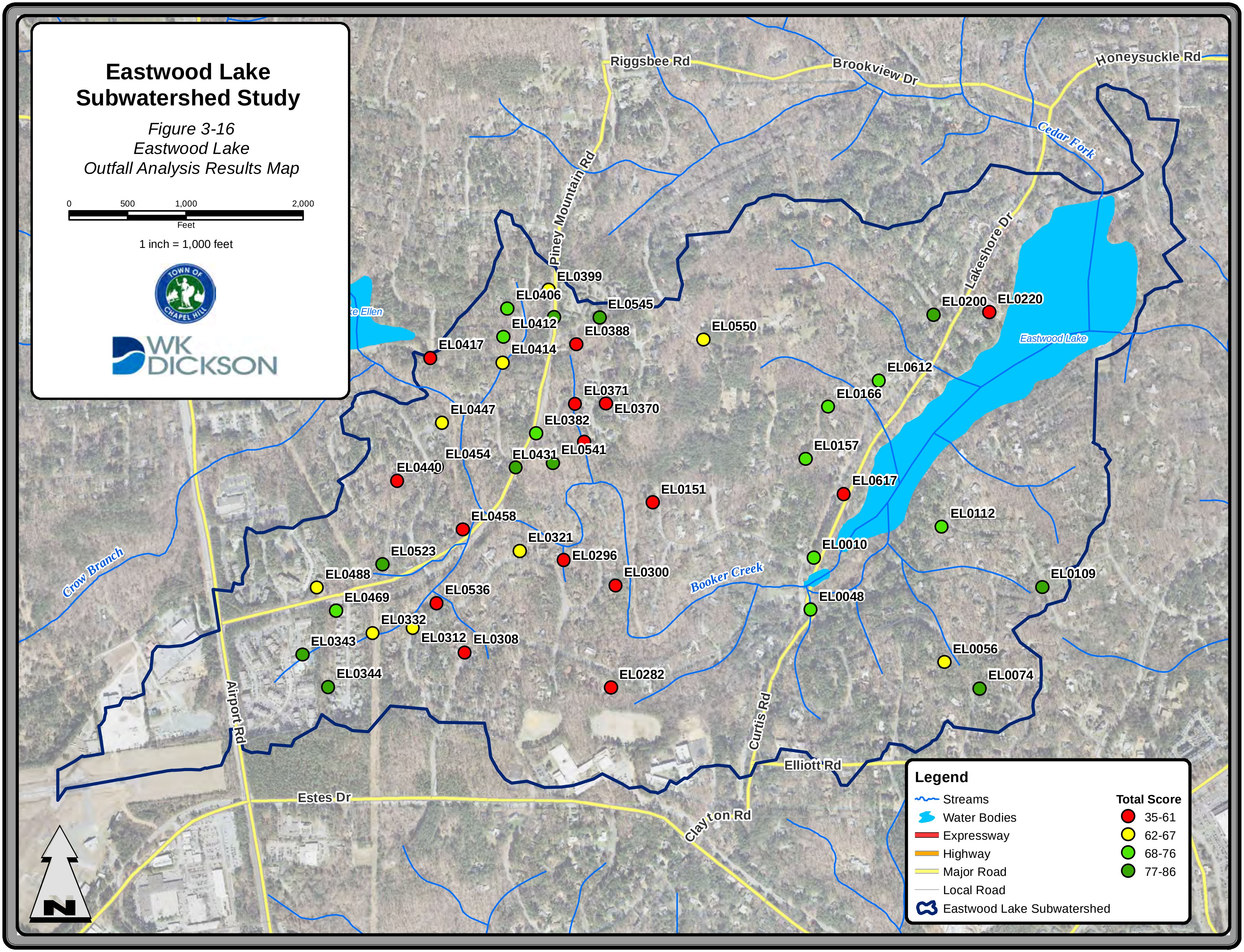
3.4.2 RESULTS

The analysis protocol was applied to the full set of 141 outfalls in Eastwood Lake subwatershed. Of the 141 outfalls, ninety-seven (97) were deemed to be infeasible due to hydraulic feasibility and thus dropped from further consideration. The remaining forty-four (44) outfalls were analyzed and ranked. Scores ranged from thirty-five (35) to eighty-six (86) and were statistically broken into quartiles (See Table 3-8 and Figure 3-16). The top ten (10) sites, representing the top quartile, were field verified to screen for fatal flaws not considered in the desktop analysis due to the limitations inherent to that process.

In addition to the top ten (10) sites identified by this analysis, two (2) additional sites (EL0157/EL0162 and EL0520) identified during the field review and public input processes are considered suitable candidates based on additional information gathered. Individual maps for the highest-ranking outfalls, after further individual analysis and refinement, are provided in Section 6.2.1.

Table 3-8: Summary Ranking of Outfalls for Eastwood Lake

	Earthwork	Retrofit Area to Drainage Area Ratio	Accessibility	Property Ownership	Impervious Cover Treated	Utilities	Tree Impacts	Additional Infrastructure	Traffic	Total Score
EL0431	15	15	15	10	4	12	10	5	0	86
EL0389	15	10	10	10	8	12	10	5	2	82
EL0541	10	15	15	10	4	12	10	5	0	81
EL0109	15	15	15	10	4	8	10	3	0	80
EL0343	15	5	15	4	12	12	10	5	2	80
EL0344	15	5	15	4	12	12	10	5	2	80
EL0074	15	10	15	8	12	12	2	3	2	79
EL0545	10	15	15	4	4	12	10	5	4	79
EL0200	10	15	15	10	4	8	10	5	0	77
EL0523	15	15	15	4	4	12	5	5	2	77
EL0010	15	15	15	8	4	12	2	3	2	76
EL0412	15	5	15	10	12	8	5	5	0	75
EL0382	15	15	15	10	4	8	2	5	0	74
EL0112	10	10	15	10	4	8	10	5	0	72
EL0469	15	10	10	8	8	12	2	5	2	72
EL0048	10	10	10	8	12	12	2	3	4	71
EL0157	5	15	10	8	12	12	2	5	2	71
EL0166	5	10	15	10	4	12	10	5	0	71
EL0612	5	15	15	10	8	2	10	5	0	70
EL0406	10	5	15	10	8	8	10	3	0	69
EL0332	10	5	15	8	8	12	2	3	4	67
EL0454	15	5	5	8	12	12	5	3	2	67
EL0488	10	5	10	8	12	12	2	5	2	66
EL0447	15	10	5	8	8	12	2	3	2	65
EL0056	5	15	15	4	8	8	2	3	4	64
EL0414	5	5	15	10	12	12	2	3	0	64
EL0312	10	10	10	4	8	12	2	5	2	63
EL0321	10	10	10	4	8	12	2	5	2	63
EL0399	10	10	10	10	4	12	2	5	0	63
EL0550	10	5	15	4	4	8	10	5	2	63
EL0220	15	5	10	4	8	2	10	5	2	61
EL0388	5	15	10	10	4	8	2	3	2	59
EL0458	5	15	10	4	4	12	2	5	2	59
EL0380	15	5	10	4	4	12	2	3	2	57
EL0371	15	5	5	4	8	12	2	3	2	56
EL0300	5	15	5	4	8	12	2	2	2	55
EL0417	10	10	10	4	8	8	2	3	0	55
EL0151	5	15	10	4	8	2	2	5	2	53
EL0296	10	5	10	4	12	2	2	5	2	52
EL0617	5	5	10	4	12	8	2	2	2	50
EL0370	5	5	5	4	12	12	2	3	2	50
EL0440	10	10	5	4	4	8	2	5	2	50
EL0536	5	5	10	4	4	12	2	5	2	49
EL0308	10	10	5	4	8	2	2	3	2	46
EL0282	5	10	5	4	4	0	2	3	2	35


Eastwood Lake
Subwatershed Study
Figure 3-16
Eastwood Lake
Outfall Analysis Results Map
0
500
1,000
2,000
Feet
1 inch = 1,000 feet
TOWN OF CHAPEL HILL
WK DICKSON
Riggsbee Rd
Brookview Dr
Honeysuckle Rd
Cedar Fork
Piney Mountain Rd
Lakeshore Dr
Eastwood Lake
Booker Creek
Crow Branch
Airport Rd
Curtis Rd
Elliott Rd
Estes Dr
Clayton Rd
EL0399
EL0406
EL0545
EL0412
EL0388
EL0550
EL0417
EL0414
EL0200
EL0220
EL0612
EL0371
EL0166
EL0447
EL0370
EL0382
EL0157
EL0454
EL0431
EL0541
EL0440
EL0617
EL0151
EL0112
EL0458
EL0321
EL0010
EL0523
EL0296
EL0300
EL0109
EL0488
EL0536
EL0048
EL0469
EL0332
EL0343
EL0312
EL0308
EL0056
EL0344
EL0282
EL0074
Legend
Streams
Water Bodies
Expressway
Highway
Major Road
Local Road
Eastwood Lake Subwatershed
Total Score
35-61
62-67
68-76
77-86

3.5 NEIGHBORHOOD ANALYSIS

A desktop assessment was conducted on the Eastwood Lake 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 throughout the entire Booker Creek watershed 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 3-9). 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 rights-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.

3.5.1 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 3-1): 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 3-2): 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%.

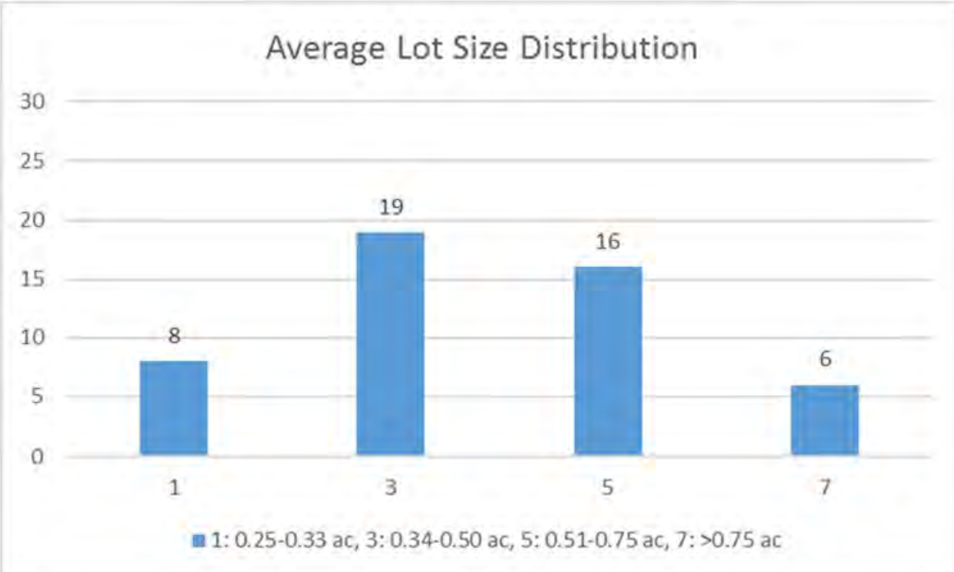


Exhibit 3-1: Average Lot Size Distribution

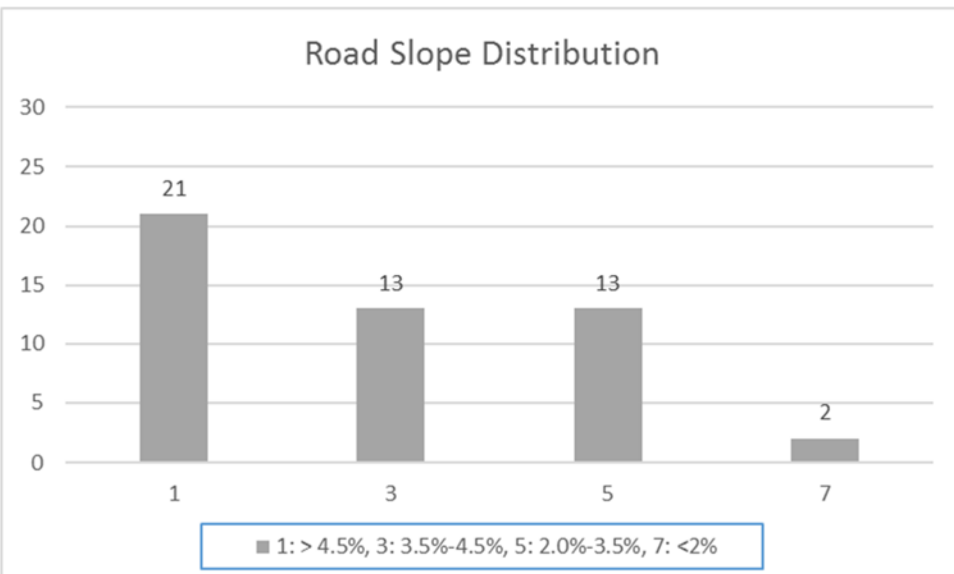


Exhibit 3-2: Road Slope Distribution

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 3-3). 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 3-3): 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 3-3: Curb Extension Example

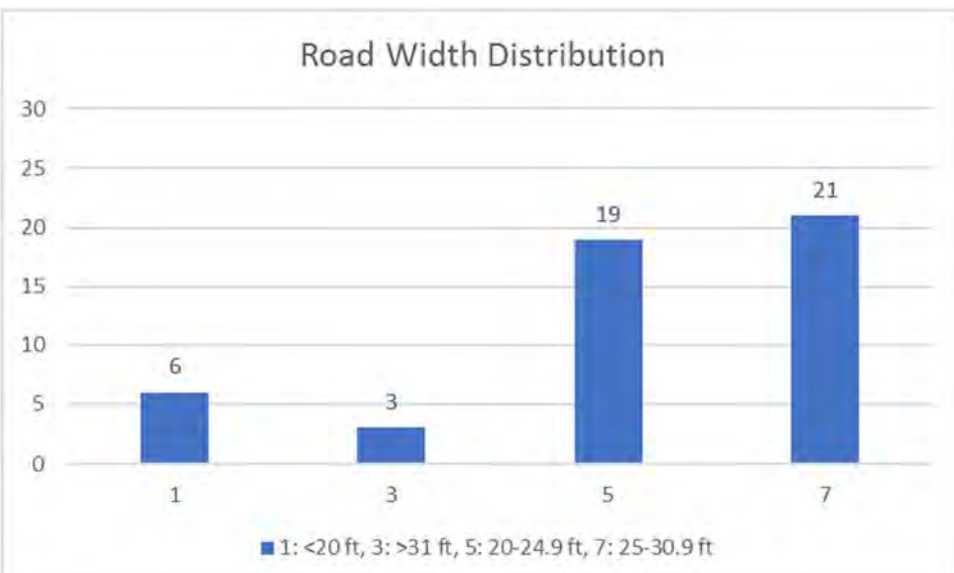


Exhibit 3-3: Road Width Distribution

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 3-4): 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.

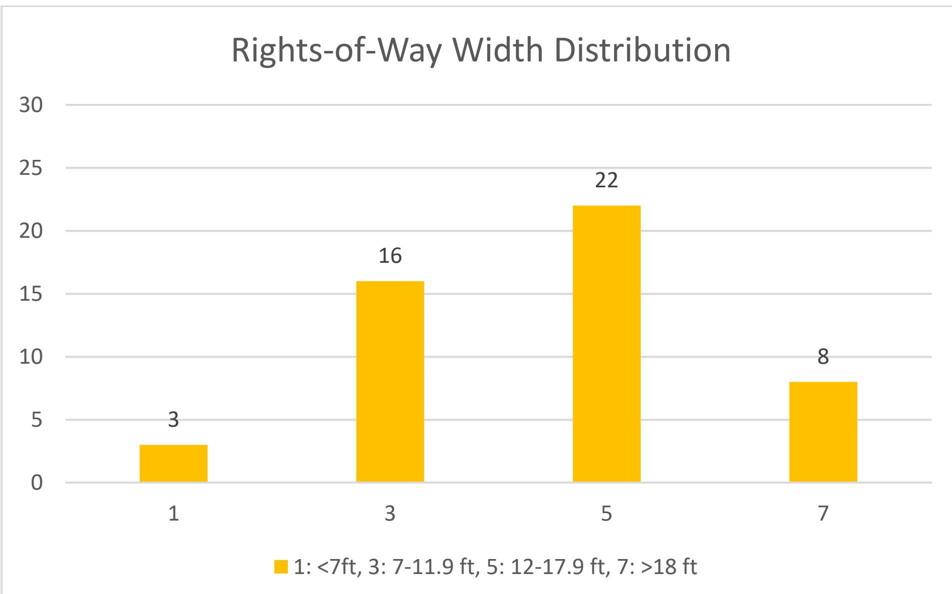


Exhibit 3-4: Rights-of-Way Width Distribution

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 3-5 shows the score distribution of this parameter.

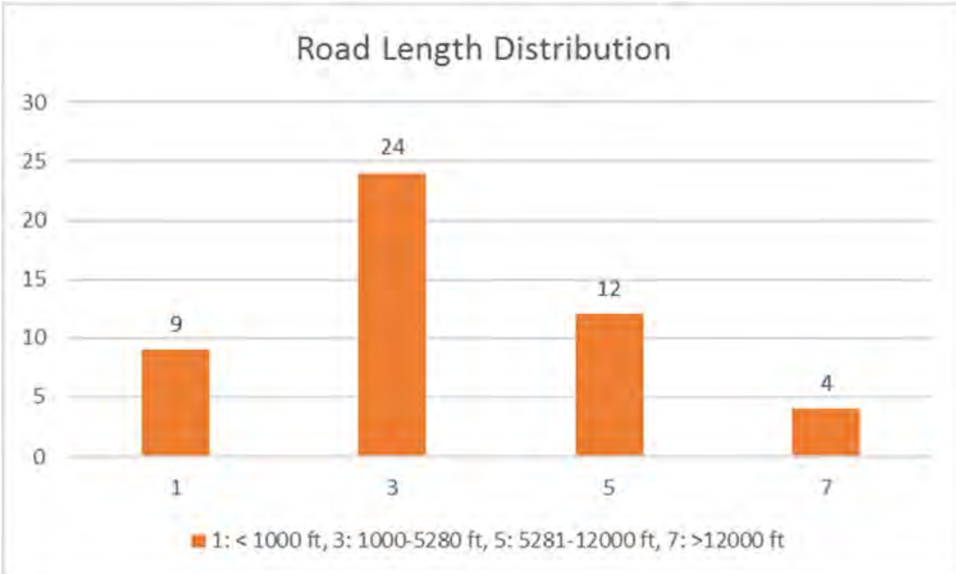


Exhibit 3-5: Road Length Distribution

3.5.2 RESULTS

The scores for each parameter were then added together to compute a final neighborhood score. These total scores were then compiled into four (4) ranking categories (poor, fair, good, very good) to represent the favorability of a neighborhood to retrofitting (See Exhibit 3-6 and Table 3-9). 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.

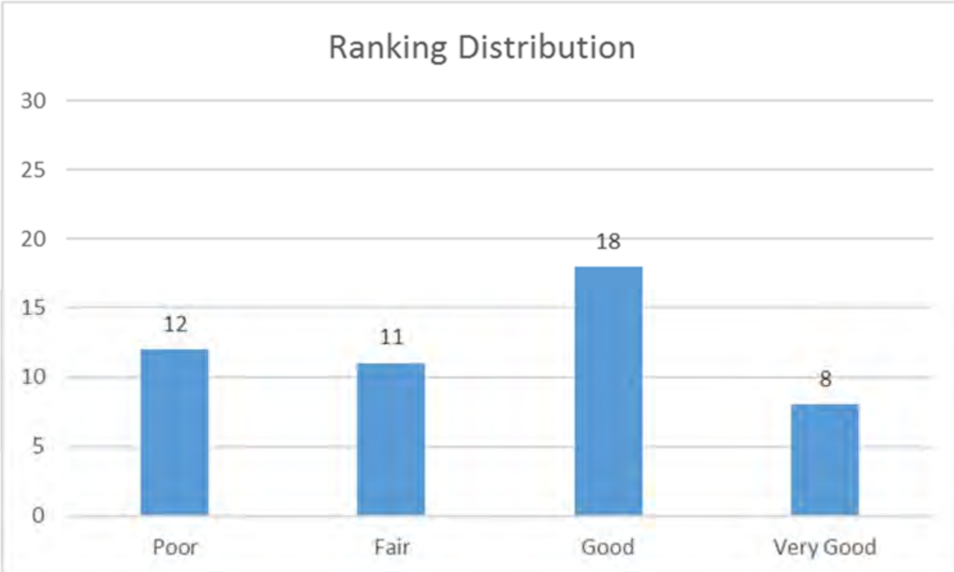


Exhibit 3-6: Ranking Distribution

Table 3-9: 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.

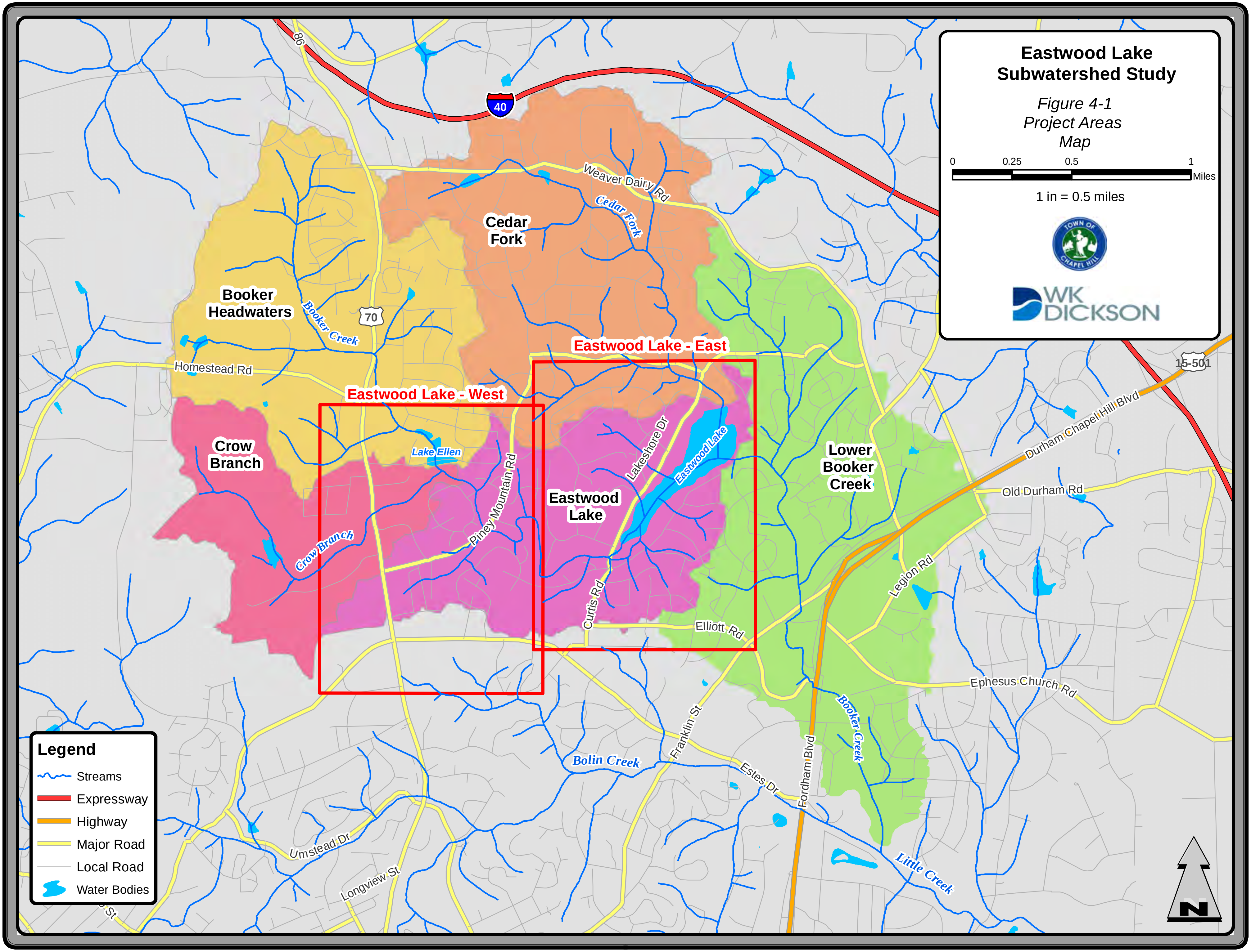
As noted in Section 3, significant development has occurred within the natural floodplain prior to the current federal and local regulations regarding development in a floodplain. The proposed solutions required to reduce the risk of flooding in these areas are a combination of the following:

(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 Eastwood Lake and how those systems interact with each other, the proposed alternatives are best grouped geographically into three (3) distinct areas as shown in Figure 4.1 and described as follows:

(1) The Overall Booker Creek watershed includes proposed storage projects previously identified as part of the Lower Booker Creek Subwatershed Study that can influence peak flows within the Eastwood Lake subwatershed.
(2) Eastwood Lake West consists predominantly of secondary systems located on the upstream portion of Booker Creek in the western portion of the Eastwood Lake subwatershed area.
(3) Eastwood Lake East consists predominantly of secondary systems located on the downstream portion of Booker Creek in the eastern portion of the Eastwood Lake subwatershed area.

All proposed projects are developed based on built-out land use conditions as described in Section 4.4 and Appendix A. All reported water surface elevations and flood depth reductions are based on future land use conditions.



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

4.1 OVERALL BOOKER CREEK WATERSHED

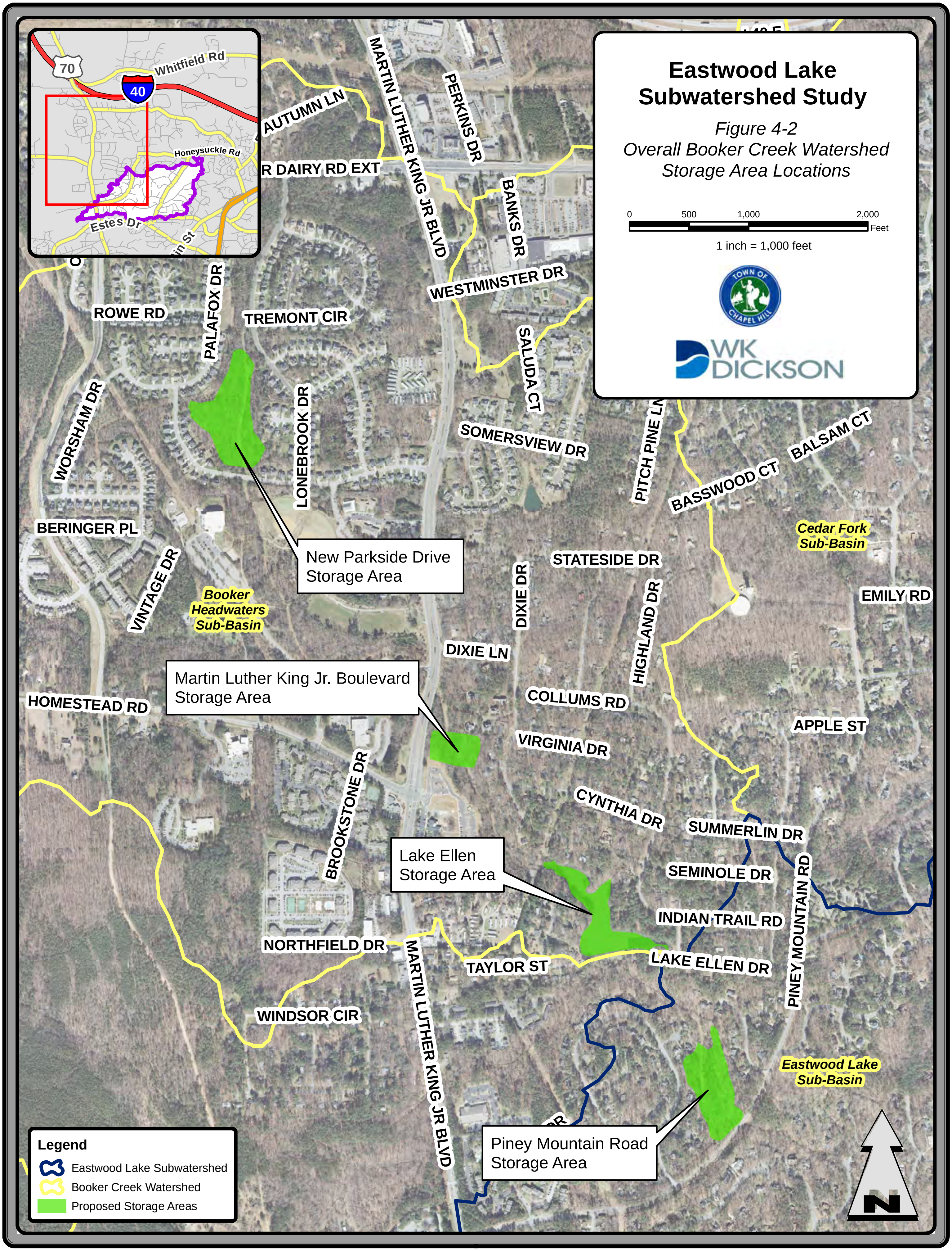
While the focus of this study is to improve conditions within the Eastwood Lake subwatershed, over 80% of the drainage area contributing to the overall watershed is outside of the Eastwood Lake subwatershed. Therefore, potential projects were evaluated within the Booker Creek watershed to determine if strategically increasing flood storage in the upper portions of the watershed could potentially impacts peak flows in the Eastwood Lake 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 flood 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 the Lower Booker Creek 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 four (4) proposed floodplain storage areas are shown in Figure 4.2 and summarized in Table 4-1. Detailed information about the proposed storage areas can be found in the Lower Booker Creek Subwatershed Study and the Lake Ellen Evaluation Memorandum.

Table 4-1: Potential Flood Storage Areas

Name	Location	Size (Acres)	25-Year Flow Reductions at Piney Mountain Road	25-Year Flow Reductions at North Lakeshore Drive
New Parkside Drive	North of New Parkside Drive (Booker Headwater Sub-Basin)	7.5	9%	7%
Martin Luther King Jr. Boulevard	East Side of Martin Luther King Jr. Boulevard, Just North of Intersection with Homestead Road (Booker Headwater Sub-Basin)	2.0	0%	0%
Piney Mountain Road	West Side of Piney Mountain Road approx. 0.5 Miles East of Intersection with Martin Luther King Jr. Boulevard (Eastwood Sub-Basin)	5.5	0%	0%
Lake Ellen	North of Piney Mountain Road, Upstream of Crow Branch Confluence with Booker Creek (Booker Headwater Sub-Basin)	5.0	2%	3%


Eastwood Lake 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
New Parkside Drive Storage Area
Martin Luther King Jr. Boulevard Storage Area
Lake Ellen Storage Area
Piney Mountain Road Storage Area
Booker Headwaters Sub-Basin
Cedar Fork Sub-Basin
Eastwood Lake Sub-Basin
Legend
Eastwood Lake Subwatershed
Booker Creek Watershed
Proposed Storage Areas
70
40
Whitfield Rd
Honeysuckle Rd
Estes Dr
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
CYNTHIA DR
SUMMERLIN DR
SEMINOLE DR
INDIAN TRAIL RD
PINEY MOUNTAIN RD
NORTHFIELD DR
TAYLOR ST
LAKE ELLEN DR
WINDSOR CIR
N

4.2 EASTWOOD LAKE WEST

The Eastwood Lake West portion of the study consists of the upstream portion of Booker Creek from its confluence with Crow Branch to just downstream of Piney Mountain Road. It is in the western section of the Eastwood Lake subwatershed. Eastwood Lake West generally consists of three (3) different types of projects as follows:

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

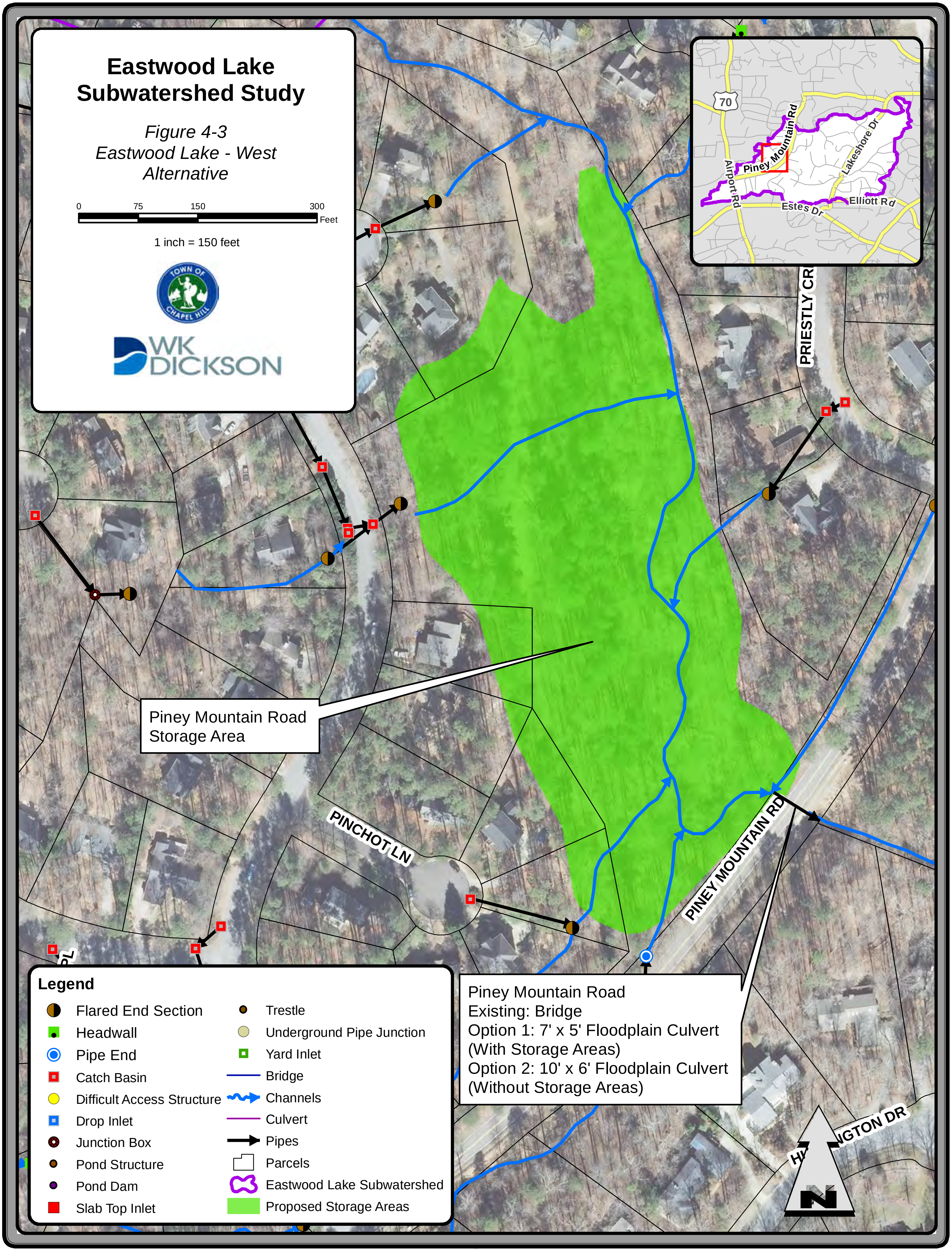
Piney Mountain Road – Based on the results obtained from the existing conditions analysis, the existing bridge at this crossing provides a 10-year level of service. For the future conditions analysis, the roadway is overtopped by 0.5 feet during a 10-year storm event. The existing and future conditions do not meet the desired 100-year level of service for roadways located within a FEMA regulated floodway.

Picture 4-1: Piney Mountain Road Bridge

With the implementation of the three (3) proposed detention projects in Section 4.1, the resulting 10-year water surface elevation will be decreased by 2.1 feet while the resulting 25-year water surface elevation will decrease by 0.3 feet.

This bridge was installed approximately 15 years ago following the failure of the previous metal pipe in the summer of 2000. The bridge is in good condition with no known structural issues; therefore, it is recommended that it be left in place. The improvements proposed at Piney Mountain Road entails installing a 7′ x 5′ reinforced concrete box floodplain culvert (See Figure 4-3). With this improvement along with the proposed detention projects, Piney Mountain Road will be brought up to a 25-year level of service. Additionally, water surface elevations will be reduced by 2.9 feet during the 10-year storm event and 1.7 feet during the 25-year storm event. If the floodplain culvert is installed without the proposed detention projects, the culvert will need to be a 10′ x 6′ reinforced concrete box floodplain culvert to achieve a 25-year level of service. The water surface elevations will be reduced by 2.8 feet during the 10-year storm event and 1.6 feet during the 25-year storm event. Without the implementation of proposed upstream storage areas, the resulting downstream water surface elevations will increase by as much as 0.14 feet in the 25-year storm event with the installation of the floodplain culvert.

During a field visit, there were several potential site restrictions and utility conflicts that were identified including overhead power lines that are located above Piney Mountain Road. The overhead power lines may need to be relocated based on where the contractor accesses the site. Along Piney Mountain Road, there is a water line (16″ ductile iron) that runs perpendicular 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. Piney Mountain Road 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. The total estimated cost for this project is $333,100 for the 7′ x 5′ reinforced concrete box floodplain culvert and $456,800 for the 10′ x 6′ reinforced concrete box floodplain culvert.


Eastwood Lake
Subwatershed Study
Figure 4-3
Eastwood Lake - West
Alternative
0
75
150
300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Airport Rd
Lakeshore Dr
Estes Dr
Elliott Rd
PRIESTLY CR
PINCHOT LN
PINEY MOUNTAIN RD
Piney Mountain Road
Storage Area
Piney Mountain Road
Existing: Bridge
Option 1: 7' x 5' Floodplain Culvert
(With Storage Areas)
Option 2: 10' x 6' Floodplain Culvert
(Without Storage Areas)
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
Eastwood Lake Subwatershed
Proposed Storage Areas
N

Woodshire Lane/Huntington Drive System

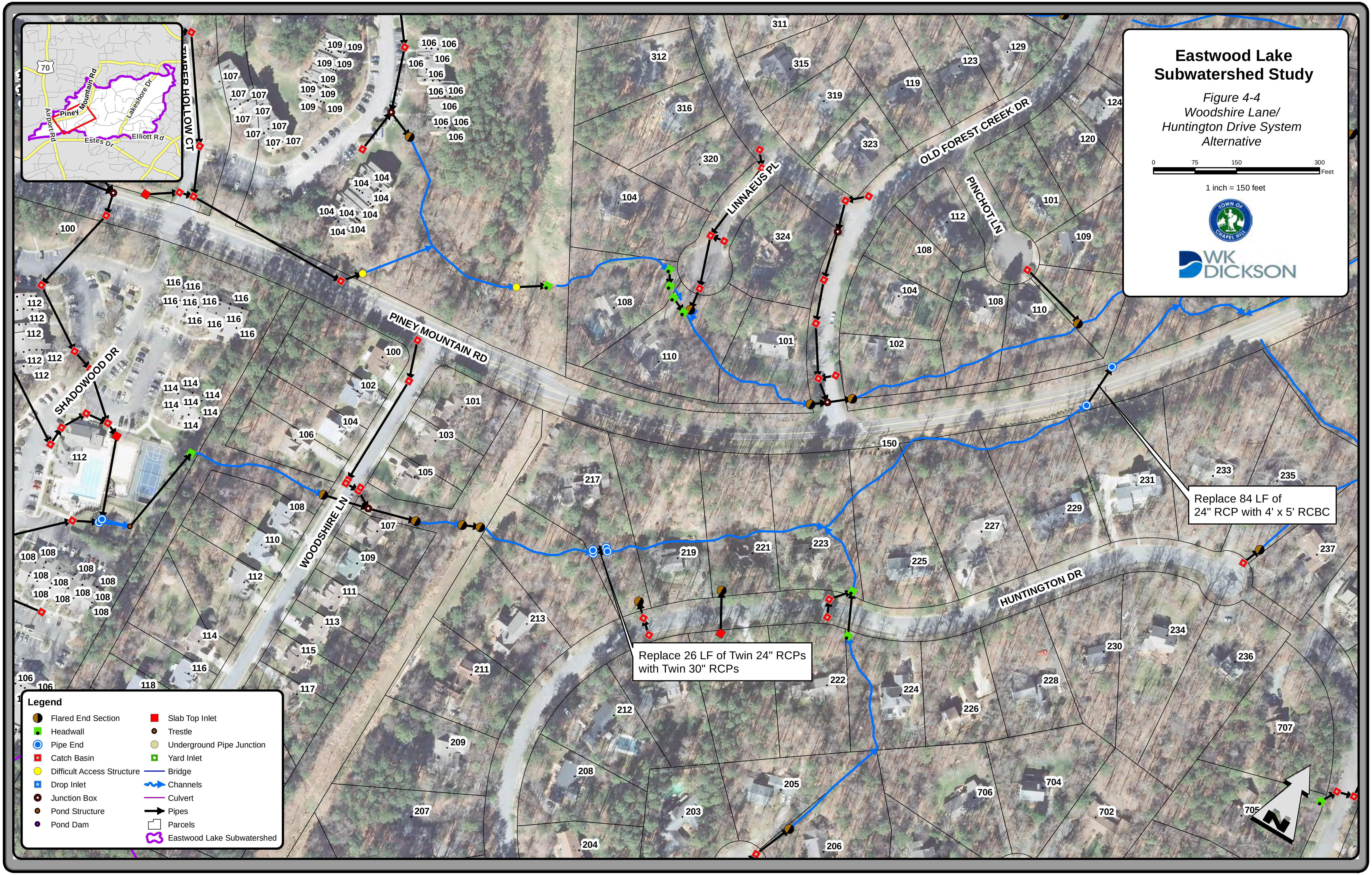
WK Dickson recommends the following improvements for the Woodshire Lane/Huntington Drive System as shown in Figure 4-4:

- Replace 26 LF of twin 24″ RCPs with twin 30″ RCPs adjacent to 217 Huntington Drive; and
- Replace 84 LF of 24″ RCP with a 4′ x 5′ RCBC across Piney Mountain Road.

In should be noted that in lieu of upsizing the segment of 24″ RCP crossing Piney Mountain Road, realigning the stream was considered as an option. Conceptually, the stream was realigned to be brought away from the Piney Mountain right-of-way and to tie-in downstream of the Piney Mountain Road crossing along Booker Creek. This would have reduced the amount of flow at this crossing and the required size of the proposed floodplain culvert at Piney Mountain Road. However, this option was not feasible due to several site constraints including sanitary sewer conflicts, private property impacts, and the steep topography.

The proposed improvements will bring the Woodshire Lane/Huntington Drive System up to the desired level of service. While a portion of the project will be located in the right-of-way, there will be 26 linear feet replaced on private property. Underground sanitary sewer lines and overhead power lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $372,300.

Due to their close proximity, the proposed improvements to the Woodshire Lane/Huntington Drive system should be coupled with the adjacent stream stabilization recommendations shown as Project 1 – Woodshire 2 and Project 2 – Woodshire 3 in Section 6.1 (Page 6-5).



Eastwood Lake Subwatershed Study
Figure 4-4
Woodshire Lane/ Huntington Drive System Alternative
0 75 150 300 Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
Replace 84 LF of 24" RCP with 4' x 5' RCBC
Replace 26 LF of Twin 24" RCPs with Twin 30" RCPs
PINEY MOUNTAIN RD
TIMBER HOLLOW CT
SHADOWOOD DR
WOODSHIRE LN
LINNAEUS PL
OLD FOREST CREEK DR
PINCHOT LN
HUNTINGTON DR
Piney Mountain Rd
Airport Rd
Lakeshore Dr
Estes Dr
Elliott Rd
70
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
Eastwood Lake Subwatershed
N

4.3 EASTWOOD LAKE EAST

The Eastwood Lake East portion of the project consists of the downstream segment of Booker Creek including Eastwood Lake to the area upstream of the North Lakeshore Drive crossing. It is in the eastern portion of the Eastwood Lake subwatershed area. Eastwood Lake East generally consists of two (2) different types of projects as follows:

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

North Lakeshore Drive – As determined by the existing conditions analysis, the existing bridge at this crossing provides a 10-year level of service. The desired level of service for a roadway located within a FEMA regulated floodway is the 100-year design storm. Currently, it is overtopped by 0.51 feet during the 25-year storm event.

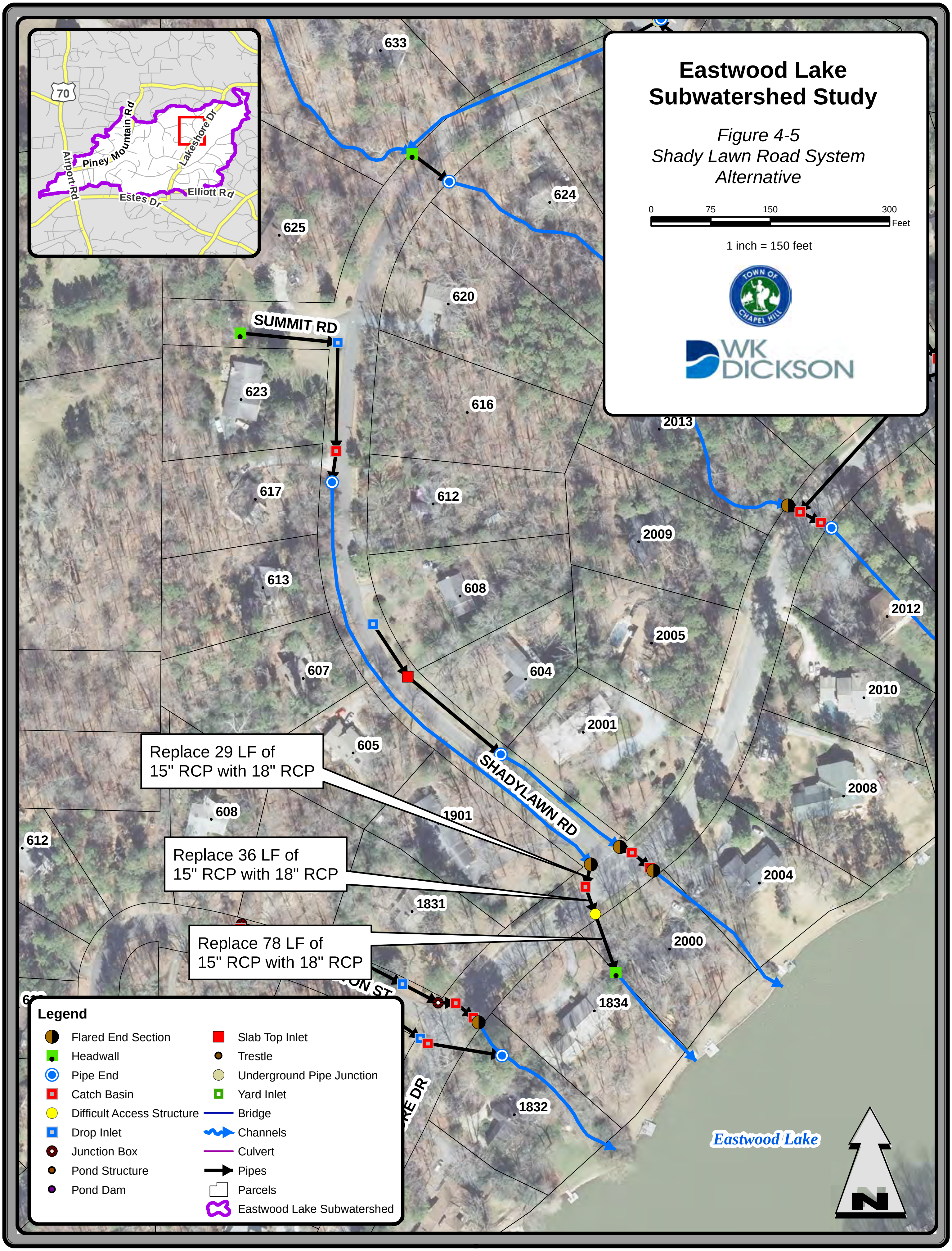
With the storage area improvements proposed upstream, water surface elevations will be reduced by 0.37 feet during the 10-year storm event and 0.11 feet in the 25-year storm event. These reductions will improve the performance of North Lakeshore Drive bridge when considering the future flows. Floodplain culverts are not feasible at this location due to the limited space adjacent to the bridge. The existing bridge is in good condition; therefore, no infrastructure improvements are proposed for this location.

Shady Lawn Road System

WK Dickson recommends the following improvements for the Shady Lawn Road System as shown in Figure 4-5:

- Replace 65 LF of 15″ RCP with 18″ RCP along North Lakeshore Drive near intersection with Shady Lawn Road;
- Replace 78 LF of 15″ RCP with 18″ RCP adjacent to 1834 and 2000 North Lakeshore Drive; and
- Install 2 inlets.

The proposed improvements will provide the desired 10-year level of service. While a portion of the project will be located in the right-of-way, there will be 78 linear feet replaced on private property. Sections of the curb and gutter along North Lakeshore Drive will need to be removed and replaced as part of the proposed improvements. Underground water and sanitary sewer lines were identified as potential utility conflicts. Other potential site restrictions include a power pole and overhead power lines. The total estimated cost for the recommended alternative is $153,300.



Eastwood Lake Subwatershed Study
Figure 4-5
Shady Lawn Road System Alternative
0
75
150
300
Feet
1 inch = 150 feet
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
SUMMIT RD
SHADYLAWN RD
633
624
625
620
623
616
617
612
2013
2009
613
608
2012
2005
607
604
2010
605
2001
2008
1901
608
612
2004
1831
2000
1834
1832
Replace 29 LF of 15" RCP with 18" RCP
Replace 36 LF of 15" RCP with 18" RCP
Replace 78 LF of 15" RCP with 18" RCP
Eastwood Lake
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
Eastwood Lake Subwatershed
N

Arlington Street #1 Road Closed System

WK Dickson recommends the following improvements for the Arlington Street #1 Closed System as shown in Figure 4-6:

- Remove and replace 22 LF of 24″ RCP at intersection of North Lakeshore Drive and Arlington Street (existing pipe has negative slope);
- Replace existing manhole with inlet at intersection of North Lakeshore Drive and Arlington Street;
- Replace 113 LF of 24″ RCP with open channel; and
- Install berm on the back side of 1831 North Lakeshore Drive.

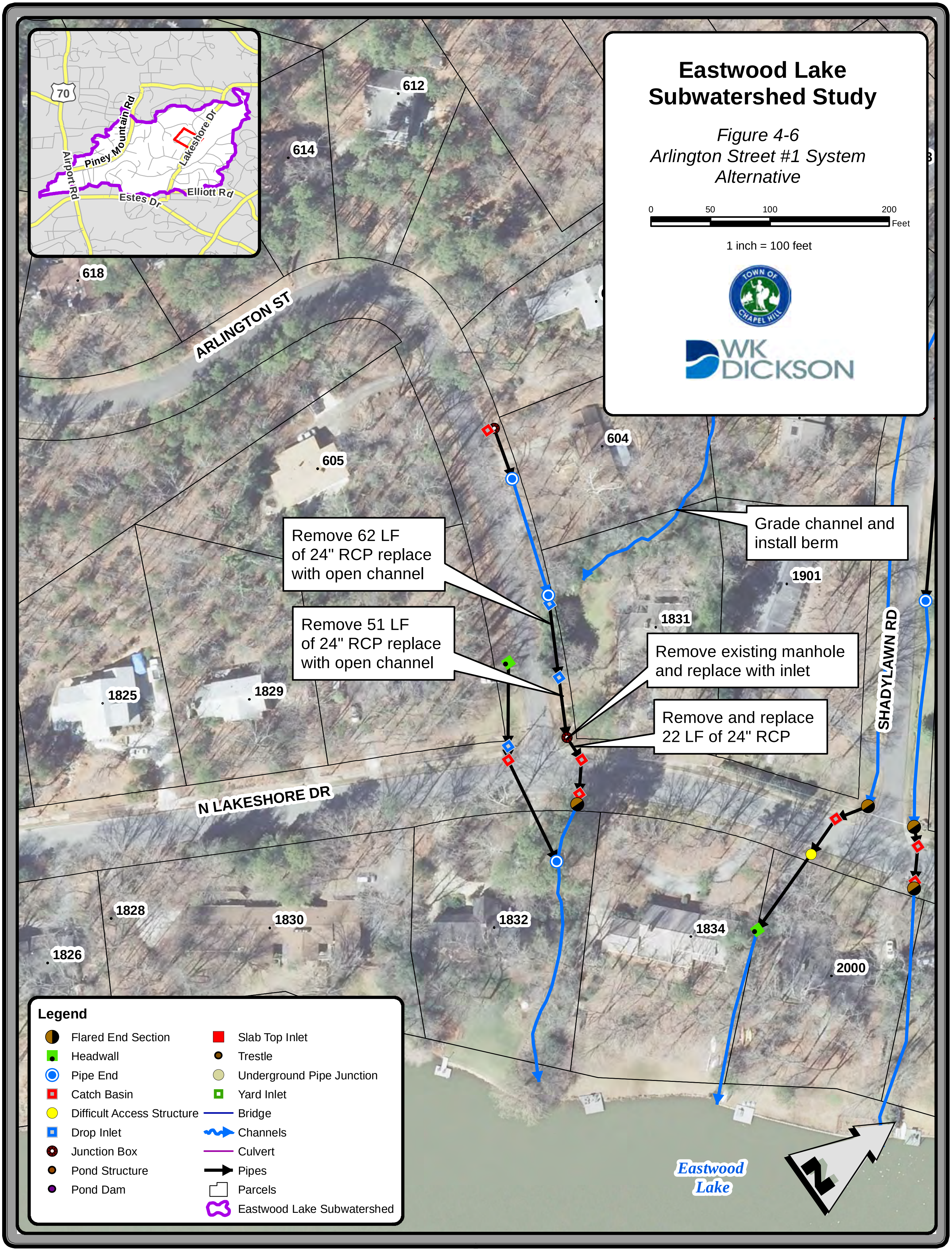
The proposed improvements will continue to provide a 10–year level of service while reducing the spread for the Arlington Street #1 Road Closed System. The project is located in the public right-of-way, so there will be minimal impacts to private properties. The driveways and/or landscaping at the following properties will be impacted: 1831 and 1833 North Lakeshore Drive. Sections of curb and gutter at the intersection of Arlington Street and North Lakeshore Drive will need to be removed and replaced to complete the proposed improvements. Underground sewer lines, overhead power lines, and a power pole were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $104,400.

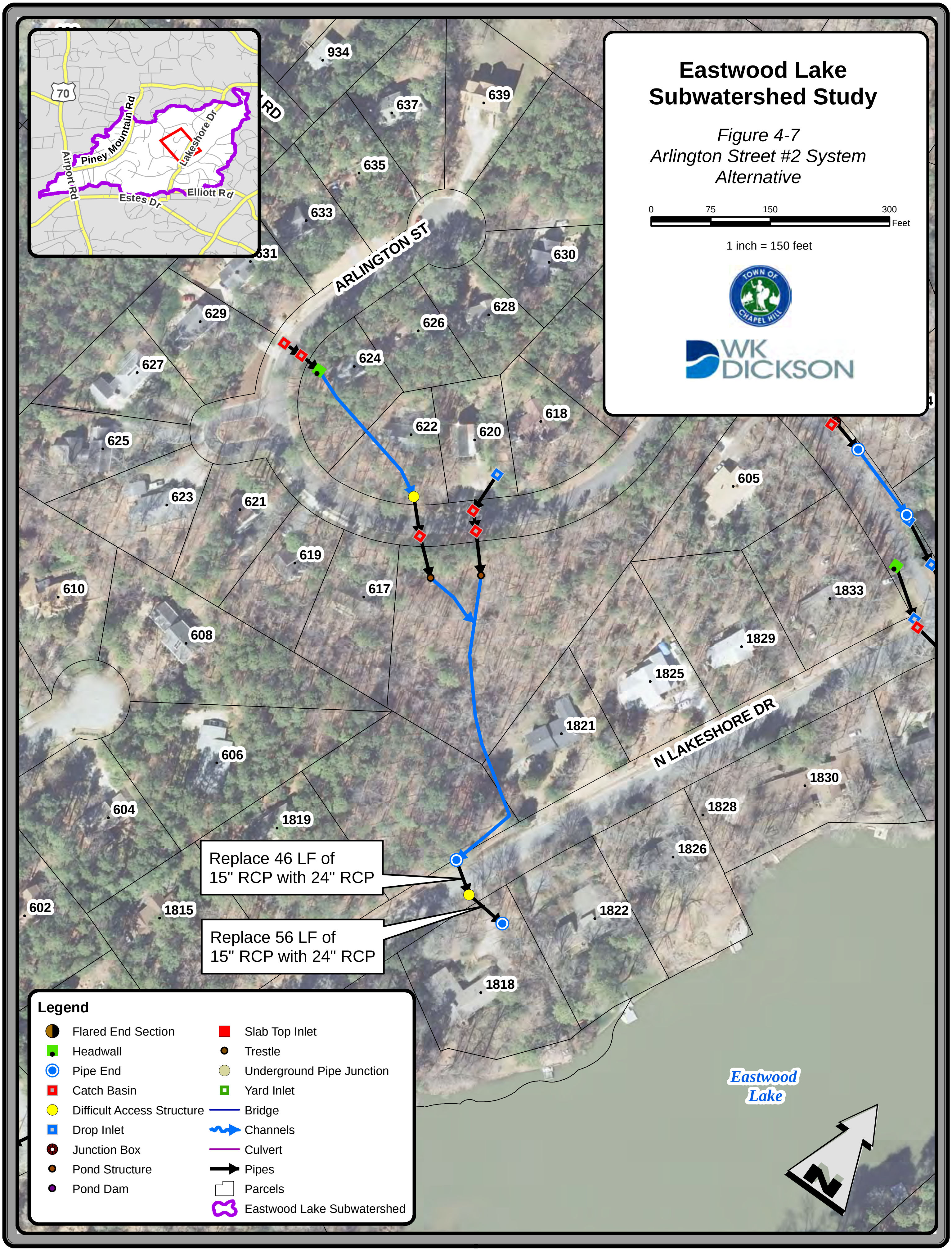
Arlington Street #2 Closed System

WK Dickson recommends the following improvements for the Arlington Street #2 Closed System as shown in Figure 4-7:

- Replace 46 LF of 15″ RCP with 24″ RCP across North Lakeshore Drive; and
- Replace 56 LF of 15″ RCP with 24″ RCP adjacent to 1818 North Lakeshore Drive.

The proposed improvements will provide the desired 10-year level of service for the Arlington Street #2 Closed System. Approximately half of the project will be located in the right-of-way, while the remaining half will be located on private property (1818 North Lakeshore Drive). The driveway and landscaping at 1818 North Lakeshore Drive will be impacted. Section of the curb and gutter along North Lakeshore Drive will need to be removed and replaced as part of the proposed improvements. Underground water lines and overhead power lines were also identified as potential utility conflicts and site restrictions. The total estimated cost for the recommended alternative is $133,100. If funds allow, the Town should consider installing the proposed SCM project upstream of the Arlington Street #2 system improvements concurrently.


Eastwood Lake
Subwatershed Study
Figure 4-6
Arlington Street #1 System
Alternative
0
50
100
200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
612
614
618
605
604
ARLINGTON ST
Remove 62 LF of 24" RCP replace with open channel
Remove 51 LF of 24" RCP replace with open channel
Grade channel and install berm
Remove existing manhole and replace with inlet
Remove and replace 22 LF of 24" RCP
1901
1831
1825
1829
SHADYLAWN RD
N LAKESHORE DR
1828
1830
1832
1834
1826
2000
Eastwood Lake
N
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
Eastwood Lake Subwatershed


Eastwood Lake
Subwatershed Study
Figure 4-7
Arlington Street #2 System
Alternative
0
75
150
300
Feet
1 inch = 150 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
RD
ARLINGTON ST
N LAKESHORE DR
934
637
639
635
633
631
630
629
628
626
627
624
625
622
620
618
623
621
605
619
610
617
1833
608
1829
1825
1821
606
1830
604
1819
1828
1826
602
1815
1822
1818
Replace 46 LF of
15" RCP with 24" RCP
Replace 56 LF of
15" RCP with 24" RCP
Eastwood
Lake
N
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
Eastwood Lake Subwatershed

South Lakeshore Drive/Ridgecrest Drive Closed System

WK Dickson recommends the following improvements for the South Lakeshore Drive /Ridgecrest Drive Closed System as shown in Figure 4-8:

- Replace and lower 127 LF of 15" RCP with 18" RCP from the South Lakeshore Drive and Ridgecrest Drive intersection across South Lakeshore Drive.

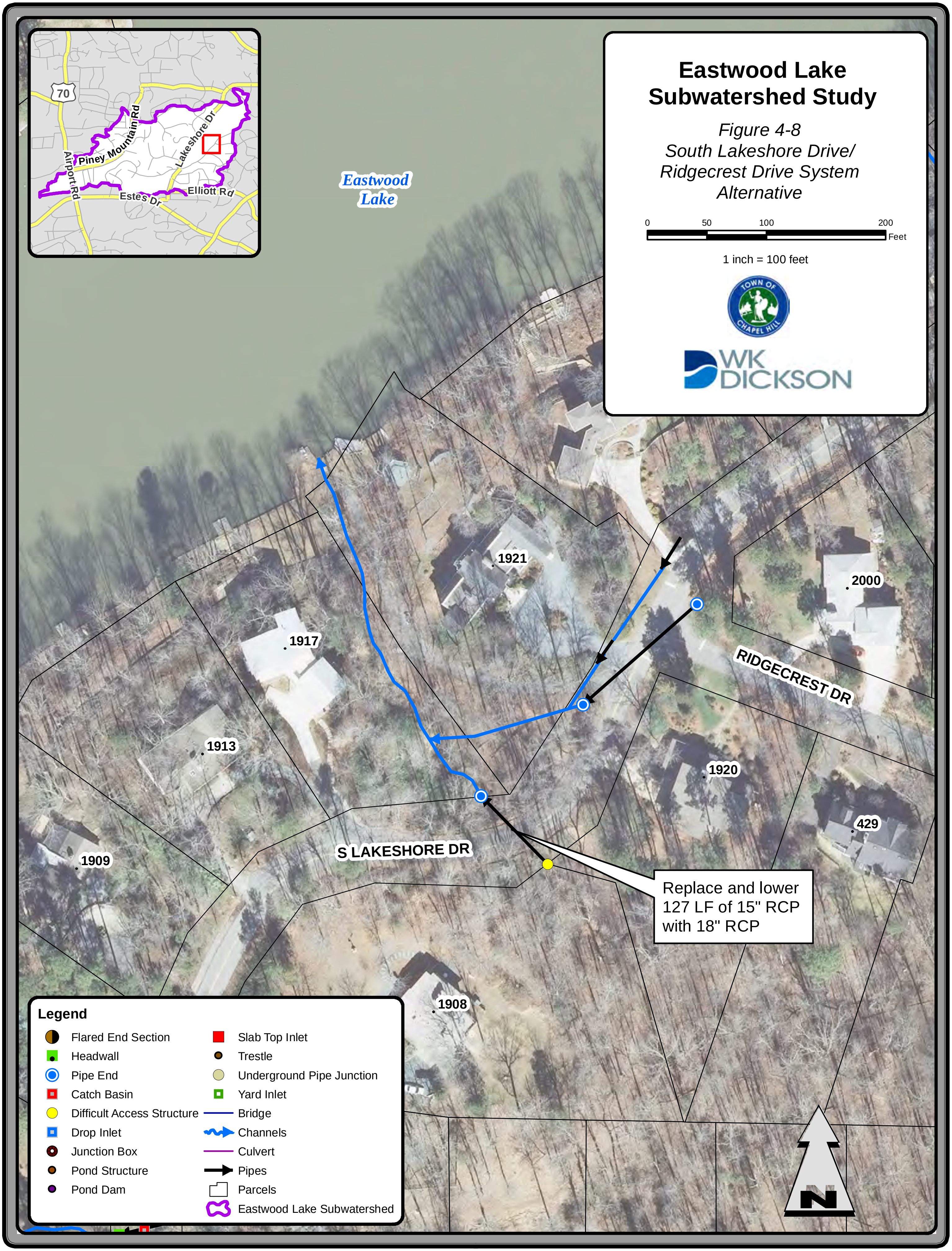
The proposed improvements will provide the desired 10-year level of service for the South Lakeshore Drive /Ridgecrest Drive Closed System. The project is located within the public right-of-way, there will be minimal impacts to private properties. Underground water and sanitary sewer lines were identified as potential utility conflicts. Other potential site restrictions include overhead power lines. The total estimated cost for the recommended alternative is $125,200. Due to the close proximity, the proposed improvements to the South Lakeshore Drive/Ridgecrest Drive system should be coupled with the adjacent stream stabilization recommendations shown as Projects 11 through 14 – Ridgecrest 1 – 4 in Section 6.1 (Pages 6-9 and 6-10).

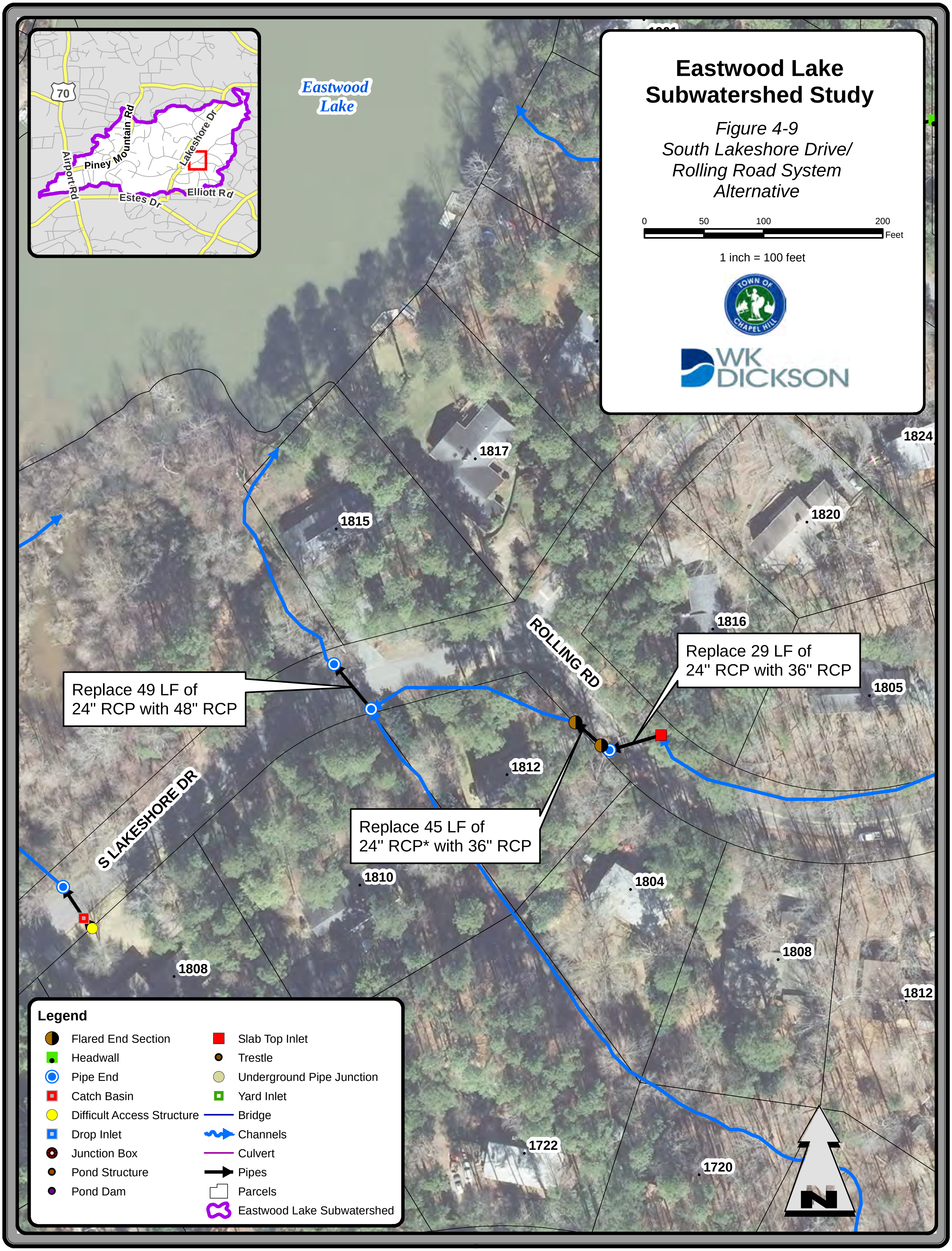
South Lakeshore Drive/Rolling Road Closed System

WK Dickson recommends the following improvements for the South Lakeshore Drive /Rolling Road Closed System as shown in Figure 4-9:

- Replace 45 LF of 24" RCP with 36" RCP across Rolling Road,
- Replace 29 LF of 24" RCP with 36" RCP (driveway culvert at 1812 South Lakeshore Drive); and
- Replace 49 LF of 24" RCP with 48" RCP across South Lakeshore Drive.

The proposed improvements will provide the desired 10-year level of service for the South Lakeshore Drive /Rolling Road Closed System. While a significant portion of the project will be located within the public right-of-way, there will be approximately 30 linear feet that will be located on private property. The driveway and landscaping at 1812 South Lakeshore Drive will be impacted. Underground water and sanitary sewer lines were identified as potential utility conflicts. Other potential site restrictions include overhead power lines. The total estimated cost for the recommended alternative is $216,800. Due to their close proximity, the proposed improvements to the South Lakeshore Drive/Rolling Road system should be coupled with the adjacent stream stabilization recommendations shown as Project 9 – Allard 2 in Section 6.1 (Page 6-9).


Eastwood Lake Subwatershed Study
Figure 4-8
South Lakeshore Drive/
Ridgecrest Drive System
Alternative
0 50 100 200
Feet
1 inch = 100 feet
TOWN OF CHAPEL HILL
WK DICKSON
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
Eastwood Lake
1921
2000
1917
RIDGECREST DR
1913
1920
429
S LAKESHORE DR
1909
Replace and lower
127 LF of 15" RCP
with 18" RCP
1908
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
Eastwood Lake Subwatershed
N


Eastwood Lake
Subwatershed Study
Figure 4-9
South Lakeshore Drive/
Rolling Road System
Alternative
0
50
100
200
Feet
1 inch = 100 feet
WK DICKSON
Eastwood Lake
70
Piney Mountain Rd
Lakeshore Dr
Airport Rd
Estes Dr
Elliott Rd
ROLLING RD
S LAKESHORE DR
Replace 49 LF of
24" RCP with 48" RCP
Replace 29 LF of
24" RCP with 36" RCP
Replace 45 LF of
24" RCP* with 36" RCP
1817
1815
1824
1820
1816
1805
1812
1810
1804
1808
1808
1812
1722
1720
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
Eastwood Lake Subwatershed
N

A summary of the hydraulic performance for the improvements proposed are include in Table 4-2. 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 4-2: Hydraulic Performance for Eastwood Lake – West and 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
BOOKER CREEK							
North Lakeshore Drive	301.63	100	298.73 299.02 298.52	301.06 **301.75** 301.51	**302.31** **302.44** **302.26**	**302.52** **302.57** **302.43**	**302.61** **302.66** **302.47**
Piney Mountain Road	385.66	100	378.56 379.80 379.20	383.64 **386.15** 383.21	**386.70** **387.13** 385.42	**387.32** **387.70** **386.61**	**387.72** **388.00** **387.00**

*Bold text indicates the existing water surface has exceeded the lowest 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 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. The water surface reductions shown in Table 4-3 are the cumulative benefits when all of the proposed storage area projects are implemented.

Table 4-3: WSEL Reductions for Future Conditions

Location	**Decrease in Water Surface Elevations (feet NAVD)**				
	2-year flood	**10-year flood**	**25-year flood**	**50-year flood**	**100-year flood**
North Lakeshore Drive	0.50	0.24	0.18	0.14	0.19
Piney Mountain Road	0.60	2.94	1.71	1.09	1.00

4.4 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 (future with all projects). The future conditions peak flows are summarized in Table 4-4. In comparison to the existing conditions flows, the future conditions flows increase between 0 and 11 percent for the 25-year storm. The future flows with all projects were developed from the future conditions taking into account attenuation for the proposed storage areas. The flood storage proposed in the watershed contributes to the alternative flows being less than the future flows. The reductions in flows provided by the proposed detention projects in the alternative are presented in Table 4-5.

Table 4-4: Future Conditions Flows from HEC-HMS for Eastwood Lake 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
ADD-CB-BH	Confluence of Crow Branch and Booker Creek	21577	505 583 549	1,018 1,128 1,006	1,318 1,478 1,311	1,600 1,750 1,585	1,837 1,976 1,744
Piney Mountain Rd – Booker Ck	Piney Mountain Road	20223	566 634 524	1,022 1,134 1,028	1,373 1,519 1,365	1,661 1,804 1,642	1,899 2,030 1,803
ADD-EL-50	Upstream of Eastwood Lake	16524	603 675 538	1,059 1,165 1,057	1,419 1,559 1,407	1,714 1,853 1,689	1,950 2,075 1,850
N Lakeshore Dr – Booker Ck	North Lakeshore Drive	15024	615 687 542	1,070 1,174 1,065	1,431 1,570 1,416	1,728 1,865 1,699	1,964 2,086 1,863
Eastwood Lake	Downstream of Eastwood Lake	11352	668 697 589	1,641 1,714 1,538	2,217 2,335 2,107	2,614 2,865 2,563	2,850 3,444 2,789

Table 4-5: Flow Reductions for Future vs. Future with All Projects for Eastwood Lake 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)
ADD-CB-BH	Confluence of Crow Branch and Booker Creek	21577	6%	11%	11%	9%	12%
Piney Mountain Rd – Booker Ck	Piney Mountain Road	20223	17%	9%	10%	9%	11%
ADD-EL-50	Upstream of Eastwood Lake	16524	20%	9%	10%	9%	11%
N Lakeshore Dr – Booker Ck	North Lakeshore Drive	15024	21%	9%	10%	9%	11%
Eastwood Lake	Downstream of Eastwood Lake	11352	15%	13%	10%	5%	5%

4.5 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 and changes in flows.

CONDITION ASSESSMENT

As part of the Eastwood Lake 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 was 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 a criticality assessment by running the criticality toolset to generate results. The results of this prioritization are included in this report as the findings of asset criticality within the Eastwood Lake subwatershed. The detailed methodology for customizing the prioritization tool for the Town can be found in Appendix I.

5.2 CRITICALITY ANALYSIS

After 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. 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.

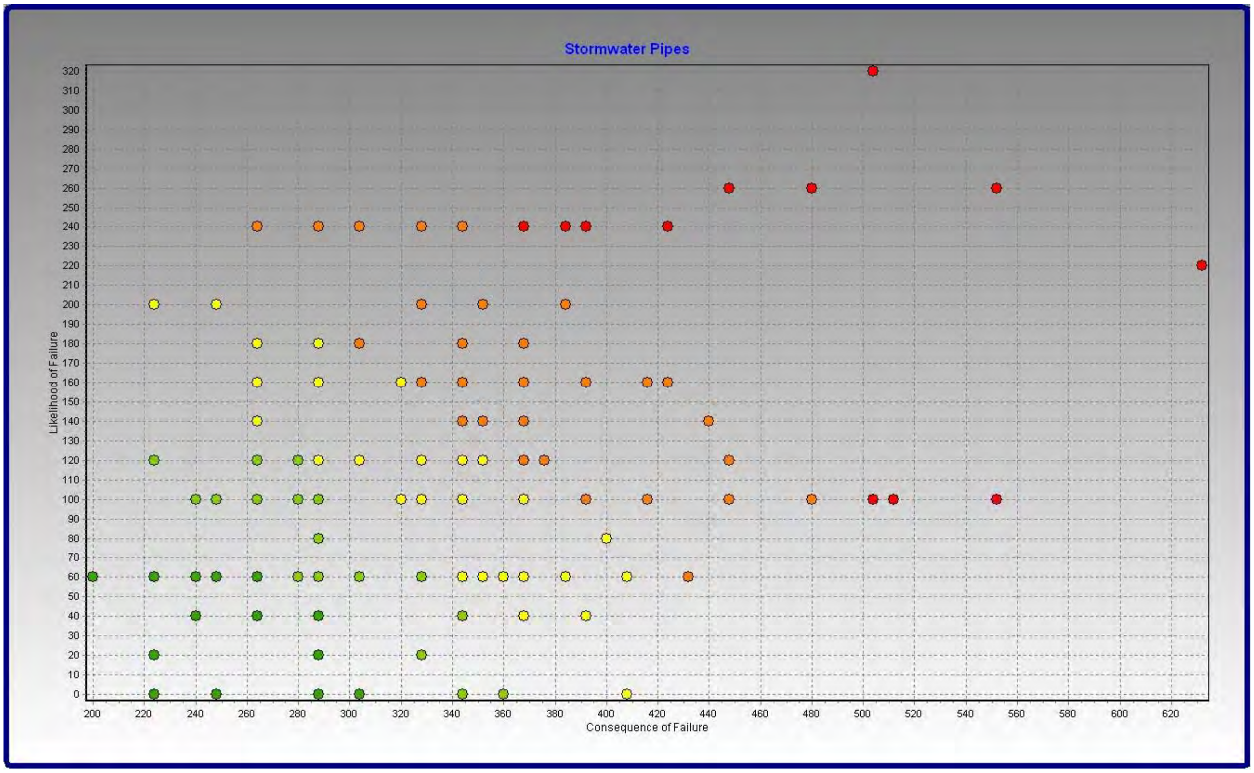
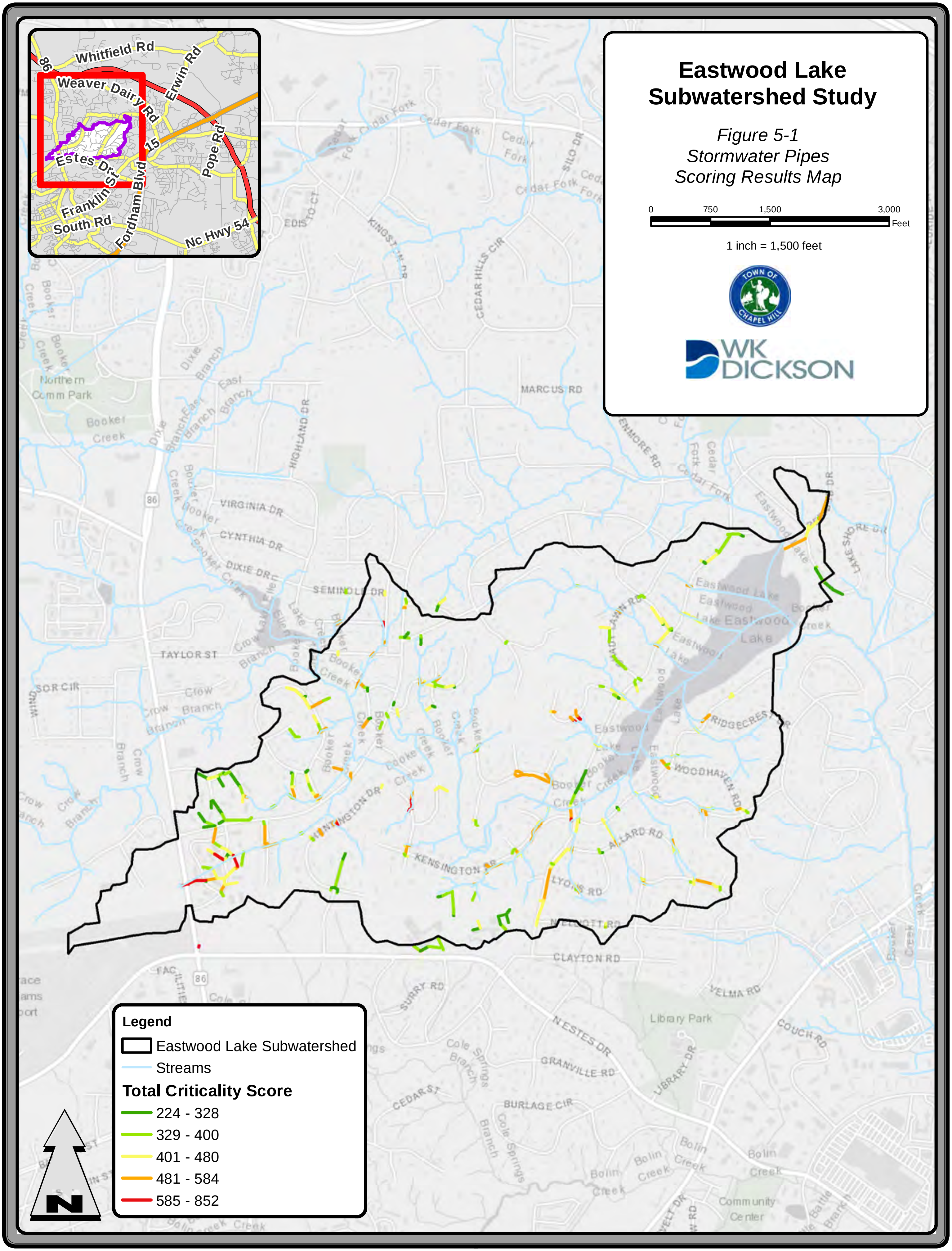
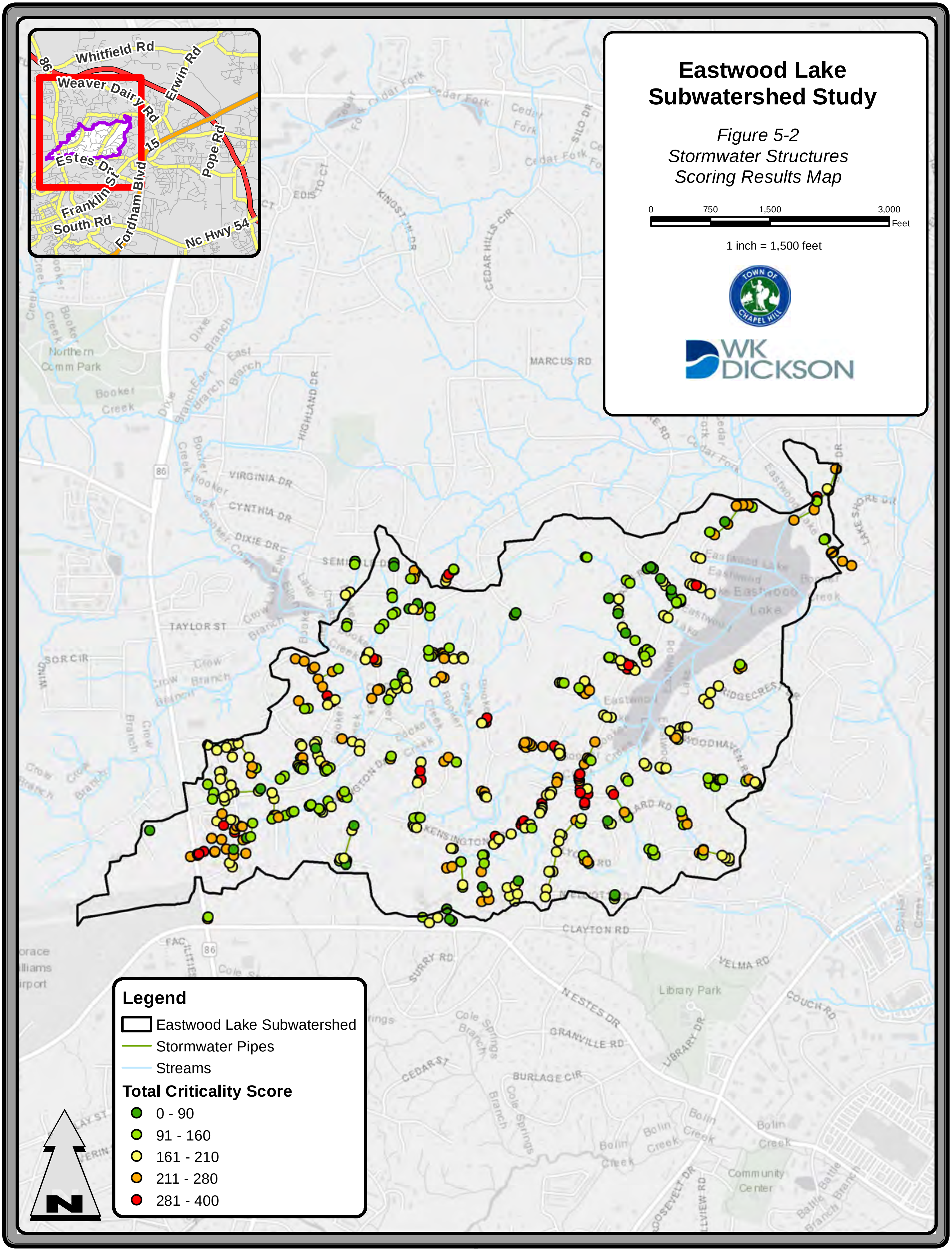


Exhibit 5-1: Stormwater Pipes Scoring Results


Eastwood Lake
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
Eastwood Lake Subwatershed
Streams
Total Criticality Score
224 - 328
329 - 400
401 - 480
481 - 584
585 - 852
N
Whitfield Rd
Weaver Dairy Rd
Erwin Rd
Pope Rd
Estes Dr
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
86
15
Eastwood Lake
Booker Creek
Cedar Fork
Crow Branch
Dixie Branch
East Branch
Bolin Creek
Cole Springs Branch
Northern Comm Park
Library Park
Community Center
VIRGINIA DR
CYNTHIA DR
DIXIE DR
SEMINOLE DR
TAYLOR ST
HIGHLAND DR
KINGSTON DR
CEDAR HILLS CIR
MARCUS RD
EDISTO CT
SILO DR
ELMORE RD
RIDGECREST DR
WOODHAVEN RD
HUNTINGTON DR
KENSINGTON DR
ALLARD RD
LYONS RD
ELLIOTT RD
CLAYTON RD
SURRY RD
VELMA RD
COUCH RD
N ESTES DR
GRANVILLE RD
LIBRARY DR
CEDAR ST
BURLAGE CIR
LAKE SHORE DR


Eastwood Lake
Subwatershed Study
Figure 5-2
Stormwater Structures
Scoring Results Map
0
750
1,500
3,000
Feet
1 inch = 1,500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Eastwood Lake Subwatershed
Stormwater Pipes
Streams
Total Criticality Score
0 - 90
91 - 160
161 - 210
211 - 280
281 - 400
N
Whitfield Rd
Weaver Dairy Rd
Erwin Rd
Estes Dr
Franklin St
Fordham Blvd
Pope Rd
South Rd
Nc Hwy 54
15
86
Cedar Fork
Silo Dr
Kingston Dr
Cedar Hills Cir
Marcus Rd
Highland Dr
Virginia Dr
Cynthia Dr
Dixie Dr
Taylor St
Booker Creek
East Branch
Northern Comm Park
Crow Branch
Eastwood Lake
Ridgecrest Dr
Woodhaven Rd
Kensington
Clayton Rd
Surry Rd
N Estes Dr
Velma Rd
Library Park
Granville Rd
Library Dr
Couch Rd
Cole Springs Branch
Cedar St
Burlage Cir
Bolin Creek
Community Center
Battle Branch
Lake Shore Dr

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 385 pipes evaluated, 31% of stormwater pipes scored in Level 4 or 5 indicating the highest need for stormwater rehabilitation efforts. Similarly, 31% 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 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 stormwater 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**
	0-328	**329-400**	**401-480**	**481-584**	**>584**
Stormwater Pipes	48	98	120	103	16
Likelihood Score Distribution					
	0-60	**61-120**	**121-160**	**161-200**	**>201**
Stormwater Pipes	98	137	79	38	33
Consequence Score Distribution					
	0-264	**265-320**	**321-376**	**377-448**	**>448**
Stormwater Pipes	139	78	127	33	8

Table 5-2 shows the criticality levels for stormwater structures. Within the assets evaluated 39% of the structures score in Level 4 or 5 indicating the highest need for stormwater structure rehabilitation efforts. Similarly, 32% 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 5-2: Stormwater Structures Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		→		**High**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	0-90	**91-160**	**161-210**	**211-280**	**>280**
Stormwater Structures	36	109	161	140	58
Likelihood Score Distribution					
	0	**1-20**	**21-60**	**61-100**	**>100**
Stormwater Structures	216	10	1	1	276
Consequence Score Distribution					
	0	**1-70**	**71-150**	**151-220**	**>220**
Stormwater Structures	7	121	233	130	13

5.4 TOWN-MAINTAINED ASSET ANALYSIS

Streets in the Eastwood Lake subwatershed are the responsibility of one of three (3) entities: 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 Martin Luther King Jr. Boulevard from the project area.

Stormwater assets adjacent to privately-owned roads were also eliminated from the study. Overall, 86.5% of stormwater structures and 86.5% of stormwater pipes fall within Town-maintained areas. Exhibit 5-2 presents the detailed results of this analysis in the same manner as the overall criticality analysis.

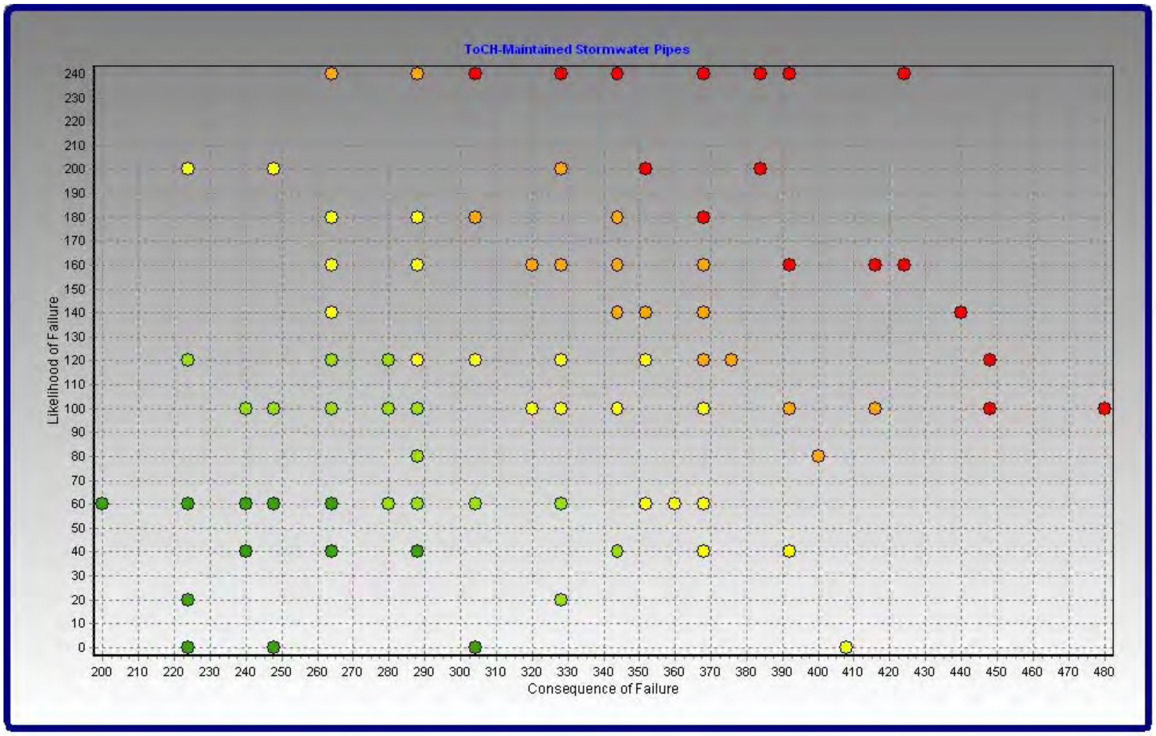
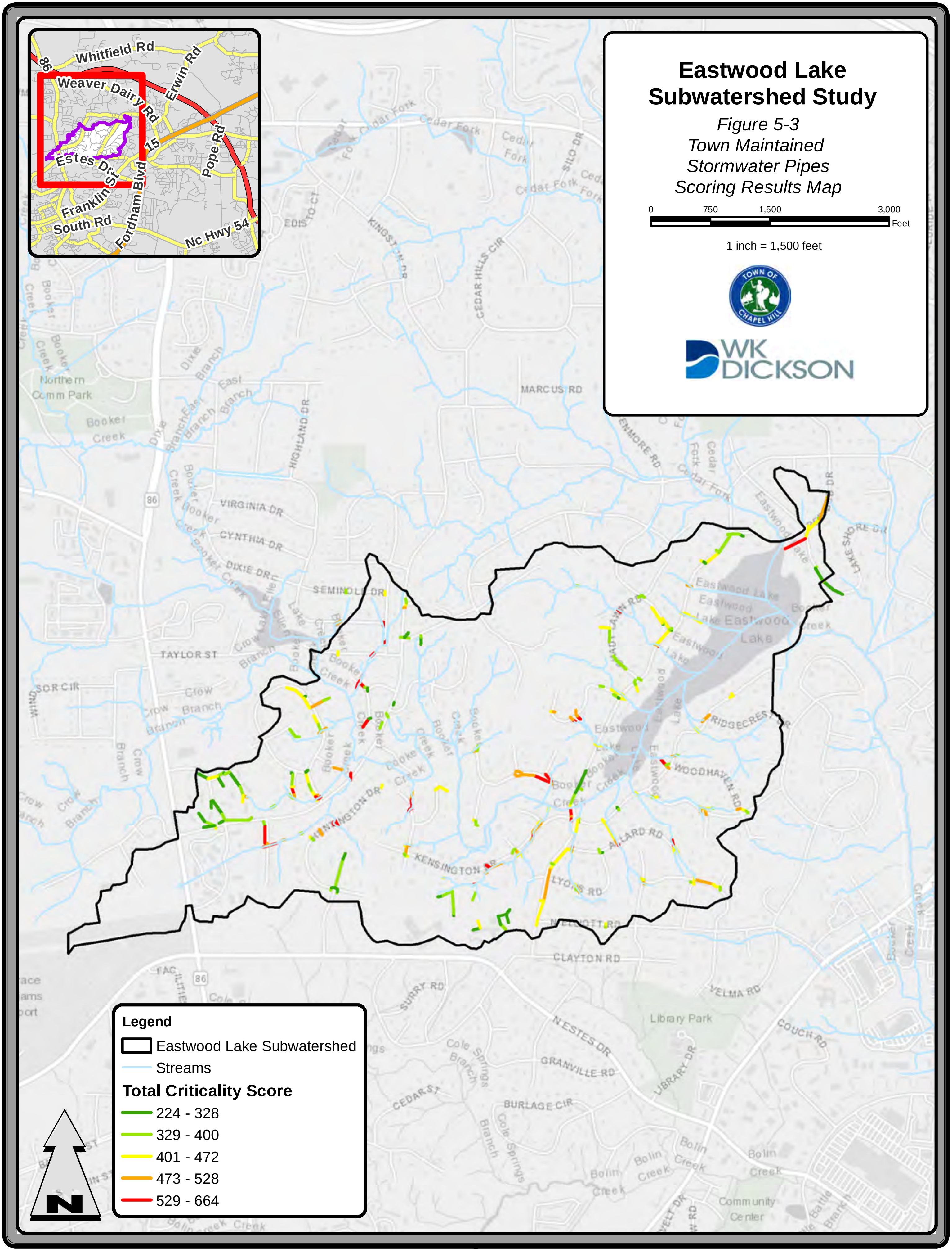
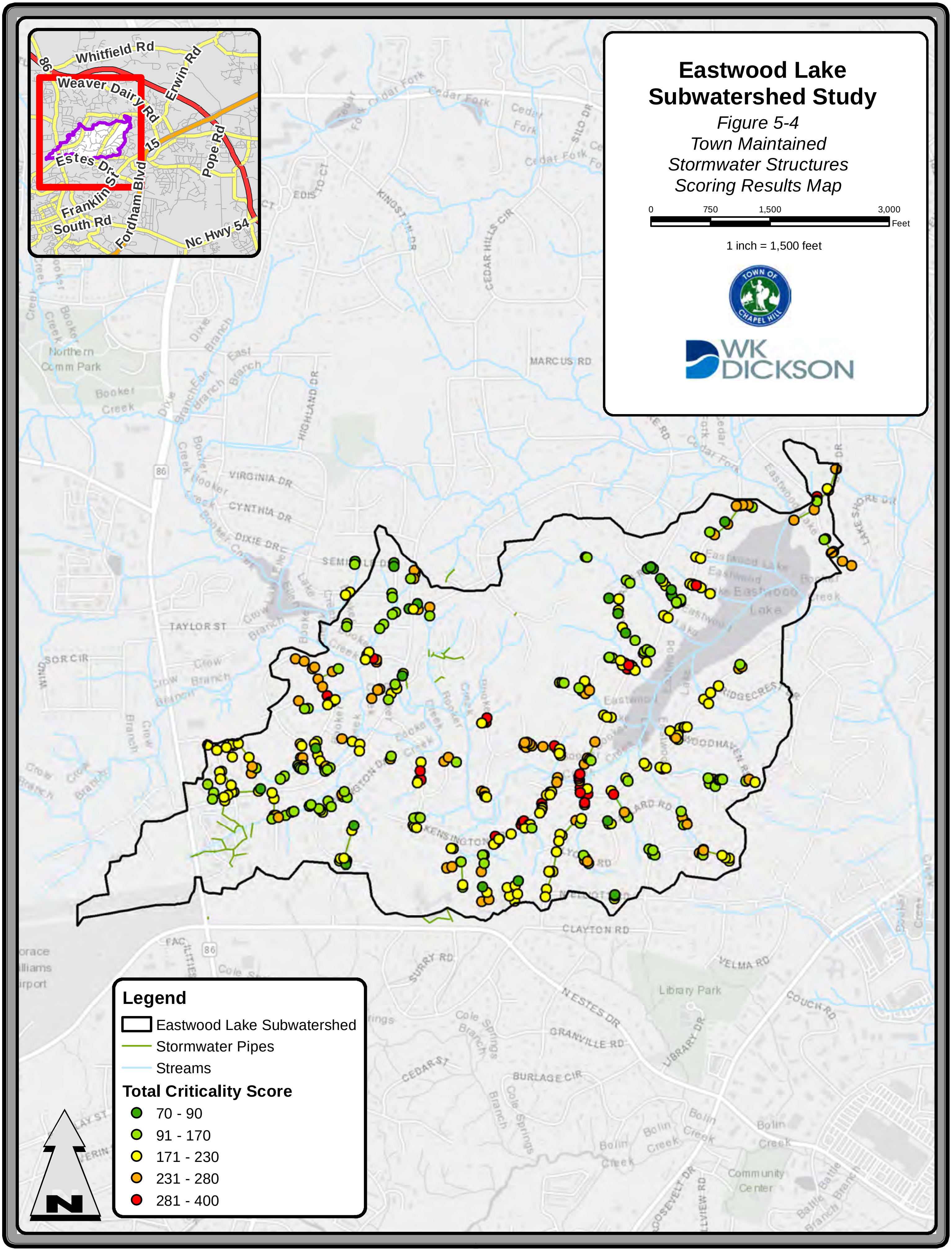


Exhibit 5-2: Town-Maintained Stormwater Pipes Scoring Results



Eastwood Lake 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
Eastwood Lake Subwatershed
Streams
Total Criticality Score
224 - 328
329 - 400
401 - 472
473 - 528
529 - 664
N
Whitfield Rd
Weaver Dairy Rd
Erwin Rd
Pope Rd
Estes Dr
Franklin St
Fordham Blvd
South Rd
Nc Hwy 54
Eastwood Lake
Booker Creek
Cedar Fork
Crow Branch
Dixie Branch
East Branch
Northern Comm Park
Library Park
Community Center
Bolin Creek
Cole Springs Branch
KINGSTON DR
CEDAR HILLS CIR
MARCUS RD
HIGHLAND DR
VIRGINIA DR
CYNTHIA DR
DIXIE DR
SEMINOLE DR
TAYLOR ST
RIDGECREST DR
WOODHAVEN RD
KENSINGTON DR
ALLARD RD
LYONS RD
CLAYTON RD
N ESTES DR
GRANVILLE RD
LIBRARY DR
BURLAGE CIR
CEDAR ST
VELMA RD
COUCH RD
SURRY RD
SILO DR
EDISTO CT
ELLIOTT RD



Eastwood Lake
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
Eastwood Lake Subwatershed
Stormwater Pipes
Streams
Total Criticality Score
70 - 90
91 - 170
171 - 230
231 - 280
281 - 400
N
Whitfield Rd
Weaver Dairy Rd
Erwin Rd
Estes Dr
Franklin St
Fordham Blvd
Pope Rd
South Rd
Nc Hwy 54
Eastwood Lake
Library Park
CLAYTON RD
N ESTES DR

Tables 5-3 and 5-4 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 5-3 shows the criticality levels for Town-maintained stormwater pipe assets falling into each scoring range. Of the 333 pipes evaluated 32% scored in Level 4 or 5 indicating the highest need for stormwater rehabilitation efforts. Similarly, 30% 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 5-3: Town Stormwater Pipes Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		→		**High**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	0-328	**329-400**	**401-472**	**473-528**	**>528**
Stormwater Pipes	41	85	101	65	41
Likelihood Score Distribution					
	0-20	**21-60**	**61-120**	**121-200**	**>200**
Stormwater Pipes	7	66	122	110	28
Consequence Score Distribution					
	0-264	**265-304**	**305-352**	**353-400**	**>400**
Stormwater Pipes	131	60	61	69	12

Table 5-4 shows the criticality levels for Town-maintained stormwater structures. Within the assets evaluated 39% of the structures scored in Level 4 or 5 indicating the highest need for stormwater structure rehabilitation efforts. Similarly, 34% 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 5-4: Town Stormwater Structures Scoring Summary and Distribution

Total Criticality Score Distribution					
	Low		→		**High**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	0-90	**91-170**	**171-230**	**231-280**	**>280**
Stormwater Structures	26	97	147	115	57
Likelihood Score Distribution					
	0	**1-20**	**21-60**	**61-100**	**>100**
Stormwater Structures	190	10	1	1	234
Consequence Score Distribution					
	0	**1-70**	**71-140**	**141-220**	**>220**
Stormwater Structures	4	102	198	123	9

5.5 FUTURE USE OF PRIORITIZATION TOOL

Because the data in the GIS database are dynamic, the results of the prioritization tool are a static representation based upon when the tool is run. As data are 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 different 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 their condition and proactively work to prevent a failure.

Conversely, assets with the greatest likelihood of failure 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 Eastwood Lake Subwatershed Study are described below.

6.1 STREAM STABILIZATION PROJECTS

Based on the field assessments, fourteen (14) stream reaches were identified as candidates for improvements. The locations of these reaches are shown on Figures 6-1 and 6-2. A list of steam stabilization techniques, arranged in order of less intensive to more intensive in implementation, follows:

1. Streambank stabilization
2. Head-cut stabilization and stream channel grade control
3. Perched culvert rectification
4. Stream channel restoration/relocation
5. 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.

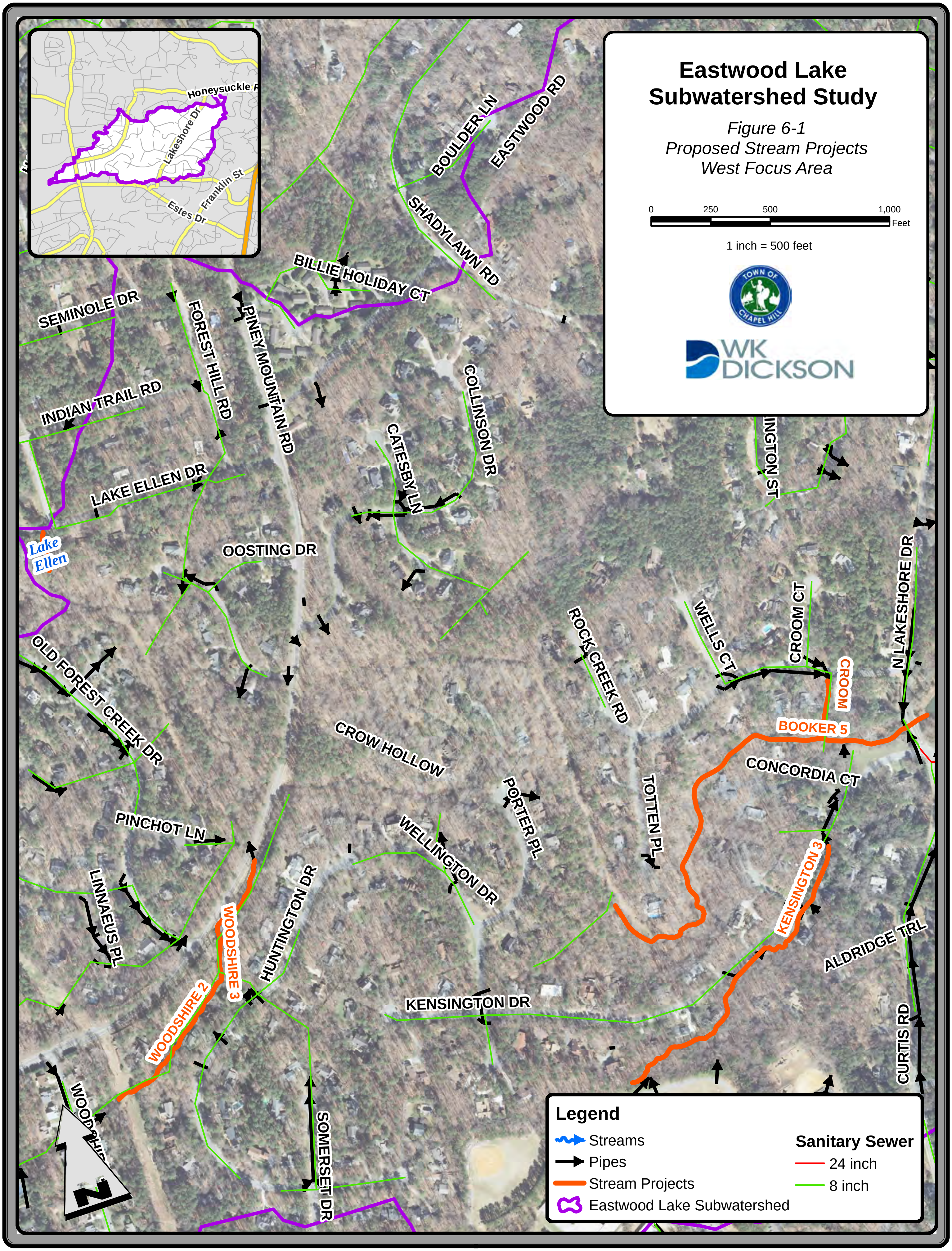
Table 6-1: Summary of Stream Stabilization Projects*

Project	Reach Name	Project Type	Reach and Habitat Score	Reach Length (feet)	Approx. Project Length (LF)
1	Woodshire 2	Stabilize channel, potentially move channel away from houses and existing hardened bank structures beside residences	161	687	200
2	Woodshire 3	Stabilize channel, protect sewer infrastructure	154	564	564
3	Lake Ellen 1	Stabilize banks and channel, RSC	112	168	168
4	Booker 5	Stabilize banks at various locations through reach	201	2,191	1,500
5	Croom	Stabilize outfall and incised channel downstream	169	245	245
6	Kensington 3	Stabilize identified driveway culvert outfalls and channel	206	1,433	200
7	Curtis 1	Stabilize identified driveway culvert outfalls and channel	197	1,292	200
8	Lyons 1	Stabilize channel, protect sewer infrastructure	148	241	241
9	Allard 2	Stabilize channel, protect sewer infrastructure	148	1,229	1,229
10	Woodhaven	Stabilize channel, protect sewer infrastructure	153	395	395
11	Ridgecrest 1	Stabilize channel, protect sewer infrastructure	122	210	210
12	Ridgecrest 2	Stabilize channel, protect sewer infrastructure	90	429	429
13	Ridgecrest 3	Stabilize channel, protect sewer infrastructure	145	872	872
14	Ridgecrest 4	Stabilize channel, protect sewer infrastructure	175	410	410
		TOTALS		10,370	6,863

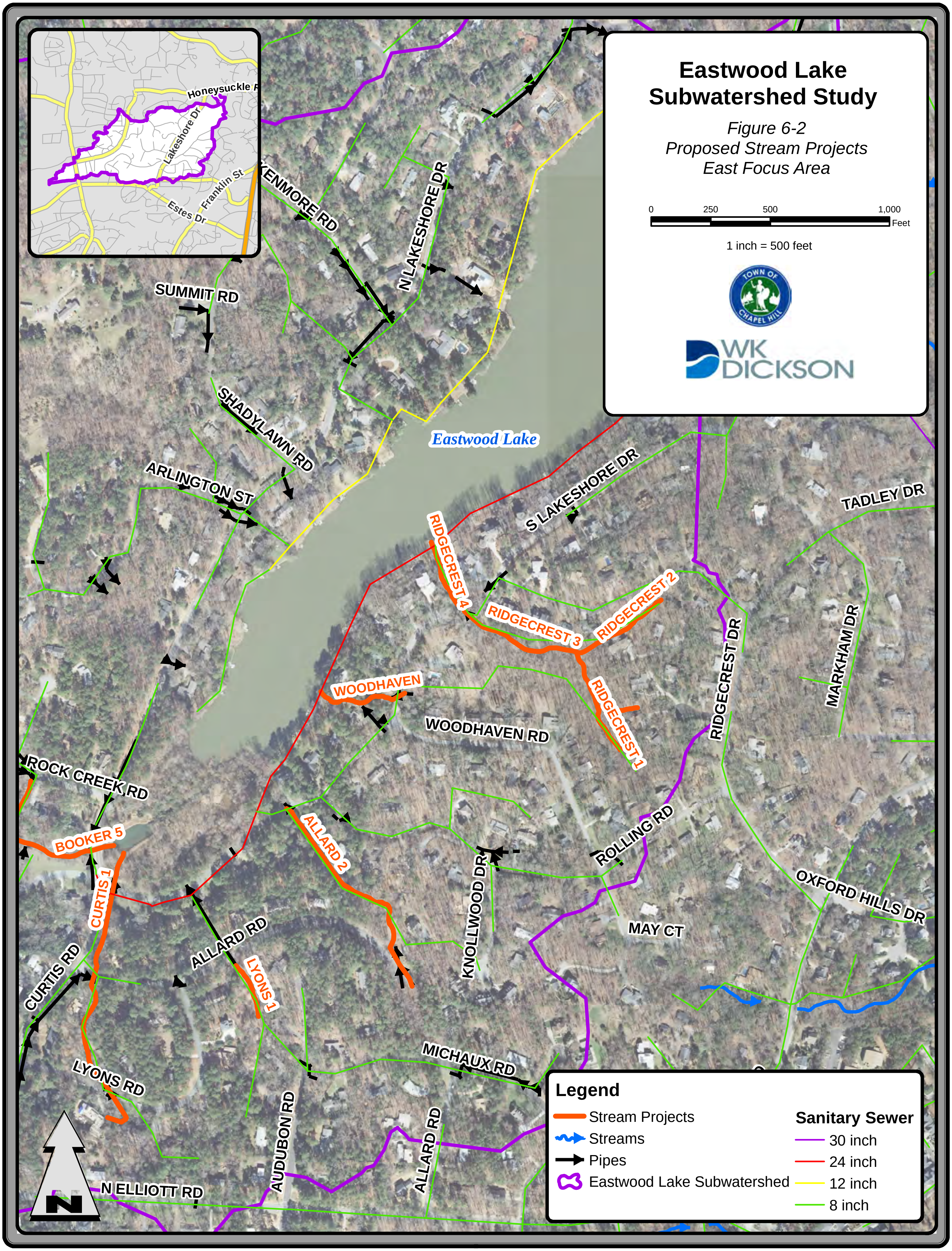
*Projects are not listed in order of priority in Table 6-1. See Section 9 for prioritization list.

The most common recommendation was streambank stabilization, head-cut stabilization and stream grade control, which in relative comparison, are 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 one (1) location. 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.



Eastwood Lake Subwatershed Study
Figure 6-1
Proposed Stream Projects
West Focus Area
0
250
500
1,000
Feet
1 inch = 500 feet
TOWN OF CHAPEL HILL
WK DICKSON
Legend
Streams
Pipes
Stream Projects
Eastwood Lake Subwatershed
Sanitary Sewer
24 inch
8 inch
Honeysuckle
Lakeshore Dr
Franklin St
Estes Dr
BOULDER LN
EASTWOOD RD
SHADYLAWN RD
BILLIE HOLIDAY CT
SEMINOLE DR
FOREST HILL RD
PINEY MOUNTAIN RD
COLLINSON DR
INDIAN TRAIL RD
CATESBY LN
LAKE ELLEN DR
Lake Ellen
OOSTING DR
OLD FOREST CREEK DR
ROCK CREEK RD
WELLS CT
CROOM CT
N LAKESHORE DR
CROOM
BOOKER 5
CROW HOLLOW
CONCORDIA CT
PINCHOT LN
PORTER PL
TOTTEN PL
WELLINGTON DR
LINNAEUS PL
WOODSHIRE 3
HUNTINGTON DR
KENSINGTON 3
ALDRIDGE TRL
WOODSHIRE 2
KENSINGTON DR
CURTIS RD
SOMERSET DR


Eastwood Lake
Subwatershed Study
Figure 6-2
Proposed Stream Projects
East Focus Area
0
250
500
1,000
Feet
1 inch = 500 feet
Legend
Stream Projects
Streams
Pipes
Eastwood Lake Subwatershed
Sanitary Sewer
30 inch
24 inch
12 inch
8 inch
Eastwood Lake
KENMORE RD
N LAKESHORE DR
SUMMIT RD
SHADYLAWN RD
ARLINGTON ST
S LAKESHORE DR
TADLEY DR
RIDGECREST 4
RIDGECREST 3
RIDGECREST 2
RIDGECREST 1
RIDGECREST DR
MARKHAM DR
WOODHAVEN
WOODHAVEN RD
ROCK CREEK RD
BOOKER 5
ALLARD 2
ROLLING RD
OXFORD HILLS DR
CURTIS 1
KNOLLWOOD DR
MAY CT
ALLARD RD
LYONS 1
CURTIS RD
MICHAUX RD
LYONS RD
AUDUBON RD
N ELLIOTT RD
Honeysuckle R
Lakeshore Dr
Franklin St
Estes Dr

Stream Stabilization Project 1: Woodshire 2

Woodshire 2 is located south of Piney Mountain Road upstream of the Huntington reach. Most of the project is located on private, residential property in the Cooker Woods West subdivision. The stream channel flows closely beside or behind three (3) residences along Huntington Drive. Several perched culverts are located along this section of the stream. An 8" sewer line parallels the stream which makes relocation challenging. Additionally, a stream located so close to residential housing can be perceived as a landscaping feature to residents further complicating moving the stream.

Picture 6-1: Woodshire 2 – Driveway Culverts

The proposed project would likely include stabilization of the channel near eroding driveway crossings, including resolving the perched culverts. The Town should consider moving the stream to the north immediately downstream of the 217 Huntington Drive driveway crossing, which could allow for incorporating restoration techniques and reduce the potential for structural damage to the nearby residences. Private property owner approval would be required for the project to move forward. If the homeowners are not interested in moving the stream, additional spot bank stabilization would be required. The sewer easement provides good access to most of this reach.

Picture 6-2: Woodshire 3 – Stream Crossing

Stream Stabilization Project 2: Woodshire 3

Woodshire 3 is located southeast of Piney Mountain Road, downstream of the confluence between the Woodshire 2 reach and the Huntington reach. The channel alignment is close to the road embankment of Piney Mountain Road along much of this reach with eroding banks that may ultimately compromise road stability. This project includes bank stabilization and channel grade control to protect Piney Mountain Road and the existing sewer line. A sewer line is located beside the stream, mostly on the right bank, providing a narrow corridor for potential stream stabilization. The sewer easement provides good access to most of this reach.

Stream Stabilization Project 3: Lake Ellen 1

Lake Ellen 1 is a short reach located south of Lake Ellen Drive, downstream of Lake Ellen between two (2) residential properties. The channel is very deeply incised, and the banks are eroding and falling into the channel. Repair options are to: (1) stabilize the channel in place, with grade control and hardened structures along the channel to control bank erosion; or (2) install a regenerative stormwater conveyance or similar device, which creates a sequence of step pools out of an underlying substrate of sand and mulch, with boulder structures used to stabilize the channel bed and banks. The site can be most easily accessed from the sewer right of way on Booker Creek. Repairs on this site are challenging due to access and the deeply incised condition of the existing channel.

Picture 6-3: Lake Ellen 1 – RSC Opportunity

Picture 6-4: Booker 5 – Bank Stabilization

Stream Stabilization Project 4: Booker 5

The Booker 5 reach is located along the main stem of Booker Creek upstream of Eastwood Lake. The surrounding land use is generally wooded residential lots. Approximately 1,500 feet of this 2,191-foot reach needs bank stabilization (on one or both banks) and in some places channel grade control. Repairs include stabilization of both banks for 200 feet on the upstream end, bank stabilization on the right bank farther downstream, bank stabilization on the left bank adjacent to a sewer manhole farther downstream, and bank and streambed stabilization on the lower section as it approaches North Lakeshore Drive. The sewer easement provides good access to this reach.

Stream Stabilization Project 5: Croom

The Croom reach is located south of Rock Creek Road, downstream of the upstream reach that parallels Croom Road. The outfall under Croom Road is perched approximately 5 feet above the channel and extensive erosion is taking place here threatening the future structural integrity of the culvert and the road above. Downstream, the channel needs stabilization where it is incised approximately 2 to 3 feet. The sewer easement provides good access to this reach.

Picture 6-5: Croom – Perched Culvert

Stream Stabilization Project 6: Kensington 3

The Kensington 3 reach is located southeast of Kensington Drive flows north towards Booker Reach 5. Repairs in this reach are limited to two short sections, where bank and channel bed stabilization are needed to control erosion, and one perched driveway outfall that is eroding and threatening the structural integrity of the crossing. Accessibility to this reach is fair, although the entire reach is located on private property. There are no sewer utilities present along this reach.

Picture 6-6: Kensington 3 – Bank and Channel Stabilization

Stream Stabilization Project 7: Curtis 1

This reach flows north to the Eastwood Lake forebay. The stream includes crossings Lyons Road, Allard Road and South Lakeshore Drive. The proposed repair consists of stabilization of the eroding banks and channel bed on a relatively short 200-foot section that flows behind a residence on private property. A grade control structure will likely be required to keep the head-cut from propagating upstream. Access is fair from the street.

Stream Stabilization Project 8: Lyons 1

Lyons 1 is collects runoff from Michaux Road and Audobon Road flowing north through private properties to a 30" RCP pipe system at Allard Road. The steep stream has significant head-cuts and bank erosion resulting in sediment loads entering directly to Eastwood Lake downstream of the forebay. A sanitary sewer line is located along the west bank and may be contributing to the bank erosion. Repairs in this reach include establishing reliable grade control in the channel bed, repairing the head-cuts, protecting the sewer line system, and establishing riparian buffer vegetation. Access is good along the sewer easement.

Picture 6-7: Lyons 1 – Bank Stabilization

Picture 6-8: Allard 2 – Stream Stabilization

Stream Stabilization Project 9: Allard 2

Allard 2 flows northwest to Eastwood Lake through residential properties between Rolling Road and Allard Road. A sanitary sewer is located along the left bank similar to the Lyons 1 reach. The steep terrain and limited vegetated buffer has resulted in multiple head-cuts and significant bank erosion. Potential stabilization activities in this reach include establishing reliable grade control in the channel bed, repairing the head-cuts, and protecting the sewer line system. Access to the channel is good along the sewer.

Stream Stabilization Project 10: Woodhaven

This reach is located north of Woodhaven Road and passes under South Lakeshore Drive between Woodhaven Road and Ridgecrest Drive. The erosion concerns are similar to those listed above for Allard 2 and Lyons 1 with steep terrain resulting in head-cuts and bank erosion. Proposed repairs include grade control structures and flattening of the banks to reduce the shear forces. Spot stabilization will also be required immediately downstream of the South Lakeshore Drive crossing. Access is fair along the sewer easement.

The remaining four (4) projects are all part of the same stream network draining Ridgecrest Drive and Rolling Road. The streams ultimately drain to Eastwood Lake through private properties.

Picture 6-9: Ridgecrest 1 – Existing Sewer Manhole

Stream Stabilization Project 11: Ridgecrest 1

Ridgecrest 1 is located in a sewer right-of-way northwest of Woodhaven Road and west of Ridgecrest Drive, and is the southern fork of the upstream end of the reach. Runoff on the steep terrain has created multiple head-cuts and streambank erosion. The project consists of establishing reliable grade control in the channel bed, stabilizing channel banks, and moving the channel to protect the sewer manhole infrastructure that is currently in the channel. Access to the channel is fair along the sewer easement.

Picture 6-10: Ridgecrest 2 – Bank Stabilization

Stream Stabilization Project 12: Ridgecrest 2

This reach is located north of Ridgecrest 1, the northern fork at the upstream end. Similar to the conditions on Ridgecrest 1, runoff on the steep terrain has created multiple head-cuts and streambank erosion. Repairs consist of establishing reliable grade control in the channel bed, stabilizing channel banks, and protecting sewer infrastructure. Access is fair along the sewer easement.

Stream Stabilization Project 13: Ridgecrest 3

Ridgecrest 3 is located downstream of the confluence of Ridgecrest 1 and 2, upstream of South Lakeshore Drive. This reach is also steep, and repairs consist of establishing reliable grade control in the channel bed, stabilizing channel banks, and protecting sewer infrastructure. Access is fair along the sewer easement.

Stream Stabilization Project 14: Ridgecrest 4

This reach is located downstream of South Lakeshore Drive. Repairs consist of stabilizing the outfall under the street, establishing reliable grade control in the channel farther downstream, and stabilizing stream banks. Access is good from a private driveway, if permission is obtained.

6.2 SCM PROJECT IDENTIFICATION

6.2.1 OUTFALL OPPORTUNITIES

As described in Section 3.4 (See Table 3-8), 114 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. Additional opportunities (EL0157/EL0162 and EL0520) were added based on field review of existing stormwater control measure infrastructures and community input. Through these processes, ten (10) outfall retrofit opportunities were identified for water quality improvement in the Eastwood Lake subwatershed (Table 6-2).

Table 6-2: Eastwood Lake Outfall Opportunities

	Area (ac)	Location
EL0431	0.034	Within ROW on west side of Piney Mountain Road, south of intersection with Priestly Creek Drive
EL0389	0.017	Within ROW on west side of Piney Mountain Road at Eastwood Road
EL0541	0.014	Within ROW on west side of Piney Mountain Road at Collinson Drive
EL0109	0.022	Northwest corner of Woodhaven Road and Rolling Road
EL0343[1]	0.016	East of Shadowood Drive, south of tennis courts
EL0344[1]	0.016	East of Shadowood Drive, south of tennis courts
EL0074	0.062	North of Michaux Road at Allard Road
EL0545	0.029	Northeast corner of Piney Mountain Road and Eastwood Road
EL0200	0.023	Within ROW on west side of Kenmore Road at North Lakeshore Drive
EL0523	0.015	Southwest of Linneaus Place dead-end
EL0157/EL0162[2]	0.058	Southeast of Arlington Street, in large, undeveloped lot
EL0520[3]	0.410	North of Piney Mountain Road at Woodshire Lane

[1]EL0343 and EL0344 are outfalls that both flow to the same location, see description of Project 5.

[2]EL0157/EL0162 are field identified stormwater dissipater structures that do not rank highly but have been included as an opportunity in response to community input.

[3]EL0520 is the site of an existing but apparently unmaintained stormwater retention area. It is included in this list as an optional unranked opportunity due to its location within an intermittent stream but may be considered if future investigations identify constraints that preclude other higher-ranking sites. This site was not included in the water quality modeling analysis because it is located within an intermittent stream and is considered an optional opportunity.

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: EL0431

Location: Within ROW on west side of Piney Mountain Road, south of intersection with Priestly Creek Drive (See Figure 6-3).

Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance channel that is not optimized to provide water quality benefits.

Proposed Retrofit: The proposed opportunity is a linear ROW bioretention facility within the existing ephemeral drainage channel at the downstream end of a 24" culvert. There is additional space available along the roadway to treat 0.1 acres of impervious drainage area in a location with few anticipated tree impacts. This location is situated within the existing drainage network downstream of the opportunities identified at EL00541.

Picture 6-11: EL0431

Potential Constraints: Traffic impacts during construction are expected.

Accessibility: The project has good accessibility from Piney Mountain Road.

Comments: The steepness of the site and the relatively narrow ROW pose design concerns, but do not appear to be insurmountable conceptually. The picture is looking northeast towards Priestly Creek Road, with Piney Mountain Road on the right-hand side of the image.

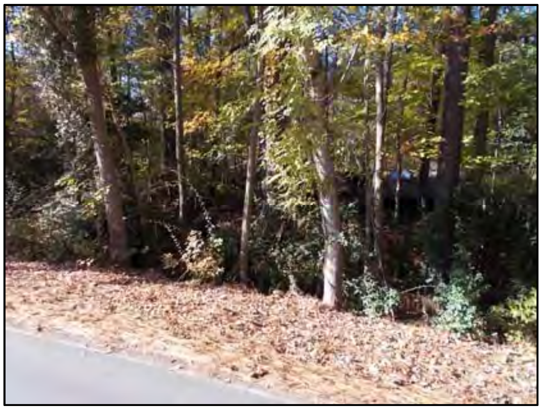
Project 2: EL0389

Location: Within ROW on west side of Piney Mountain Road at Eastwood Road (See Figure 6-4).

Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance element that is not optimized to provide water quality benefits.

Proposed Retrofit: The proposed opportunity is a linear ROW bioretention facility within the existing ephemeral drainage channel. There is additional space available along the roadway to treat 0.7 acres of impervious drainage area in a location with few anticipated tree impacts. This location is situated within the existing drainage network downstream of opportunities identified at EL0399 and EL0545 and upstream of EL0412 and EL0414.

Potential Constraints: There are potential traffic impacts associated with the construction of this measure.



Picture 6-12: EL0389

Accessibility: The project site is easily accessible from Piney Mountain Road.

Comments: Based on the field review, the topography of this site, and immediate adjacency to private property present greater obstacles to feasibility than the GIS model could detect. Therefore, relative to the other sites that were reviewed in the field, this site's feasibility is low. Picture 6-12 is looking west from the Piney Mountain Road/Eastwood Road intersection.

Project 3: EL0541

Location: Within the ROW on the west side of Piney Mountain Road at Collinson Drive (See Figure 6-5).

Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance channel that is not optimized to provide water quality benefits.

Proposed Retrofit: The proposed project is a linear ROW bioretention facility within the existing ephemeral drainage channel at the upstream end of a culvert crossing Piney Mountain Road. There is sufficient space available along the roadway to treat a significant portion of the entire 0.2 acres of impervious drainage area in a location with few anticipated tree impacts.

Potential Constraints: The contributing drainage area is small, constraining the opportunity to treat a large volume of runoff in this location.

Accessibility: The project has good accessibility from Piney Mountain Road.

Comments: No outlet found visually at this location, counter to the GIS information, but might be obscured by sediment or buried. However, there is an opportunity to treat roadside stormwater flow with relatively minimal disturbance. This site is just upslope from EL0431 and the outflow from this location would be in series with any potential device located at EL0431.

Picture 6-13: EL0541

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0431
Figure 6-3

Legend

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

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

Outfall Assessment

Orange County

Chapel Hill, NC

Eastwood Lake Watershed Plan

Outfall EL0389

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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet

1 in = 50 ft

N

Biohabitats

September 2018

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0541
Figure 6-5

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

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

Project 4: EL0109

Location: Northwest corner of Woodhaven Road and Rolling Road (See Figure 6-6).

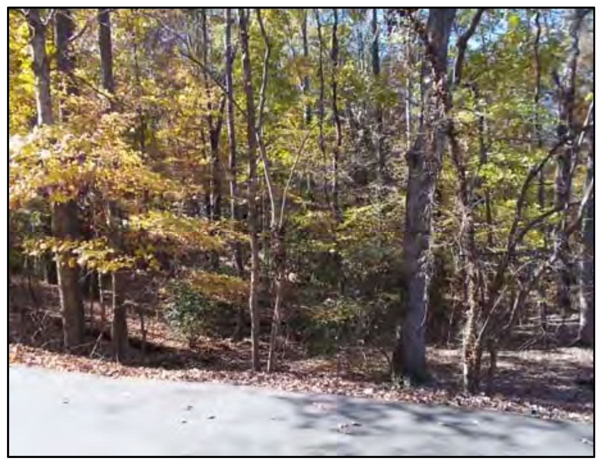
Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance channel that is not optimized to provide water quality benefits.

Proposed Retrofit: The proposed opportunity is a linear ROW bioretention facility within the existing ephemeral drainage channel at the downstream end of an 18″ culvert crossing Woodhaven Road. There is sufficient space available along the roadway to treat a significant portion of the 0.2 acres of impervious drainage area in a location with few anticipated tree impacts.

Potential Constraints: Constraints to the implementation of this proposed opportunity are expected traffic impacts during construction and potential impacts to the existing water utility running along Woodhaven Road.

Accessibility: The project has good accessibility along Woodhaven and Rolling Roads.

Comments: The site topography may limit the size of the proposed SCM. Access is limited to a steep embankment. Several large trees would have to be removed to construct the SCM. The picture is looking north from Rolling Road onto the site.



Picture 6-14: EL0109

Project 5: EL0343/EL0344

Location: East of Shadowood Drive, south of tennis courts (See Figure 6-7).

Description of Observed Problems/Opportunity: This site is an older in-line stormwater SCM receiving runoff from the Shadowood Apartments complex.

Proposed Retrofit: This site presents an opportunity to retrofit an existing in-line stormwater SCM to provide additional treatment and storage. The existing outfall is located in an area adjacent to recreational and parking facilities where it receives stormwater runoff from 18.2 acres of impervious surfaces. The existing SCM also receives stormwater runoff from 4.3 acres of impervious surfaces associated with outfall EL0344. Treatment of this volume would be improved through the proposed retrofit.

Potential Constraints: There are few constraints associated with this site. It is possible that there may be some minor traffic or parking impacts during construction.

Accessibility: The project is accessible from the parking area off Shadowood Drive.

Comments: To expand the capacity of the existing SCM, many trees that have established on its banks would have to be removed. The retrofit could be designed to be an amenity that provides wetland habitat. The photo is looking northwest across the SCM, from the area near the riser/dam (See Picture 6-15).

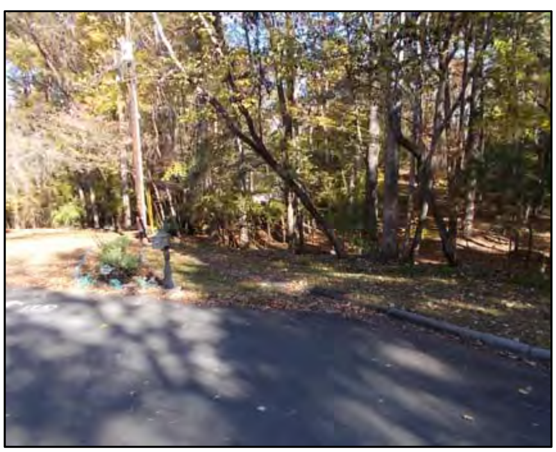
Picture 6-15: EL0343

Project 6: EL0074

Location: North of Michaux Road at Allard Road (See Figure 6-8).

Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance channel that is not optimized to provide water quality benefits.

Proposed Retrofit: There is adequate room here to provide some level of water quality treatment for a large portion of the 1.5 acres of impervious area that drains to the outfall. The retrofit concept is to construct an inline bioretention facility within the ephemeral channel. If inline bioretention is determined unfeasible at this location, there may be sufficient space for offline bioretention with the installation of a flow splitter at the outfall.



Picture 6-16: EL0074

Potential Constraints: This opportunity has potential tree and traffic impacts during construction.

Accessibility: Access is possible along the north side of Michaux Road.

Comments: The site is situated in the front yard of a private lot. Site topography would allow some treatment; however, several trees would have to be removed. Picture 6-16 is looking south from the Allard Road/Michaux Road intersection towards the site.

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0109
Figure 6-6

Legend

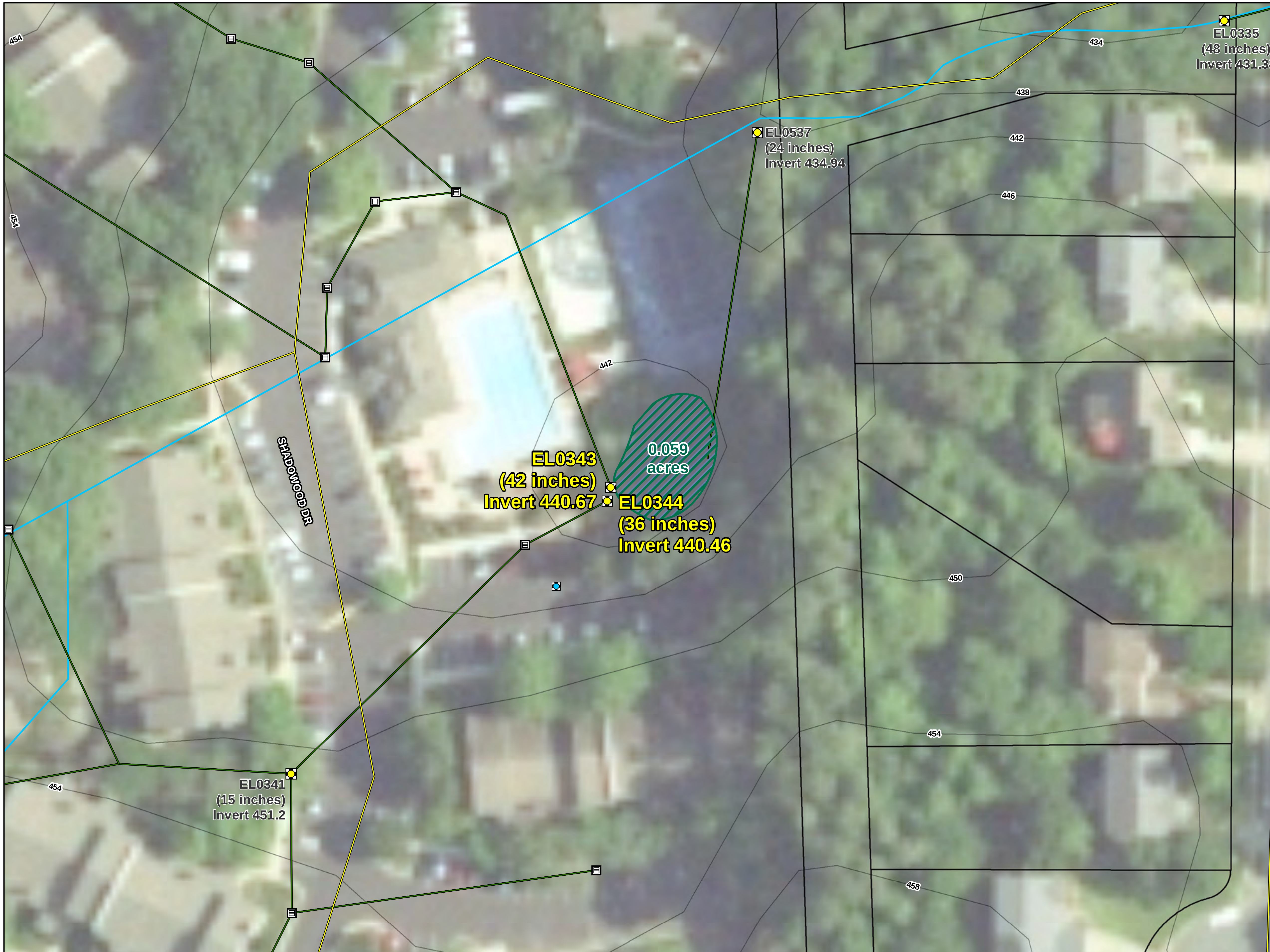
- Outfall Screening Sites
- Other Outfalls
- Catch Basin
- Access
- Gravity Sewer Mains
- Pressurized Sewer Mains
- Water Lines
- Storm Pipes
- Streams
- Contours
- Public Parcels
- Parcels
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0343/EL0344
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet

1 in = 50 ft

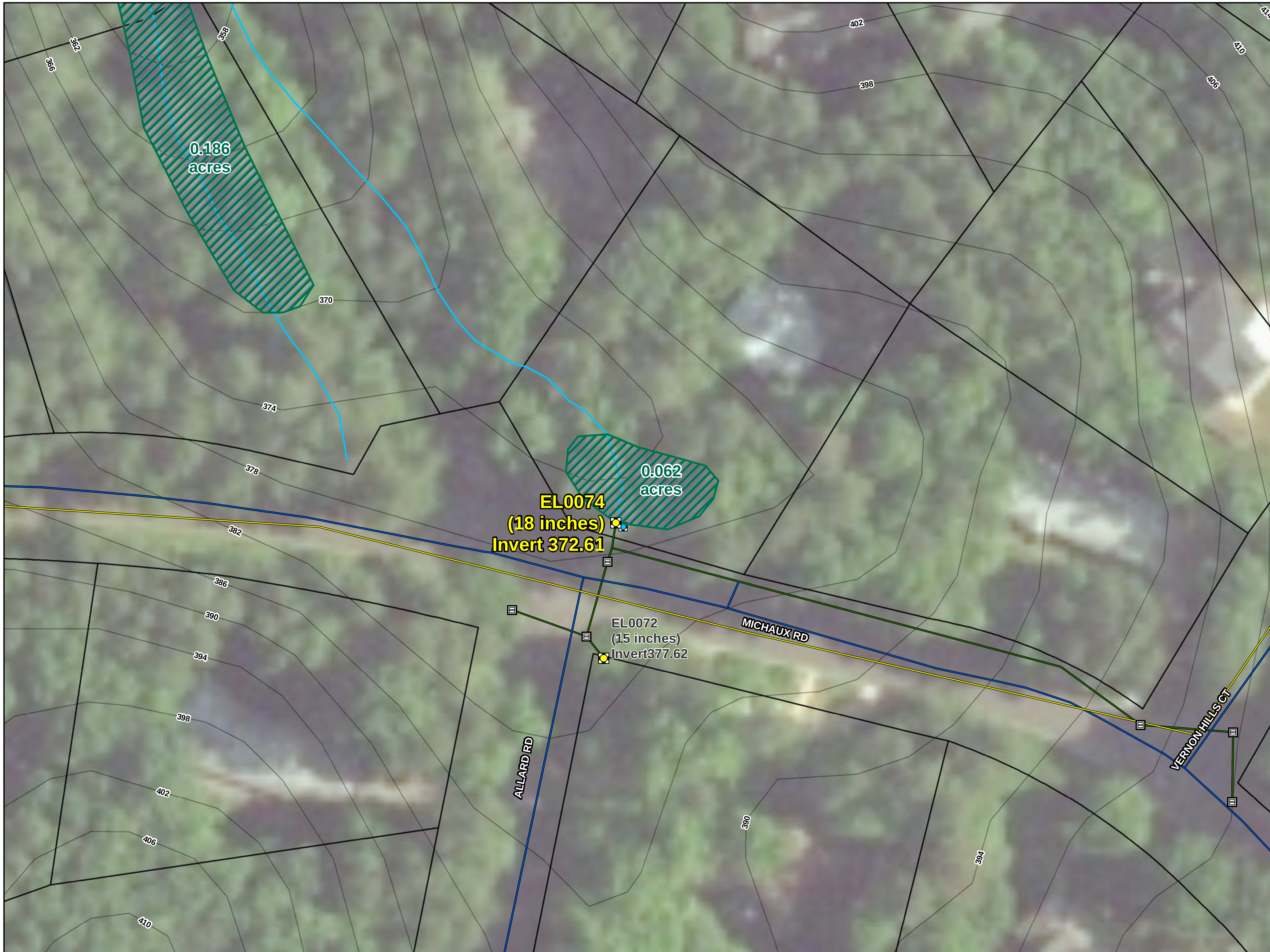
N

Biohabitats

September 2018

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0074
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

Project 7: EL0545

Location: Northeast corner of Piney Mountain Road and Eastwood Road (See Figure 6-9).

Description of Observed Problems/Opportunity: This site has untreated surface runoff from a public residential development.

Proposed Retrofit: The proposed opportunity is a bioretention facility upstream of the culvert in a mowed open area to treat the stormwater runoff from a 0.2 acres impervious drainage area from residential buildings and the Louis Armstrong Drive cul-de-sac. Flow enters the SCM through swales directing stormwater through the residential area from the cul-de-sac.

Potential Constraints: There are no obvious constraints to construction of this proposed measure.

Accessibility: The project has good accessibility from Piney Mountain Road.

Comments: There was no outlet found/located at this site, counter to the GIS information. No constraints were documented. It is likely that several large trees would have to be removed to direct flow from Eastwood Road to the site. The picture is looking northeast with Eastwood Road on the right side of the image. This site is upslope of and drains to EL0389.

Picture 6-17: EL0545

Project 8: EL0200

Location: Within ROW on west side of Kenmore Road at North Lakeshore Drive (See Figure 6-10).

Description of Observed Problems/Opportunity: This site is a roadside drainage and conveyance channel that is not optimized to provide water quality benefits.

Proposed Retrofit: The proposed retrofit is to create a linear bioswale facility that provides water quality treatment benefits for stormwater runoff from 0.16 acres of impervious drainage area.

Potential Constraints: Constraints to implementation of this opportunity are possible utility impacts and potential traffic impacts during construction.

Picture 6-18: EL0200

Accessibility: The project has good accessibility off Kenmore Road.

Comments: The steepness of the site will be a factor in future feasibility analysis. This site is beside a private residence and implementation would have to be coordinated with the owner.

Project 9: EL0523

Location: Southwest of Linneaus Place cul-de-sac (See Figure 6-11).

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

Proposed Retrofit: The proposed retrofit is to create a bioretention cell in a poorly defined ephemeral channel to treat runoff from Linneaus Place and adjacent homes prior to discharging into the intermittent channel downstream.

Potential Constraints: Constraints to the implementation of this project are associated with private ownership of the parcel where the proposed measure is located. It is also possible that there may be some traffic impacts along Linnaeus Place during construction.

Picture 6-19: EL0523

Accessibility: The project is easily accessible from the Linnaeus Pace cul-de-sac.

Comments: The site is on private property and several trees greater than 12 inched diameter breast height would have to be removed to construct. The picture is looking north from a private residence driveway onto the site (See Picture 6-19).

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0545
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

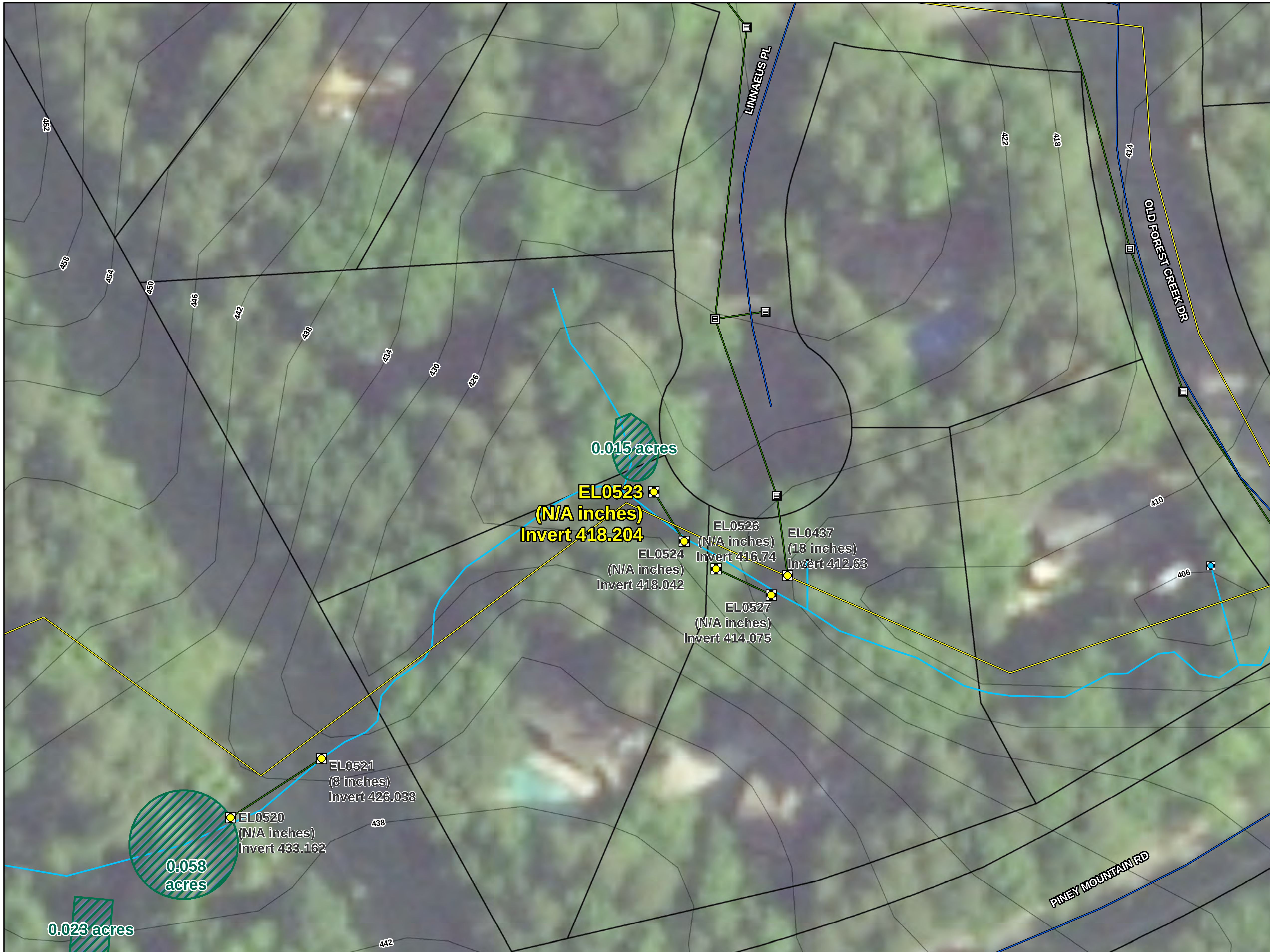
Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0200
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018



Outfall Assessment

Orange County

Chapel Hill, NC

Eastwood Lake Watershed Plan

Outfall EL0523

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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet

1 in = 50 ft

N

Biohabitats

September 2018

Project 10: EL0157/ EL0162

Location: Large, undeveloped lot southeast of Arlington Street (See Figure 6-12).

Description of Observed Problems/Opportunity: This site has two (2) unmaintained stormwater dissipaters that flow into separate channels that converge just downstream and form a single channel that flows through an undeveloped lot (See Pictures 6-20 and 6-21).

Proposed Retrofit: The proposed retrofit is to create a stormwater wetland that provides storm attenuation and water quality treatment benefits for stormwater runoff from 1.8 acres of impervious drainage area.

Potential Constraints: Constraints to implementation of this opportunity are tree impacts, site access, and relatively steep slopes in the upstream watershed.

Accessibility: The project has fair accessibility off North Lakeshore Drive.

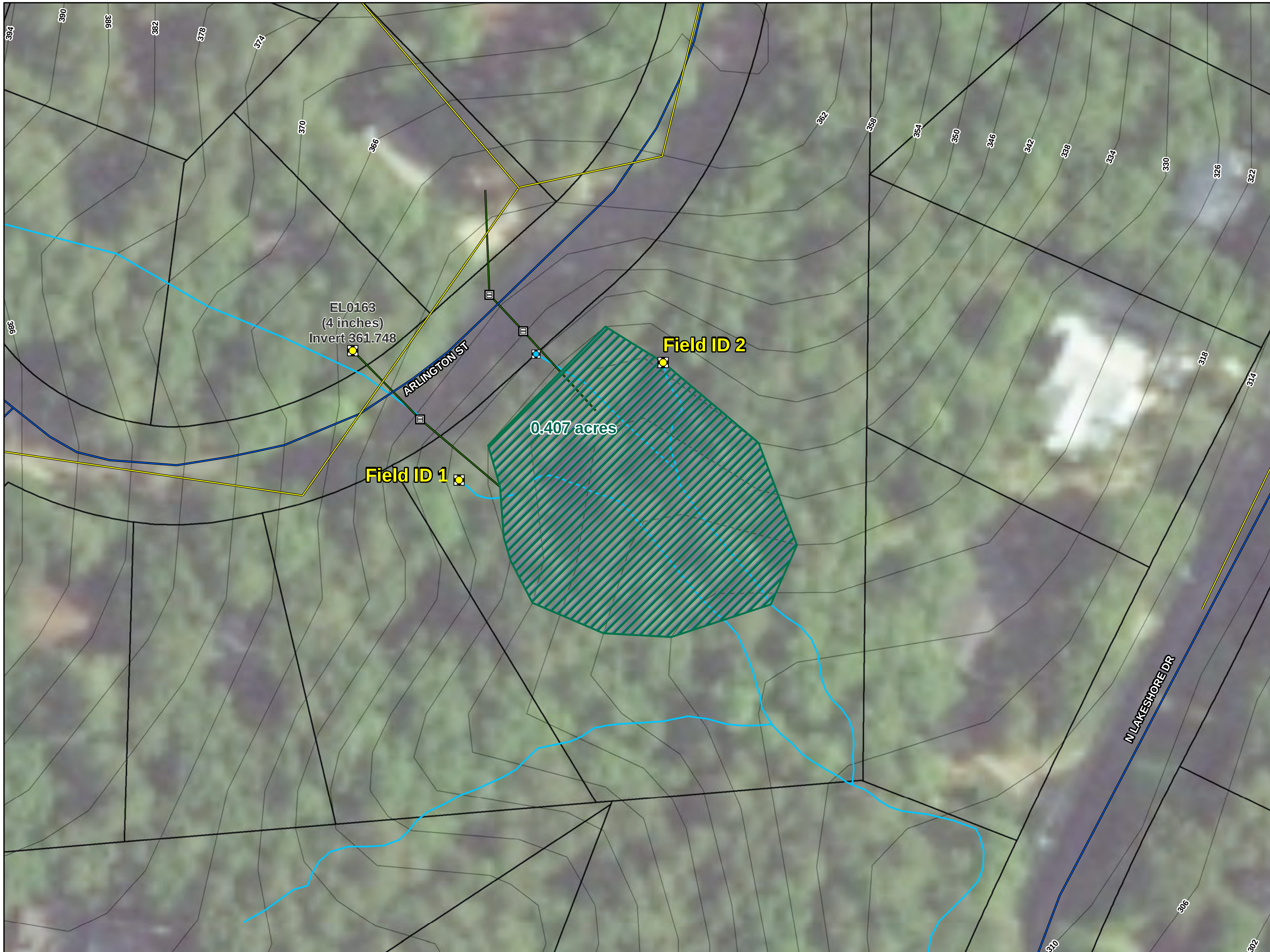
Comments: The existing dissipaters apparently treat water piped down the steep hill from Arlington Street to the northwest. The design will need to accommodate the needed energy dissipation and storage needs.

Picture 6-20: EL0157

Picture 6-21: EL0162

EL0520

This site is located north of Piney Mountain Road at Woodshire Lane (See Figure 6-13). It is an existing but apparently unmaintained stormwater retention area. It has been included as an optional unranked opportunity due to its location within an intermittent stream but may be considered if future investigations identify constraints that preclude other higher-ranking sites. This site was not included in the water quality modeling analysis because it is located within an intermittent stream and is considered an optional opportunity.



Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0157/EL0162
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

Outfall Assessment
Orange County
Chapel Hill, NC

Eastwood Lake Watershed Plan
Outfall EL0520
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
- Eastwood Lake Watershed Boundary
- BMP Footprint

0 25 50 Feet
1 in = 50 ft
N

Biohabitats
September 2018

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 (Very Good) 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)

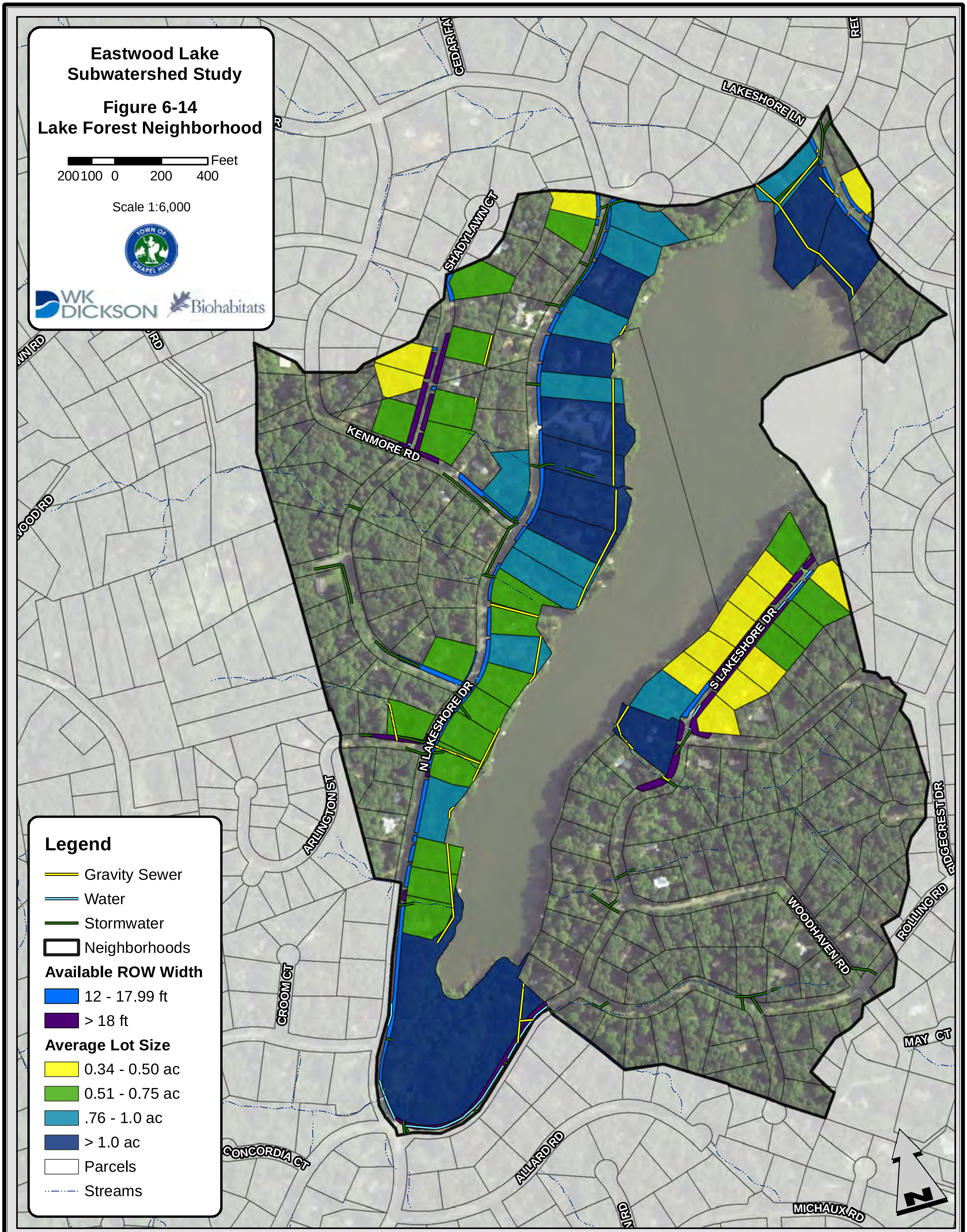
One (1) of the neighborhoods is located in the Eastwood Lake subwatershed - Lake Forest. Four (4) additional neighborhoods that were in the next lowest ranking (Good) were also analyzed. They were Eastwood Road – Johnson Farm, Forest Creek, Cooker Woods West 2 and Coker Hills. These neighborhoods were 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 6-18).

The acreages of each neighborhood are:

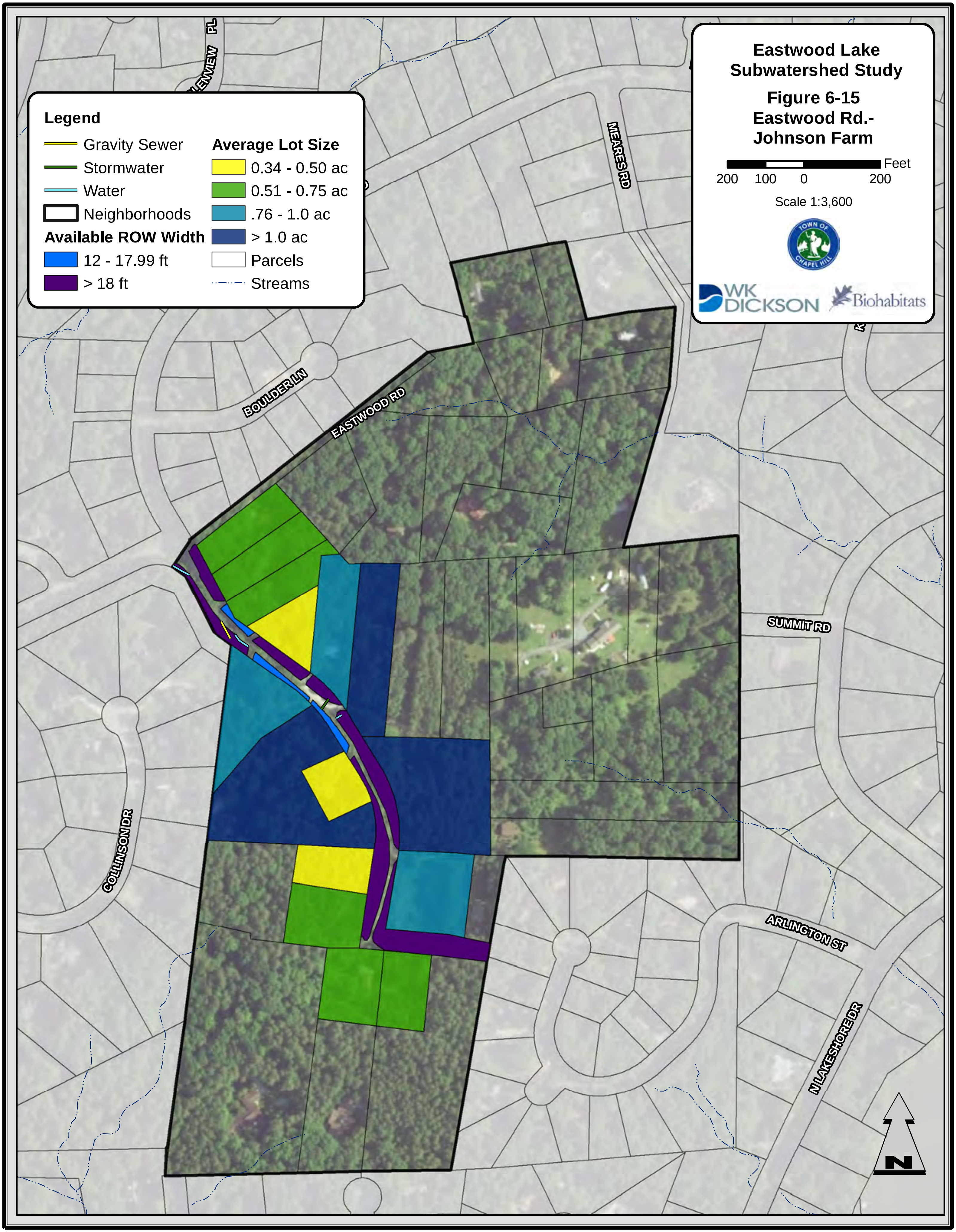
Lake Forest	195.6 ac
Eastwood Road – Johnson Farm	53.3 ac
Forest Creek	85.0 ac
Coker Woods West 2	99.7 ac
Coker Hills	61.1 ac

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 adjacent to the streets. 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.

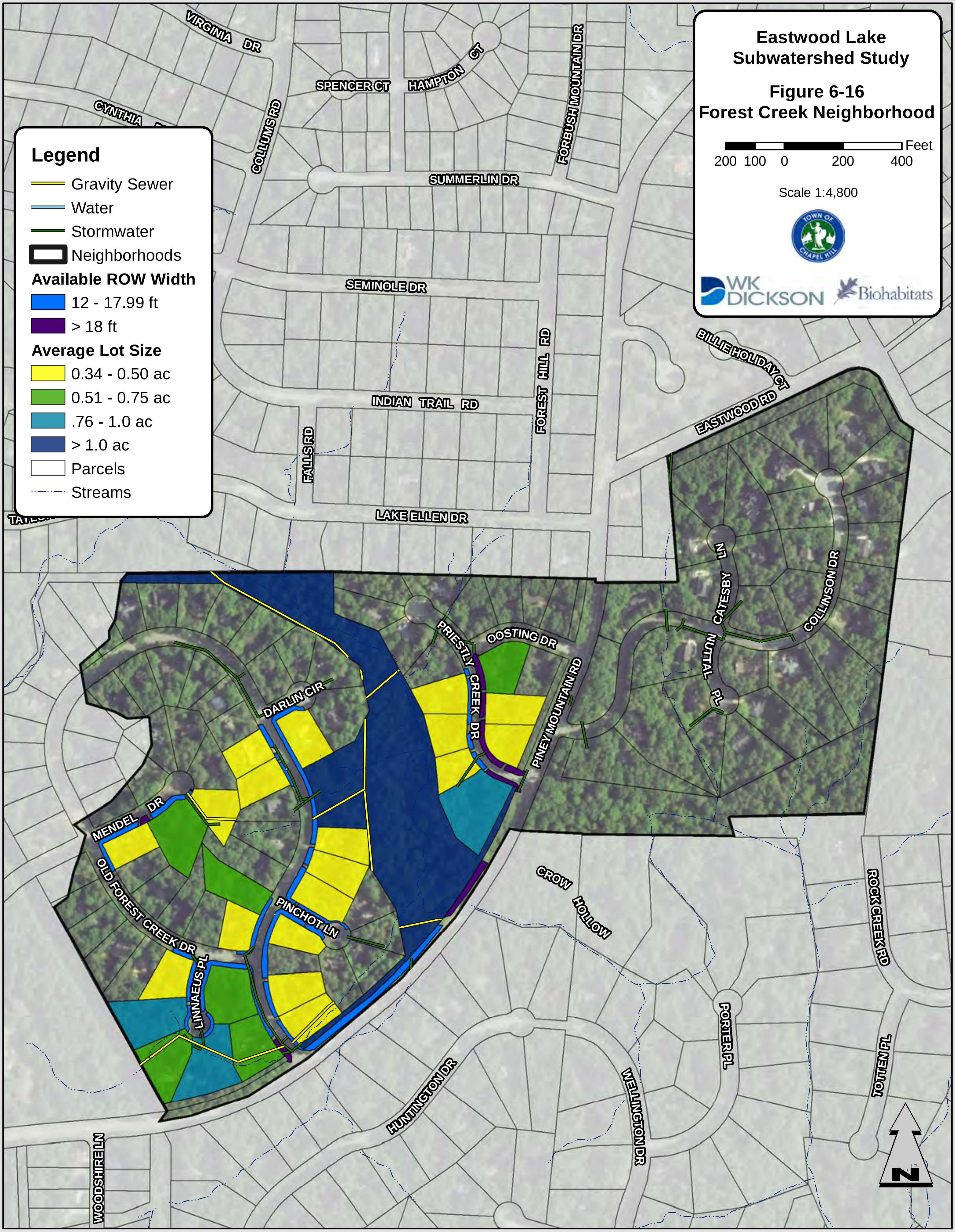
This GIS analysis identified potential areas in each neighborhood where conditions appear to be favorable for water quality retrofits. Future follow-up field work will allow specific stormwater treatment options to be identified. This analysis does not recommend specific water quality stormwater control 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.

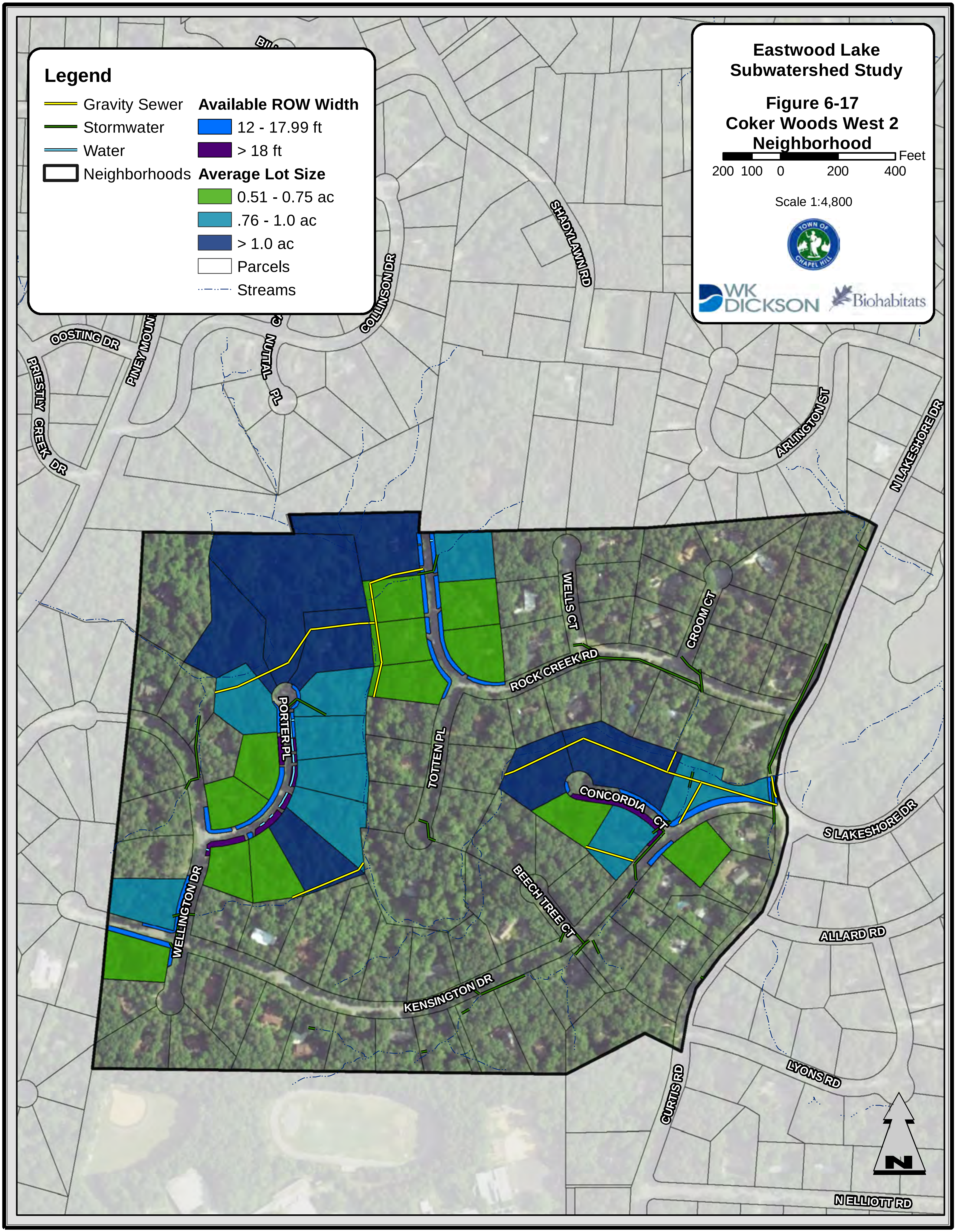


Eastwood Lake Subwatershed Study
Figure 6-14
Lake Forest Neighborhood
Feet
200 100 0 200 400
Scale 1:6,000
TOWN OF CHAPEL HILL
WK DICKSON
Biohabitats
Legend
Gravity Sewer
Water
Stormwater
Neighborhoods
Available ROW Width
12 - 17.99 ft
> 18 ft
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
LAKESHORE LN
CEDAR FA
SHADYLAWN CT
KENMORE RD
N LAKESHORE DR
S LAKESHORE DR
ARLINGTON ST
CROOM CT
CONCORDIA CT
ALLARD RD
WOODHAVEN RD
RIDGECREST DR
ROLLING RD
MAY CT
MICHAUX RD
N

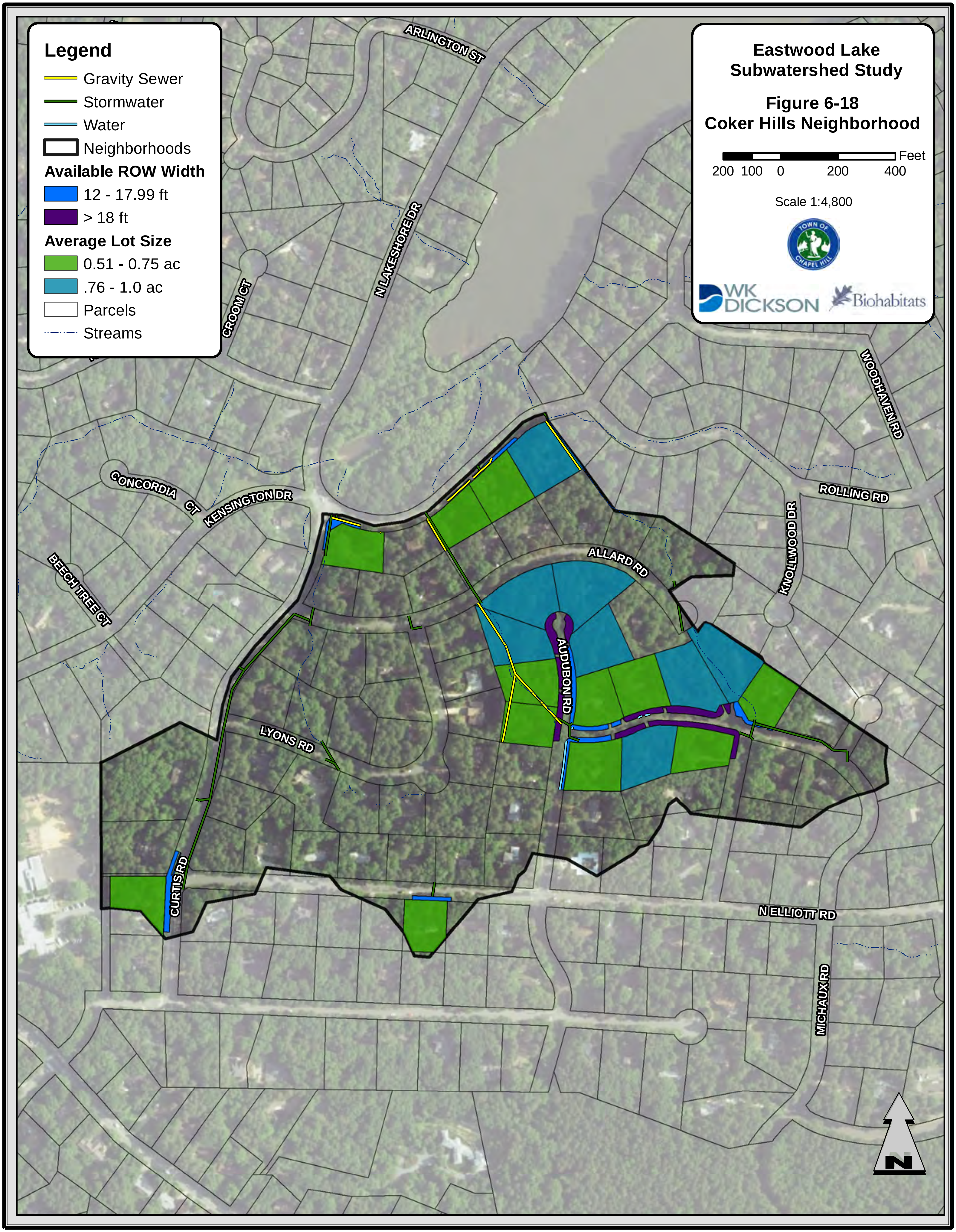


Eastwood Lake Subwatershed Study
Figure 6-15
Eastwood Rd.-Johnson Farm
Feet
200 100 0 200
Scale 1:3,600
WK DICKSON
Biohabitats
Legend
Gravity Sewer
Stormwater
Water
Neighborhoods
Available ROW Width
12 - 17.99 ft
> 18 ft
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
BOULDER LN
EASTWOOD RD
MEARES RD
SUMMIT RD
ARLINGTON ST
COLLINSON DR
N LAKESHORE DR
N


Eastwood Lake
Subwatershed Study
Figure 6-16
Forest Creek Neighborhood
Feet
200 100 0 200 400
Scale 1:4,800
TOWN OF CHAPEL HILL
WK DICKSON
Biohabitats
Legend
Gravity Sewer
Water
Stormwater
Neighborhoods
Available ROW Width
12 - 17.99 ft
> 18 ft
Average Lot Size
0.34 - 0.50 ac
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
VIRGINIA DR
CYNTHIA
SPENCER CT
HAMPTON CT
COLLUMS RD
FORBUSH MOUNTAIN DR
SUMMERLIN DR
SEMINOLE DR
INDIAN TRAIL RD
FOREST HILL RD
FALLS RD
LAKE ELLEN DR
BILLIE HOLIDAY CT
EASTWOOD RD
CATESBY LN
COLLINSON DR
NUTTAL PL
OOSTING DR
PRIESTLY CREEK DR
PINEY MOUNTAIN RD
DARLIN CIR
MENDEL DR
OLD FOREST CREEK DR
PINCHOT LN
LINNAEUS PL
CROW HOLLOW
ROCK CREEK RD
PORTER PL
TOTTEN PL
WELLINGTON DR
HUNTINGTON DR
WOODSHIRE LN
N



Eastwood Lake
Subwatershed Study
Figure 6-17
Coker Woods West 2
Neighborhood
Feet
200 100 0 200 400
Scale 1:4,800
TOWN OF CHAPEL HILL
WK DICKSON
Biohabitats
Legend
Gravity Sewer
Stormwater
Water
Neighborhoods
Available ROW Width
12 - 17.99 ft
> 18 ft
Average Lot Size
0.51 - 0.75 ac
.76 - 1.0 ac
> 1.0 ac
Parcels
Streams
OOSTING DR
PRIESTLY CREEK DR
PINEY MOUN
NUTTAL PL
COLLINSON DR
SHADYLAWN RD
ARLINGTON ST
N LAKESHORE DR
WELLS CT
CROOM CT
ROCK CREEK RD
PORTER PL
TOTTEN PL
CONCORDIA CT
S LAKESHORE DR
WELLINGTON DR
BEECH TREE CT
ALLARD RD
KENSINGTON DR
CURTIS RD
LYONS RD
N ELLIOTT RD
N


Legend
Gravity Sewer
Stormwater
Water
Neighborhoods
Available ROW Width
12 - 17.99 ft
> 18 ft
Average Lot Size
0.51 - 0.75 ac
.76 - 1.0 ac
Parcels
Streams
Eastwood Lake
Subwatershed Study
Figure 6-18
Coker Hills Neighborhood
Feet
200 100 0 200 400
Scale 1:4,800
WK DICKSON
Biohabitats
ARLINGTON ST
N LAKESHORE DR
CROOM CT
CONCORDIA CT
KENSINGTON DR
BEECH TREE CT
ALLARD RD
AUDUBON RD
LYONS RD
CURTIS RD
N ELLIOTT RD
KNOLLWOOD DR
ROLLING RD
WOODHAVEN RD
MICHAUX RD
N

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 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 (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
6,250.0	1,442.5	242,471.4

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), TN has to be reduced by 500 lbs/yr (8%) and TP has to be reduced by 72.1 lbs/yr (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	SCM Type
1	EL0431	Within ROW on west side of Piney Mountain Road, south of intersection with Priestly Creek Drive	Bioretention
2	EL0389	Within ROW on west side of Piney Mountain Road at Eastwood Road	Bioretention
3	EL0541	Within ROW on west side of Piney Mountain Road at Collinson Drive	Wetland
4	EL0109	Northwest corner of Woodhaven Road and Rolling Road	Bioretention
5	EL0343/EL0344	East of Shadowood Drive, south of tennis courts	Wetland
6	EL0074	North of Michaux Road at Allard Road	Bioretention
7	EL0545	Northeast corner of Piney Mountain Road and Eastwood Road	Bioretention
8	EL0200	Within ROW of west side of Kenmore Road at North Lakeshore Drive	Bioretention
9	EL0523	Southwest of Linneaus Place dead-end	Bioretention
10	EL0157/EL0162	Southeast of Arlington Street, in large, undeveloped lot	Wetland

As noted in Section 6.2, EL0520 was listed in Table 6-2 as an optional opportunity if a higher-ranking outfall was determined to be infeasible. Therefore, EL0520 was not included in the WTM outfalls loading reductions analysis. The modeling results of the pollutant load reductions for the outfalls listed in Table 6-4 are shown in Table 6-5.

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

	TN (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
Existing	6,250.0	1,442.5	242,471.4
Modeled (Post- Retrofit)	5,912.5	1,364.4	235,368.5
Pounds Reduced	337.5	78.1	7,102.9
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	500	N/A	N/A
TP – 5% Reduction	N/A	72	N/A
Jordan Stage 2 Target Percent Reduction	68%	107%	N/A

Based on the WTM calculations in Table 6-5, TN is reduced by 337.5 lbs/yr, a 5.4% reduction, which is 68% of the 8% reduction needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 78.1 lbs/yr, a 5.3% reduction, which is 107% of the 5% amount needed to comply with the Jordan Lake Stage 2 requirement. Total suspended solids were also reduced by 7,102.9 lbs/yr, which is a 2.9% reduction.

<u>Neighborhoods Analysis Load Reductions</u>

The five (5) top-ranked neighborhoods in the Eastwood Lake subwatershed – Coker Woods West 2, Coker Hills, Lake Forest, Forest Creek, and Eastwood Road/Johnson Farm 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:

Coker Woods West 2	99.7 ac
Coker Hills	61.1 ac
Lake Forest	195.6 ac
Forest Creek	85.0 ac
Eastwood Road/Johnson Farm	53.3 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
Coker Woods West 2	99.7	26%	26.00
Coker Hills	61.1	26%	15.86
Lake Forest	195.6	27%	52.55
Forest Creek	85.0	29%	24.55
Eastwood Road/Johnson Farm	53.3	27%	14.38
Totals	494.7		133.34

To estimate the reduction in pollutant concentrations from the 133.34 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 133.34 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 (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
Existing	6,250.0	1,442.5	242,471.4
Modeled (Post- Retrofit)	5,986.4	1,410.4	240,814.5
Pounds Reduced	263.6	32.1	1,656.9
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	500	N/A	N/A
TP – 5% Reduction	N/A	72	N/A
Jordan Stage 2 Target Percent Reduction	53%	44%	N/A

Based on the WTM calculations in Table 6-7, TN is reduced by 263.6 lbs/yr, a 4.2% reduction, which is 53% of the amount needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 32.1 lbs/yr, a 2.2% reduction, which is 44% of the amount needed to comply with the Jordan Lake Stage 2 requirement. Total suspended solids were also reduced by over 1,656.9 lbs/yr, which is a 0.7% 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)
Woodshire 2	Stabilize banks and channel, channel grade control	200	15	14	8,976
Woodshire 3	Stabilize banks and channel, channel grade control	564	42	38	25,312
Lake Ellen 1	Stabilize banks and channel, channel grade control	168	13	11	7,540
Booker 5	Stabilize banks and channel, channel grade control	1,500	113	102	67,320
Croom	Perched outfall repair, repair head-cuts, grade control, channel stabilization	245	18	17	10,996
Kensington 3	Stabilize banks and channel, channel grade control	200	15	14	8,976
Curtis 1	Stabilize banks and channel, channel grade control	200	15	14	8,976
Lyons 1	Repair head-cuts, grade control, channel stabilization	241	18	16	10,816
Allard 2	Repair head-cuts, grade control, channel stabilization	1,229	92	84	55,158
Woodhaven	Repair head-cuts, grade control, channel stabilization	395	30	27	17,728
Ridgecrest 1	Repair head-cuts, grade control, channel stabilization, sewer pipe in channel	210	16	14	9,425
Ridgecrest 2	Repair head-cuts, grade control, channel stabilization	429	32	29	19,254
Ridgecrest 3	Repair head-cuts, grade control, channel stabilization	872	65	59	39,135
Ridgecrest 4	Repair head-cuts, grade control, channel stabilization	410	31	28	18,401
	TOTALS (lbs/yr)	6,863	515	467	308,011

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 (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
Existing	6,250.0	1,442.5	242,471.4
Modeled (Post- Retrofit)	5,735.0	975	
Pounds Reduced	515	467	308,011.4
Jordan Stage 2 Reduction Target			
TN – 8% Reduction	500	N/A	N/A
TP – 5% Reduction	N/A	72	N/A
Jordan Stage 2 Target Percent Reduction	103%	647%	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 515 lbs/yr, an 8.2% reduction which is more than the amount needed to comply with the Jordan Lake Stage 2 load reduction requirement. TP is reduced by 467 lbs/yr, a 32.4% reduction, which is more than six times the amount needed to comply with the Jordan Lake Stage 2 requirement.

Table 6-10 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 6-10: 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	2.9%	36%	3.5%	70%
Neighborhood Retrofit Reduction	4.2%	52%	2.2%	44%
Stream Restoration Reduction (adjusted per explanation above)	8.2%	103%	32.4%	647%
TOTALS	15.3%	191%	38.1%	761%

Table 6-10 presents a summary of load reductions including the outfall retrofits, neighborhood retrofits, and stream restoration opportunities identified in the Eastwood Lake subwatershed. The total length of stream restoration identified is over 20% of the total length of intermittent and perennial stream in the subwatershed. The modeling estimates that stream restoration, at that scale, is the most effective practice in reducing TN and TP loads. The neighborhood retrofits are more effective in reducing TN than the outfall reductions. However, according to the modeling, the outfall retrofits are more effective at reducing TP loads in the subwatershed than the neighborhood retrofits. The results indicate that an assortment of choices are available with respect to effective nutrient load reductions in the Eastwood Lake 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 Eastwood Lake subwatershed, permits or approvals may be required for any of the following reasons:

- Stream, riparian buffer, and/or wetland impacts;
- FEMA floodway and floodplain 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 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). 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. The North Carolina Division of Water Resources (DWR) 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 DWR. DWR 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. DWR 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 DWR 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, DWR, 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 Eastwood Lake 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		
EASTWOOD LAKE - WEST					
Piney Mountain Road	X	X	X		
Woodshire Lane/Huntington Road		X			
EASTWOOD LAKE - EAST					
Shady Lawn Road System		X			
Arlington Street #1 Closed System		X			
Arlington Street #2 Closed System		X			
South Lakeshore Drive/Ridgecrest Drive Closed System		X			
South Lakeshore Drive/Rolling Road Closed System		X			

COST ESTIMATES

The cost estimates provided as part of the Eastwood Lake 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[1]	$2,786,000
Martin Luther King, Jr. Boulevard Storage Area[1]	$3,789,000
Piney Mountain Road Storage Area[1]	$1,906,000
Eastwood Lake - West	
Piney Mountain Road	$456,800
Woodshire Lane/Huntington Road	$372,300
Eastwood Lake - East	
Shady Lawn Road System	$153,300
Arlington Street #1 System	$104,400
Arlington Street #2 System	$133,100
South Lakeshore Drive/Ridgecrest Drive System	$125,200
South Lakeshore Drive/Rolling Road System	$216,800

[1] Costs taken from Lower Booker Creek Subwatershed Study

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 judgment. 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/linear foot

Medium cost estimate: $715/linear foot

High cost estimate: $910/linear foot

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
Woodshire 2	200	$104,000	$143,000	$182,000	
Woodshire 3	564	$293,280	$403,260	$513,240	
Lake Ellen 1	168	$87,360	$120,120	$152,880	$126,000
Booker 5	1,500	$780,000	$1,072,500	$1,365,000	
Croom	245	$127,400	$175,175	$222,950	
Kensington 3	200	$104,000	$143,000	$182,000	
Curtis 1	200	$104,000	$143,000	$182,000	
Lyons 1	241	$125,320	$172,315	$219,310	
Allard 2	1,229	$639,080	$878,735	$1,118,390	
Woodhaven	395	$205,400	$282,425	$359,450	
Ridgecrest 1	210	$109,200	$150,150	$191,100	
Ridgecrest 2	429	$223,080	$306,735	$390,390	
Ridgecrest 3	872	$453,440	$623,480	$793,520	
Ridgecrest 4	410	$213,200	$293,150	$373,100	
TOTALS	6,863	$3,568,760	$4,907,045	$6,245,330	$126,000

Based on Table 8-2, the cost of constructing the identified stream restoration projects ranges from approximately $3.6 million dollars to $6.2 million dollars. The costs associated with RSC implementation is estimated at $126,000.

Outfall Retrofit Cost Estimates

To estimate the cost of outfall retrofit opportunities a range of cost sources was considered depending on the proposed SCM 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 (2) 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 measures that are located within parcel sites, where the more expensive cost factor ($186,750) was applied to opportunities within the public ROW, which are likely to require additional provisions such as hardscape retrofits, utility coordination, and traffic maintenance.

For existing SCM retrofit opportunities, a unit cost was employed based on recent design and construction experience in the mid-Atlantic and North Carolina.

Three (3) identified opportunities returned a cost less than $25,000 based on the described unit cost/area calculations. These opportunities were assigned a value of $25,000, which is assumed to be the minimum for provision of design, permitting, and construction.

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

Outfall ID	SCM Area (acres)	Drainage Area (acres)	Impervious Area (acres)	SCM Type	Total Cost	Unit Cost $/IA
EL0431	0.03	0.35	0.14	ROW Bioretention	$25,585	$186,750
EL0389	0.02	1.03	0.71	Bioretention	$35,700	$50,000
EL0541	0.01	1.14	0.32	ROW Bioretention	$59,760	$186,750
EL0109	0.01	0.10	0.04	ROW Bioretention	$25,000*	$186,750
EL0343 EL0344	0.06	38.62	18.24	Retrofit	$300,960	$16,500
EL0074	0.06	5.93	1.53	Bioretention	$76,300	$50,000
EL0545	0.03	0.60	0.16	ROW Bioretention	$29,880	$186,750
EL0200	0.02	0.43	0.16	ROW Bioretention	$29,880	$186,750
EL0523	0.02	0.68	0.13	Wetland	$25,000*	$66,000
EL0157 EL0162	0.41	7.92	1.80	Wetland	$118,800	$66,000
EL0520	0.31	12.63	0.69	Retrofit	$25,000*	$16,500
				TOTAL	$751,865	

* Cost less than $25,000 based on the unit cost/area calculations; assigned a value of $25,000.

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 Eastwood Lake 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 a 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	Piney Mountain Road Culvert

As shown Table 9-1, the Piney Mountain Road Culvert is the only proposed flood reduction project in the Eastwood Lake subwatershed. The four (4) flood storage projects were prioritized in the Lower Booker Creek Subwatershed Study and Lake Ellen Evaluation Memorandum. This study does two (2) things – it prioritizes the projects identified in the Eastwood Lake subwatershed and then a merged priority list for the two studied subwatersheds will be created.

Table 9-2 below lists the Secondary Systems prioritization.

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

Priority	Project
1	South Lakeshore Drive/Ridgecrest Drive System
2	South Lakeshore Drive/Rolling Road System
3	Arlington Street #1 System
4	Woodshire Lane/Huntington Road
5	Shady Lawn Road System
6	Arlington Street #2 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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