ELLERBE CREEK LOCAL WATERSHED PLAN

EXECUTIVE SUMMARY

For the past year local watershed stakeholders and city and state resource managers have worked to gather data and outline a plan to restore the Ellerbe Creek Watershed. This document represents the culmination of the efforts undertaken by the Ellerbe Creek Stakeholders group to evaluate the varied sources of water quality degradation and to recommend a comprehensive set of strategies to address the water quality problems within Ellerbe Creek.

Section 1 presents the context of the Ellerbe Creek Local Watershed Plan. Ellerbe Creek is one of 28 local watersheds that drain into the Falls Lake Reservoir. The Upper Neuse River Basin Association, created in 1996, initiated a Watershed Management Plan for the entire upper Neuse River Basin, the Falls Lake Watershed. As part of the data analysis for this project, Ellerbe Creek was identified as having the highest percentage of impervious surfaces and delivering the highest nutrient loads to the Falls Lake water supply reservoir. As a result of these and other findings, the North Carolina Wetlands Restoration Program initiated the Ellerbe Creek Local Watershed Plan to analyze water quality issues within the Ellerbe Creek Watershed.

Section 2 summarizes the current conditions in the Ellerbe Creek watershed including hydrology, geology, water quality, human impacts, natural heritage and history of the watershed. The Ellerbe Creek Watershed is a predominately urban, 23,526-acre watershed located within the upper Neuse River Basin in Durham County, North Carolina. Its headwaters and half of its watershed are located within Durham's city limits. Approximately 47,540 people live within the watershed. Ellerbe Creek's watershed is 16% forested, 1.25% agricultural with the rest being urban or residential. The Ellerbe Creek watershed is currently 22% impervious and projected to increase to 27.5% by 2025. Water quality in Ellerbe Creek is not supporting its designated uses and will not improve without appropriate water quality protection measures.

Section 3 explains the Goals of the Ellerbe Creek Local Watershed Plan. The stakeholders identified the following five major goals.

Overall Goal: Protect Watershed Functions This is a unifying goal that embodies all of the other goals. Ellerbe Creek is impaired because its natural flow or its hydrology (in essence, the way a stream works) has been dramatically altered. Though no urban stream can be restored to its natural condition, restoring a more natural hydrology makes achieving the remaining goals more possible.

Goal 1 Improve Aquatic Life in Ellerbe Creek. Ellerbe Creek's impairment is called "Biological Impairment" because its water quality and lack of natural habitat make it difficult for aquatic life to survive. Any real improvement in the creek must be measured by how well aquatic life can survive and flourish.

Goal 2: Reduce Destructive Flooding Flooding is a natural process necessary to provide habitat and maintain water quality. However, in an urbanized environment such as Ellerbe Creek, flooding can be a destructive force to the built environment and the people who live there. Two keys to this plan are to find areas that can flood without causing property damage and to initiate projects that reduce the volume and velocity of stormwater entering streams.

Goal 3: Create Recreational Opportunities Ellerbe Creek is an underutilized resource. Despite its water quality problems, there are many opportunities for passive recreation along its banks. To the degree that people find Ellerbe Creek to be an amenity and not an eyesore they will become more involved in its protection.

Goal 4: Educate the Local Community about Ellerbe Creek Many Durham residents know very little about Ellerbe Creek or how their day to day activities affect it. To that end the Ellerbe Stakeholders group seeks to inform the public about Ellerbe Creek.

Goal 5: Protect the Falls Lake Drinking Water Supply Ellerbe Creek contributes a large pollutant load to Falls Lake. A goal of the Ellerbe Creek Watershed Plan is to reduce the amount of pollution entering this reservoir.

Section 4 Outlines the recommendations to protect Ellerbe Creek. With Ellerbe Creek's need for water quality improvement, it is the intent of the Ellerbe Creek Local Watershed Plan to identify a broad range of projects and activities that will meet these goals. The breadth of recommendations identified by this local watershed plan should enable city, county and state governments and their respective agencies as well as nonprofit organizations to take a series of actions to tangibly improve water quality in Ellerbe Creek.

Recommendations

1 Critical Area Protection

2 Riparian Area Management

3 Stream and Riparian Buffer Restoration Projects

4 Better Sire Design for Stormwater Management

5 Code and Ordinance Improvements

6 Stormwater Retrofits

7 Reduce Illicit Discharges

8 Stream Monitoring

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I Introduction

Background: The Upper Neuse River Watershed Management Plan

The Upper Neuse River Basin Association (UNRBA) was formed in 1996 to provide an ongoing forum for cooperation on water quality protection and water resource planning and management within the 770-square-mile watershed that drains into Falls Lake (Figure 1 next page). The 8 municipalities, 6 counties, and local Soil and Water Conservation Districts in the watershed voluntarily formed the Association.

The mission of the UNRBA is to preserve the water quality of the Upper Neuse River Basin through innovative and cost-effective pollution reduction strategies, and to constitute a forum to cooperate on water supply issues within the Upper Neuse River Basin by:

- Forming a coalition of units of local government, public and private agencies, and other interested and affected communities, organizations, businesses and individuals to secure and pool financial resources and expertise;
- Collecting and analyzing information and data and developing, evaluating and implementing strategies to reduce, control and manage pollutant discharge;
- Providing accurate technical, management, regulatory and legal recommendations regarding the implementation of strategies and appropriate effluent limitations on discharges into the Upper Neuse River Basin; and
- Compiling information and recommendations for the development of an Upper Neuse River Basin Watershed Management Plan.

In 1998, the North Carolina Wetlands Restoration Program (NCWRP) in cooperation with the UNRBA received an Environmental Protection Agency Wetlands Program Development Grant. One of the grant deliverables was development of the Upper Neuse River Basin Watershed Management Plan. The intent of this plan was to analyze current and future water quality conditions and strategies to address water quality concerns.

During the development of this plan, municipal and county government representatives identified water quality within water supply reservoirs as their highest priority along with limits to recreational use and habitat protection as other priorities. Based on these ranked priorities, the UNRBA and the NCWRP determined that the Ellerbe Creek watershed, located within the Upper Neuse River Basin, was an appropriate candidate for a Local Watershed Plan (LWP) (Figure 2 on page 3). The goals of this plan will work to address Ellerbe Creek's long-term poor water quality and protect water quality in the Falls Lake water supply reservoir.

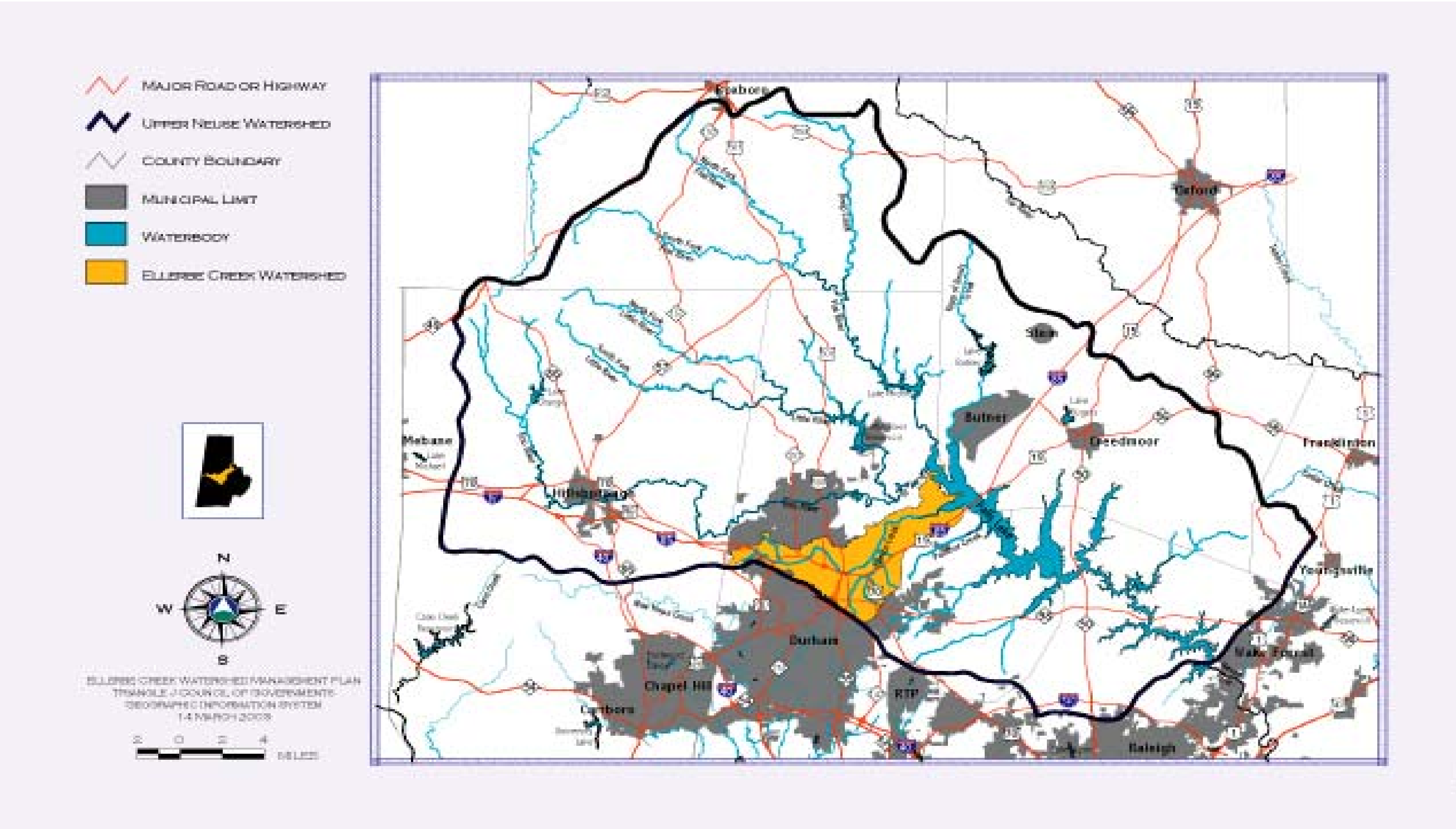


Figure 1: Map of theUpper Neuse River Basin

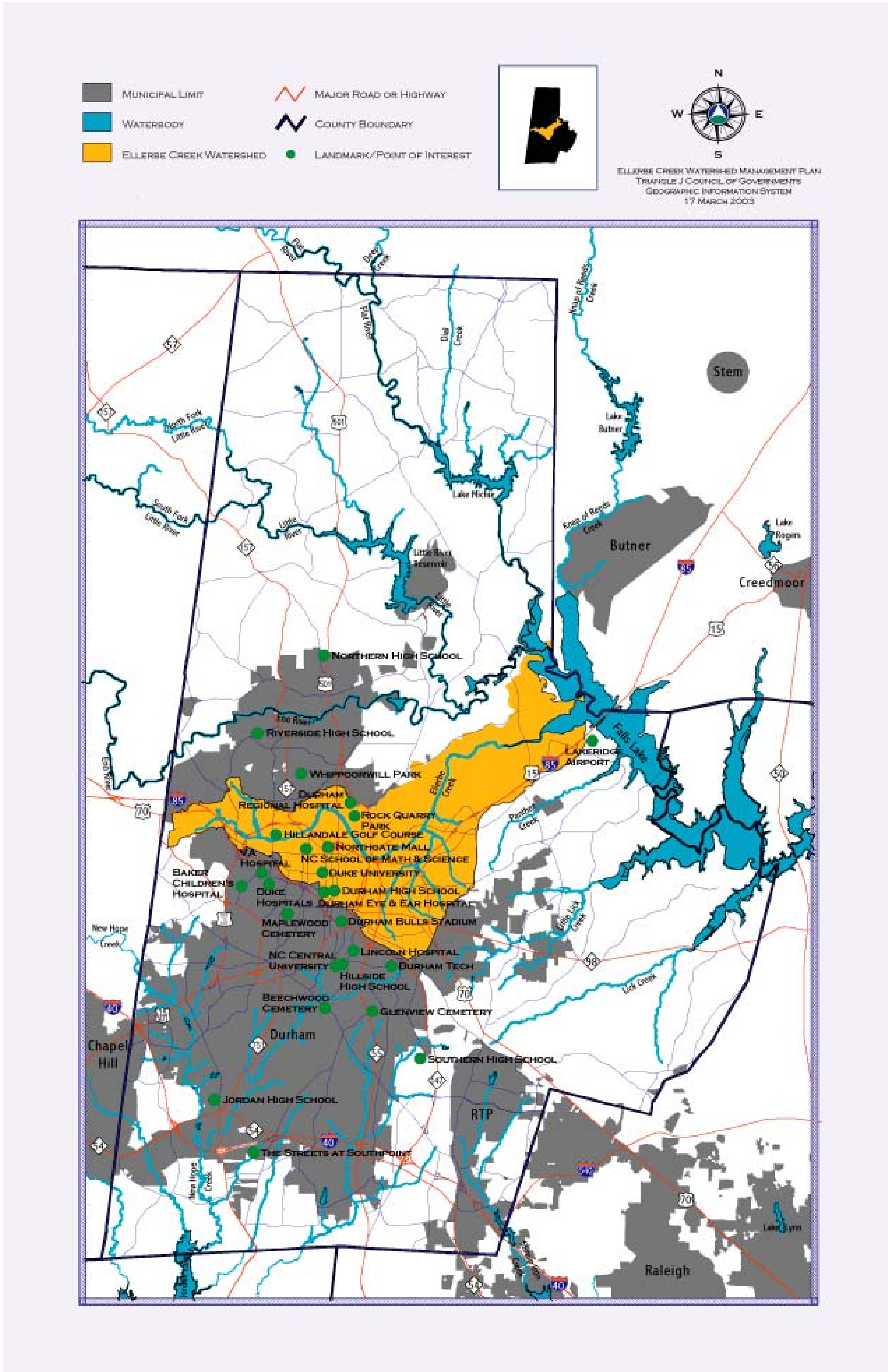


Figure 2: Map of the Ellerbe Creek Watershed in Durham County

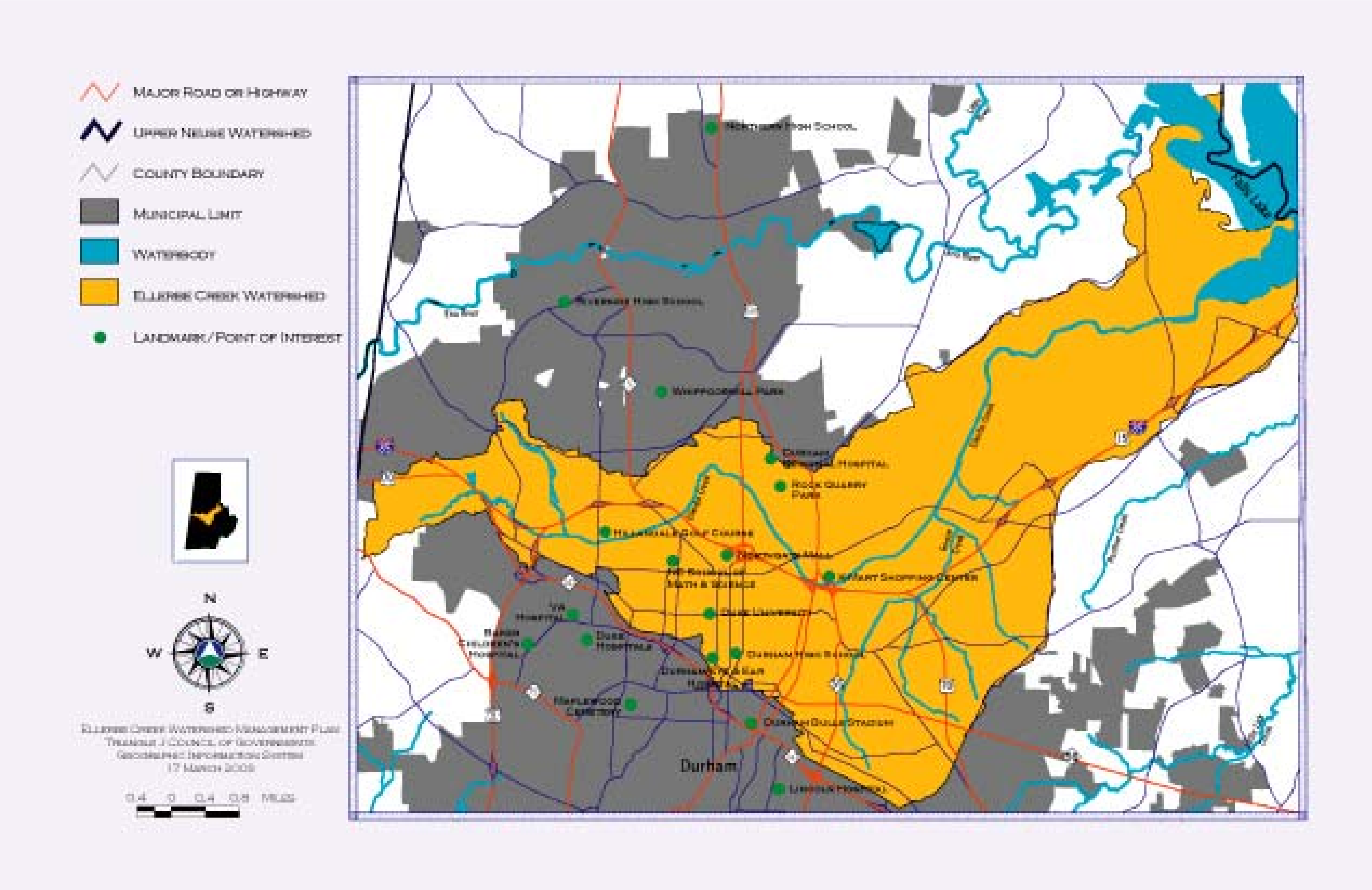


Figure 3: Map of the Ellerbe Creek Watershed

The Ellerbe Creek Local Watershed Plan development was initiated in February 2002 to provide more detailed information pertinent to the Ellerbe Creek Watershed. All information prepared and presented in the Ellerbe Creek LWP compliments the purposes outlined in the Upper Neuse River Basin Watershed Management Plan. For more information about the Upper Neuse River Basin Watershed Management Plan, see http://www.unrba.org/index.htm.

The NCWRP and the General Purpose of Local Watershed Plans

The North Carolina Wetlands Restoration Program (NCWRP) is a nonregulatory program located within the Department of Environment and Natural Resources intended to restore wetlands, streams, and riparian buffer areas for the purposes of improving water quality, flood prevention, fisheries and wildlife habitat, and recreational opportunities. The NCWRP works to accomplish these purposes and goals through the development of Local Watershed Plans.

Local Watershed Plans are developed with the help of local stakeholders to accurately describe watershed degradation issues and appropriate solutions that include restoration opportunities. Development of these plans helps local communities take a holistic look at their watersheds with an eye toward long term protection.

A Local Watershed Plan also provides a framework for utilizing various management tools and financial resources to implement solutions for watershed protection and improvement. Some of the restoration projects identified through this process may be used to help meet NC Department of Transportation future compensatory mitigation needs within specific watersheds.

UNRBA Watershed Findings and Implications for the Ellerbe Creek Watershed

The Upper Neuse Watershed Management Plan uses two primary measures to assess current and future water quality conditions within the Upper Neuse River Basin.

- imperviousness percentages (as an indicator of in-stream habitat)

- Nutrient loading and Chlorophyll *a* levels in the nine water supply watersheds

These two parameters are significant and often correlated when considering water quality and drinking water supply health. To best assess these parameters, a contracted consultant, Tetra Tech, was hired to perform a nutrient loading analysis of the entire Upper Neuse River Basin.

To determine nutrient loads for each of the 14-digit hydrologic units and each of the nine water supply reservoirs, current land use coverages and existing zoning regulations were assessed to model current and "buildout" scenarios for impervious surfaces and resulting nutrient loads. Evaluating imperviousness is important and directly related to calculating nutrient loading because impervious cover delivers nutrient loads directly to receiving waters, ultimately feeding algal growth.

This information was then used to calculate corresponding chlorophyll *a* levels within all the water supply reservoirs. Environmental Protection Agency standards recommend that water supply reservoirs should not exceed 15ug/L of chlorophyll a. Chlorophyll a is an indicator of algal growth. Accelerated algal growth lowers dissolved oxygen levels choking aquatic life and creating disagreeable odors and tastes. Correcting these problems requires additional resources for drinking water treatment.

The results of these analyses indicate that the Ellerbe Creek watershed in the City of Durham is identified as currently having the highest percentage of impervious land cover. Accordingly, of all the 14-digit watersheds draining into Falls Lake, Ellerbe generates the highest nutrient loads **(See Appendix A)**.

Additionally, Ellerbe Creek has been on the state of North Carolina's 303(d) list of impaired waters as long as the list has existed.

What is the 303(d) list?

The 303(d) list comes from section 303(d) of the original 1972 Clean Water Act. Under this section of the Clean Water Act, states are supposed to make a list of "impaired" streams that do not meet their designated uses.

Ellerbe Creek's designated uses include:
- Water supply waters,
- Aquatic life reproduction.

Impairment is defined as "detrimental effect on the biological integrity of a stream caused by an impact that prevents attainment of the designated use". Ellerbe Creek's water quality is considered "Biologically Impaired", because it is not meeting its designated use of <u>fully supporting</u> aquatic life.

Ellerbe Creek Stakeholder Process and Participants

Watershed residents and other stakeholders played a vital role in the creation of a Local Watershed Plan. Local Watershed Plans provide an important opportunity for local stakeholders to shape the future of their watershed. Through the local watershed planning process, these groups, like the Ellerbe Creek Stakeholder Team, work cooperatively to identify issues, set priorities, develop strategies, secure funding and implement protection and restoration projects within their communities. By integrating stakeholder participation into plan development and implementation, the local watershed plan for this Ellerbe Creek Watershed becomes a blueprint for strategically implementing local projects through partnerships with local governments, citizens, nonprofit organizations, and state and federal agencies.

In February of 2002, the NCWRP convened the Ellerbe Creek Stakeholders Team. The stakeholders met sixteen times, finalizing the Ellerbe Creek Local watershed Plan in March of 2003.

The following stakeholders participated in the watershed planning process and were party to the final plan:

Ellerbe Creek Stakeholder Group
John Cox - Durham Stormwater Services
Chris Dreps – Upper Neuse River Basin Association
Stephen Hiltner – Ellerbe Creek Watershed Association
Julie Holmes - Ellerbe Creek Watershed Association
Jane Korest – Durham City/County Planning
Robert Louque – Durham Stormwater Services
Noland Martin - Ellerbe Creek Watershed Association
Michele Nowlin, Friends of South Ellerbe Creek
Chris Outlaw – Durham Stormwater Services
Joshua Rose - Ellerbe Creek Watershed Association
Leigh Scott – Durham Central Park
Melissa Vernon – Duke University

II Ellerbe Creek Conditions

In order to suggest meaningful recommendations for the Ellerbe Creek Watershed's restoration, the current conditions of the watershed and their implications for water quality must be examined. The following section describes the Ellerbe Creek Watershed, its history and natural environment.

Additionally, the Ellerbe Creek stakeholders group has divided the Ellerbe Creek Watershed into 22 subwatersheds (Figure 4). The Ellerbe Creek's Watershed displays quite a bit of variability in Geology, land use, development levels, etc. This subdivision of the Ellerbe Creek Watershed is necessary to examine differences between the subwatersheds. Knowing the various subwatersheds with their different land use patterns has enabled the stakeholders to prioritize specific subwatersheds for specific recommendations.

Geology

Though the headwaters of Ellerbe creek's mainstem are in the Carolina Slate Belt, the bulk of Ellerbe Creek's watershed is composed of Triassic basin soils. (Figure 5). While the Coastal Plain is composed of sediments left by the Atlantic Ocean, the Triassic Basin is made of freshwater deposits washed down from adjacent uplands. Triassic soils are very erodable, so sedimentation is a concern in all Triassic basin streams.

The clay-silt soils of the Triassic basin have significant implications for water quality because the sedimentary rocks underlying the Triassic Basin have the lowest average yield of water to wells of all rock types in the state. This low yield implies the soil has low permeability (the soil doesn't absorb water very well), and thus, result in low base flows (base flows come from groundwater) of streams in the region.

In addition, the overall low permeability of residual soils derived from the Triassic sedimentary rocks results in low percolation rates for septic systems. This low permeability inhibits infiltration and promotes surface runoff during rainstorms. Historic loss of topsoil during the agricultural era, together with the removal of topsoil and compaction of soils during development, has further reduced the capacity of the soils to absorb rainfall.

In a few locations, the sedimentary soils of the Triassic Basin are penetrated by Diabase igneous intrusions. The Diabase parent material is more resistant to erosion than the surrounding Triassic soils, and serves as a source of rock that is otherwise absent in Triassic basin streams.

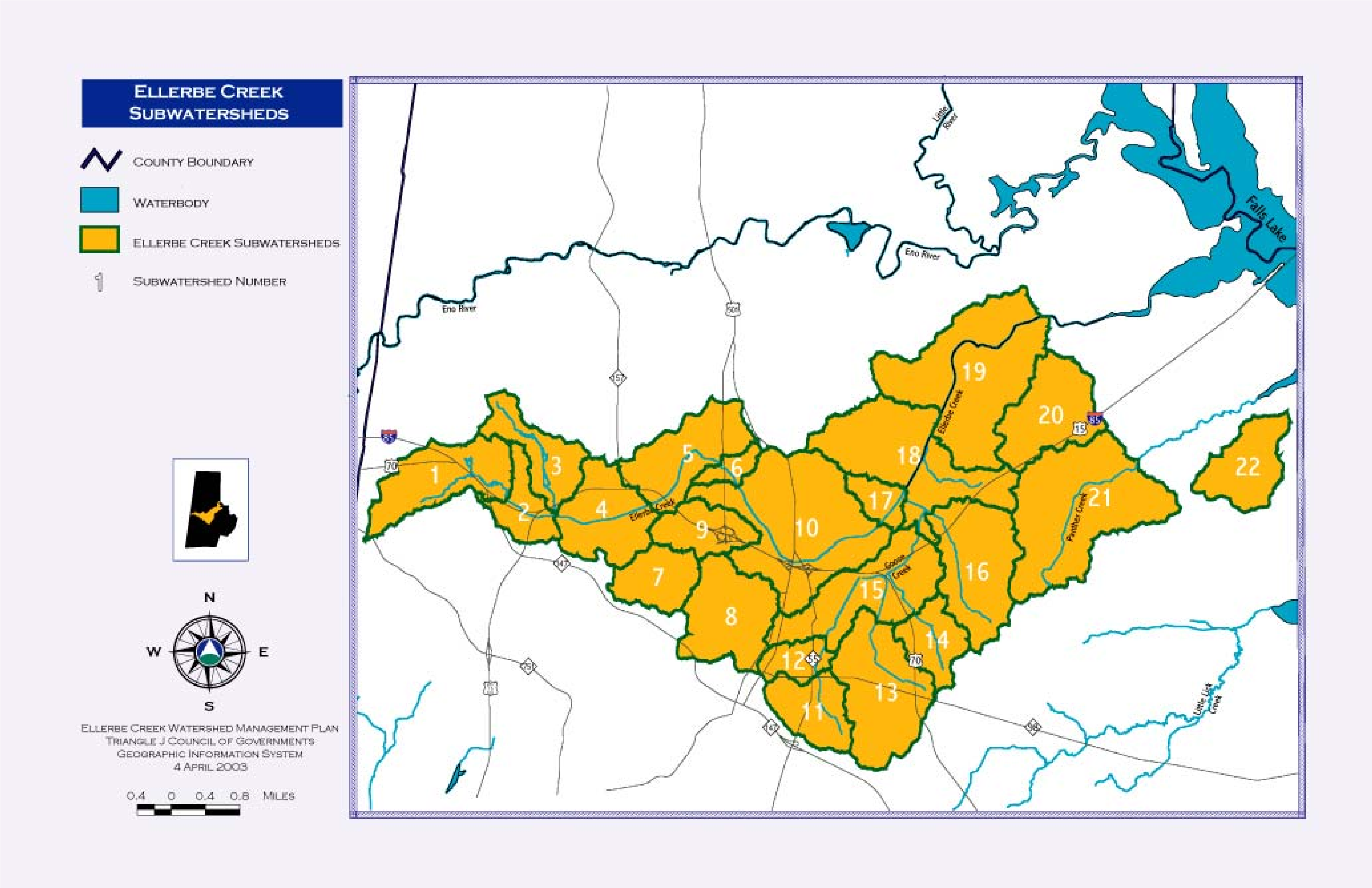


Figure 4: Map of Ellerbe Creek's Subwatersheds

History

Pre-Colonial Landscape

To rediscover Ellerbe Creek's history is to cut back through layers of human intervention. In the 17th century, Lederer described an open landscape, with Indian trails kept open by burning, and use of the land by the Eno, Shoccoree and Adshusheer tribes. Landscape under Indian and natural fire influence was likely a mosaic of prairie, savannah and forest.

Erosion in the Agricultural Era

Change has been radical in the past 150 years, as the plow loosened the watershed's soils and the creek became a dumping ground for industrial and human waste, as well as runoff from roads. Much of the watershed's topsoil—some 7 inches worth—was washed away during the agricultural era that extended well into the 20th Century. Though agriculture persists now only in a few fields in the lower valley out Glenn Road, the furrows still visible in woodlots throughout the watershed reveal just how much of the land was disrupted and exposed to erosion.

According to a 1974 article by Stanley Wayne Trimble, Man-Induced Soil Erosion on the Southern Piedmont, erosion from plowed land had the effect of stripping soil from the uplands—soil, that then accumulated in streambeds. Writing about erosion in South Carolina and Georgia, Trimble states, "Aggradation of streambeds caused the ground water levels in valleys to rise. Eventually many streams flowed at levels near or even above their valley floors, causing bottomlands to become swampy and unfit for agriculture. Even when not swamped, bottoms were often covered with less fertile erosional debris classified by soil surveyors as "Meadow" (This made the original dark bottomland soils (Congaree soils) unavailable to crops.) "Since many bottom lands were no longer suitable for corn and other crops, cultivation was transferred to the uplands, thus imposing even more erosional pressure there."

The decline in agriculture after 1920 brought another transformation to piedmont streams. Trimble states "The filling of stream channels and valleys persisted as long as erosion continued at high rates. When erosive land use decreased and erosion was diminished, streams no longer carried heavy sediment loads and became much clearer. With renewed stream competency, these sediment deposits became unstable and are now being eroded. By means of this active streambed erosion, streams incised themselves into the modern alluvium lowering their beds as much as 12 feet. In addition, there has been intensive erosion of the friable stream banks (composed in large part of modern sediment) taking trees, fences, and good pasture or cropland."

Erosion during the agricultural era in Ellerbe Creek may have been less than elsewhere in the southern piedmont because of the nature of its soils. A look at a geological map (Figure 5) of Durham County will show that the geology is not at all uniform in the watershed, but instead is an interweaving of many types of soil. A number of the soil types, being rocky and/or thin hardpans, resisted plowing, and therefore were more likely to be used as pastures. Depending on the intensity of grazing, these soils may well have been spared intense erosion.

The upper reaches of Ellerbe Creek, for instance, once contained large tracts used for dairy farming, including those owned by the Croasdailes and the Scoggins. Hillandale Golf Course, one of the oldest golf courses in North Carolina, was originally a milk farm before being converted at the turn of the century.

William Boyd, in The Story of Durham, states that farming in Durham County was concentrated in the rich valleys of the Eno, Little and Flat Rivers to the north, and the New Hope Creek watershed to the south. In between he describes “a series of hills which form a watershed” with less fertile soils, where industry took hold and the city of Durham developed.

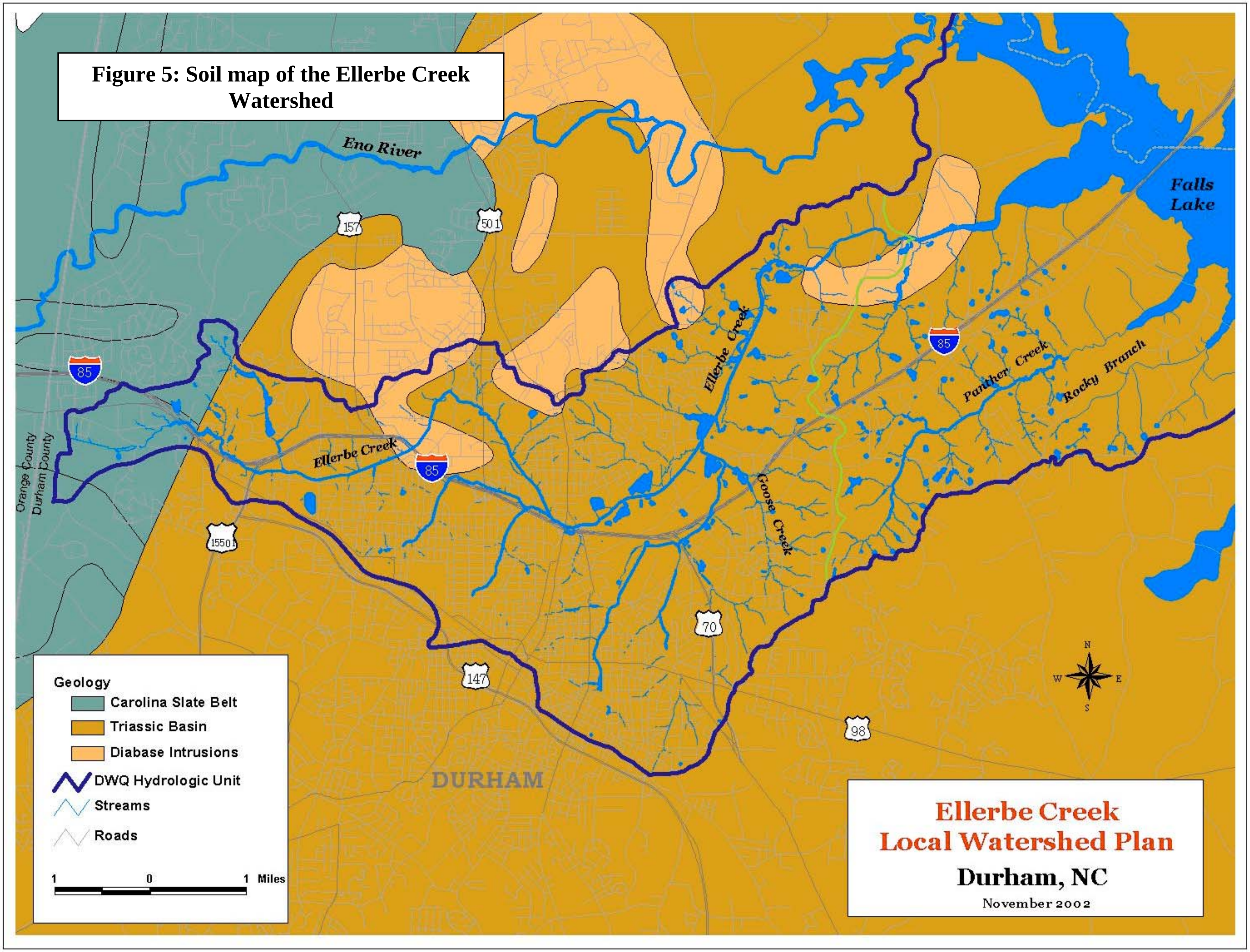


Figure 5: Soil map of the Ellerbe Creek Watershed
Eno River
Falls Lake
Ellerbe Creek
Ellerbe Creek
Goose Creek
Panther Creek
Rocky Branch
85
85
85
85
157
501
1550
70
147
98
Orange County
Durham County
DURHAM
Geology
Carolina Slate Belt
Triassic Basin
Diabase Intrusions
DWQ Hydrologic Unit
Streams
Roads
1 0 1 Miles
N
W
E
S
Ellerbe Creek
Local Watershed Plan
Durham, NC
November 2002

Urbanization and Channelization

Main thoroughfares in the watershed, such as Roxboro Street and Club Boulevard, have homes dating from the 1920s. The 1950s and 1960s saw the conversion of surrounding fields into residential neighborhoods, and the construction of Interstate 85 through the Ellerbe Creek valley. With development came higher rates of runoff, and increasing problems with flooding.
This was also the time of massive alteration to the creek channel itself. Except for a few spared sections, the natural meander and habitat of Ellerbe Creek's channel was obliterated when the Army Corps of Engineers straightened and deepened the creek. This action had tremendous consequences. Though flooding was reduced in places, the artificial straightening of the channel lead to greatly increased erosion of the creekbanks. The natural tendency of streams to meander caused the boxed-in creek to cut into the sides of the channel, causing collapse of the banks and increased sediment loads. The deepened channel also caused an "abandonment" of the floodplains. In a healthy stream, floodplains are a place where floodwater can disperse its energy, drop its sediment, and percolate into the groundwater. A deeply cut stream channel prevents these beneficial processes from occurring, as floodwater instead is carried in a powerful torrent downstream, where it can actually increase flooding in downstream areas.

The Marginalization of Native Plant and Aquatic Life

Widespread agriculture and channelization combined to uproot native vegetation and aquatic life from large portions of the watershed. As the agricultural era faded, the old fields not converted to residential use grew up in trees. However these urban woodlots bear little resemblance to those of pre-colonial times. The loblolly pines that now dominate were not present in the original forests. The shrubs and vines of the understory are typically the same invasive non-native weeds that plague people's backyards. Native aquatic and terrestrial species did not die out altogether, but now persist in sporadic, small pockets of adequate habitat, much of it highly vulnerable. These remnants provide a window into the past, as well as a source of genetic material from which to draw in repopulating the Ellerbe Creek valley with its historical native diversity.

From Creek to Ditch to Creek Again

With the raising of environmental awareness that gained momentum in the 1970s, the perception of Ellerbe Creek as a ditch—exemplified by the channelization in the two preceding decades—began to be questioned.

In restoring a profoundly altered urban creek, the goal cannot be to turn the clock back 400 years, or even ten. The original hydrologic balance that has long since been lost cannot be regained. It is possible, however, to work towards a new balance that allows natural processes to function once again, for the benefit of people as well as the health of the creek. To achieve this new balance, it is necessary to learn as much as possible about how the creek originally functioned. Though the original meander and profile would not be stable under the current conditions these along with remnants of the original flora and fauna are important guides in restoring the hydrologic and ecological functioning of this green urban corridor. The original soil profile is another important component. The soil’s capacity to absorb rainwater and transport it via baseflow to the creek has implication for flood control and sustaining flow during droughts.

Natural Heritage

Ellerbe Creek and some of its tributaries flow through some of the most densely developed parts of Durham. Much of its length has been channelized and some parts of South Ellerbe Creek are piped beneath the asphalt. Many of the most commonly found plant and animal species carpeting urban woodlots today are native to other countries, as American species were mostly pushed out during the agricultural period and replaced with English Ivy, Japanese Honeysuckle, Chinese Wisteria, Russian-Olive, Eurasian Starlings, House Sparrows, and numerous other invasive exotic species. However, parts of the watershed still harbor surprising biodiversity.

At either end of Ellerbe Creek lie important wildlife refuges. The headwaters of the Ellerbe are adjacent to the Duke Forest, a privately owned research property of nearly 8000 acres with significant wildlife populations. The mouth of the creek, which once fed the Neuse River, now empties into Falls Lake, a reservoir surrounded by over 5000 acres of land managed by the US Army Corps of Engineers, the NC Wildlife Resources Commission, and the NC Division of Parks and Recreation. The lands around Falls Lake harbor over 200 bird species and a great deal of other wildlife, plus they provide an indirect connection to the Eno and the extensive chain of well-preserved habitat along that waterway.

<u>Ellerbe Creek and its adjoining riparian habitats may be a significant urban wildlife corridor connecting the Duke Forest with Falls Lake and the Eno River watershed.</u>

In addition to varied woodland plant communities, several remnants of prairie habitat persist in the watershed, harboring once-widespread plant species that are now increasingly uncommon. Bennett Place, a N.C. Natural Heritage site and part of the Ellerbe headwaters region, is home to a population of Lewis’ Heartleaf Ginger (Hexastylis lewisii), a rare woodland wildflower. A few patches of Diabase soil provide neutral-pH soil conditions that provide habitat for other unusual plants. A nesting colony of Great Blue Herons (Ardea herodias) persists in the lower valley closer to Falls Lake. Deer, fox, beaver, river otters, wild turkey, and snapping and box turtles are among the varied wildlife observed along the creek in remaining wooded areas of old city neighborhoods. Thirty-seven fish species are documented as resident to the creek, as are roughly 80 species of aquatic arthropods (**Appendix G**).

Local birdwatchers have chronicled numerous species of migratory birds in the area. As growth and development continues to displace forest and wetland habitat across the Triangle, the creek's strip of riparian habitat will become increasingly important as a rest stop for these migrants.

Geography and Population

Ellerbe Creek is a small, predominately urban watershed located within the upper Neuse River Basin in Durham County, North Carolina. Its headwaters and half of its 23,526-acre watershed are located within Durham's city limits. Approximately 47,540 people currently reside within the Ellerbe Creek watershed, and based on current population trends, this number will increase to 58,000 by 2020 (Ellerbe Creek Watershed Association).

The Ellerbe Creek watershed takes the shape of a boot balanced on its heel. The main channel of the creek flows from west to east, interweaving with I-85 for much of its length. The Durham Freeway and Junction Road define the southern border of the watershed. Carver Street, Old Oxford Road and Hamlin Road define the watershed's northern boundary with Eno River lands. All of the drainage in this watershed flows to Ellerbe Creek and enters Falls Lake just south of the Eno River. Its two largest tributaries are South Ellerbe Creek and Goose Creek.

Land Use

Land use within the watershed is a mixture of medium to high-density residential and commercial development. Outside of the city the Ellerbe Creek watershed is dominated by bottomland hardwood forests and loblolly pine forests, with a limited amount of agricultural activity. Over 22 % of the watershed is currently impervious (**Appendix A**). Table 1 below describes the major land use in the Ellerbe Creek watershed within the City of Durham.

Table 1:Land Use in Ellerbe Creek Watershed within Durham's City Limits

Land use	Percentage
Residential Low Density	3.9%
Residential Medium Density	49.7%
Residential High Density	10.7%
Commercial	15.4%
Industrial	8.3%
Transportation	2.6%

Hydrology

Hydrology is the science that studies how water cycles from the atmosphere, to the surface of the oceans or earth, through the ground, into water bodies, and back into the atmosphere again. Scientists have observed a “water balance” or "water budget" that describes what happens to water when it reaches the earth. Although the amounts vary depending on climate, topography, geology, soils, and land cover, a general water balance is relatively predictable and serves as a useful starting point for this discussion. Figure 6 presents the hydrologic cycle, a useful starting point for understanding the water balance.

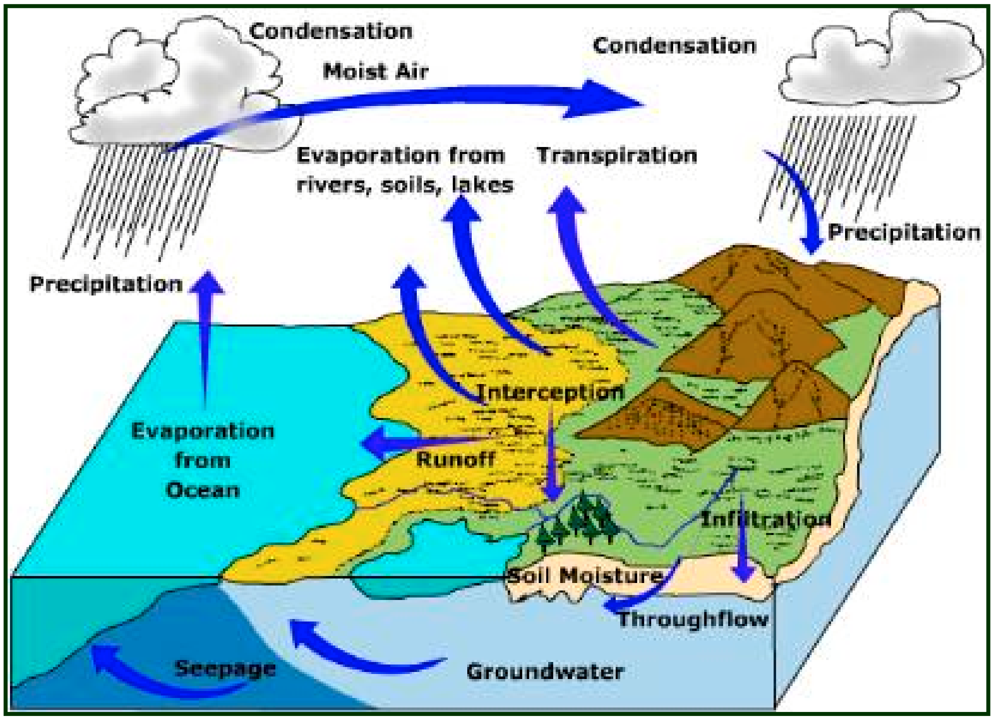


Figure 6: Hydrologic Cycle

The hydrologic cycle begins with precipitation. An average of 45 inches per year of precipitation falls in the Upper Neuse Basin. In a natural landscape, most of this water is evaporated or transpired by plants, returning to the atmosphere to become rain again. Of the water reaching the ground, most becomes shallow or deep groundwater, feeding streams or recharging aquifers. A small portion becomes surface flow.

There has been little study of where the water goes in the Piedmont area of North Carolina. However, studies conducted in the region can provide us with a general idea of what happens to this 45 inches per year of rainfall. A 2002 study in the Duke Forest (Schafer et al 2002) examined the water budget in a forested area over a three-year period (1998-2000). The Duke Forest study shows that over two-thirds (71%) of all precipitation is either evaporated or transpired by plants. Of the remaining twenty-nine percent that reaches the ground, twenty-one percent (21%) becomes shallow or deep groundwater, while five percent (5%) becomes surface runoff. Table 2 shows these figures for total precipitation, evapotranspiration (evaporation + transpiration), surface flow, and groundwater. The study's residual error (that amount of rainfall not accounted for) is three percent (3%).

Table 2: Estimated water balance for the Upper Neuse Basin (based on findings from Schafer et al 2002)

Component	Percentage of total precipitation	Annual Amount (based on percentage)
Total Precipitation	100%	45 inches
Evapotranspiration	71%	32 inches
Surface Flow	5%	2.3 inches
Groundwater	21%	9.5 inches
Residual Error	3%	1.2 inches

It is important to remember that this water balance can vary from place to place. As mentioned in the Geology section, Ellerbe flows over Triassic soils that are not very permeable, whereas the example above is from the Slate Belt that has soils with significantly higher permeability. The Triassic soils of the Ellerbe Creek watershed likely experience slightly higher surface flows in comparison to those described in Table 2. During periods of drought, even undeveloped watersheds in the Triassic Basin can exhibit low-flow conditions because there is less base flow from the ground feeding the stream. Conversely, during periods of high precipitation, Triassic soils provide less absorption, and more water flows into Ellerbe Creek.

It is important to remember that a water balance very similar to the natural balance described above created our natural water systems, including the streams, ponds, wetlands, groundwater aquifers, and even the forests. From a hydrologic point of view, this budget changed little over the course of human history until the last 100 years.

Development and Hydrologic Change

When land development removes tree cover, compacts topsoil, and adds impervious surfaces, as has occurred in Ellerbe Creek, more water runs off into streams, less is evaporated or transpired, and less water slowly infiltrates into groundwater. More stormwater in streams means higher flow conditions. These high flow conditions cause erosion of the streambanks and scouring of the stream bottom to the detriment of all aquatic life. During times of low rainfall, there is less water in the ground to maintain the streams, and aquatic life suffers. As the Ellerbe Creek Watershed has developed, the number of roads, parking lots, and roofs (impervious surfaces) has increased. When Ellerbe Creek flowed through an agricultural watershed before 1850, there were few impervious surfaces. Now, 22% of Ellerbe Creek's land is under impervious cover. Figures 7 and 8 below illustrate the effect that urbanization can have on the water budget. Figure 6 shows the hydrologic balance of a natural Piedmont stream. Figure 8 shows what happens when trees are removed, soils are compacted, and impervious surfaces occupy the landscape.

Figure 7: Forested Landscape Water Budget

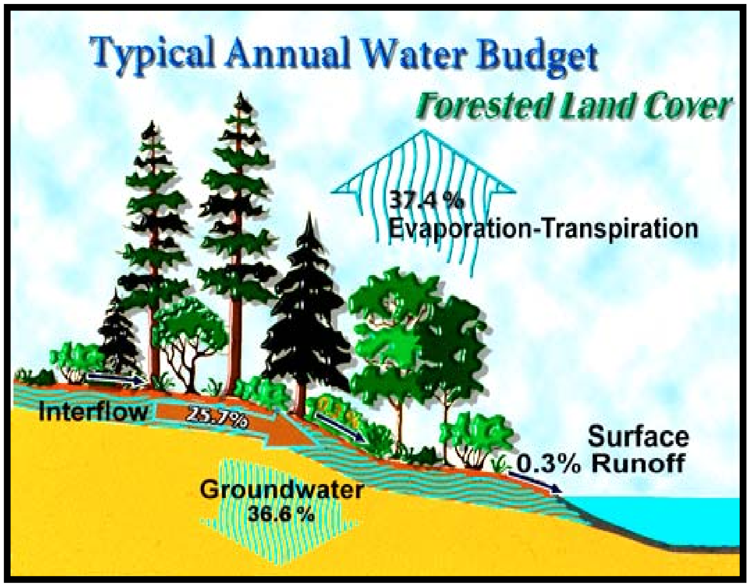
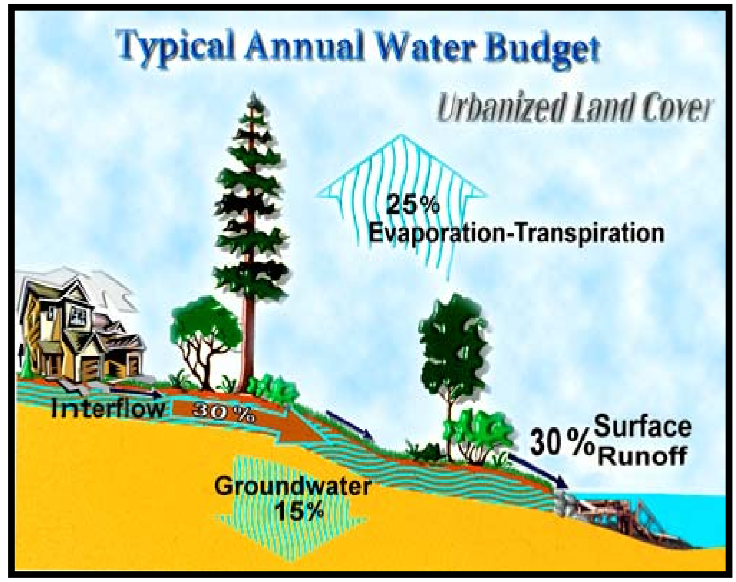


Figure 8: Urbanized Landscape Water Budget

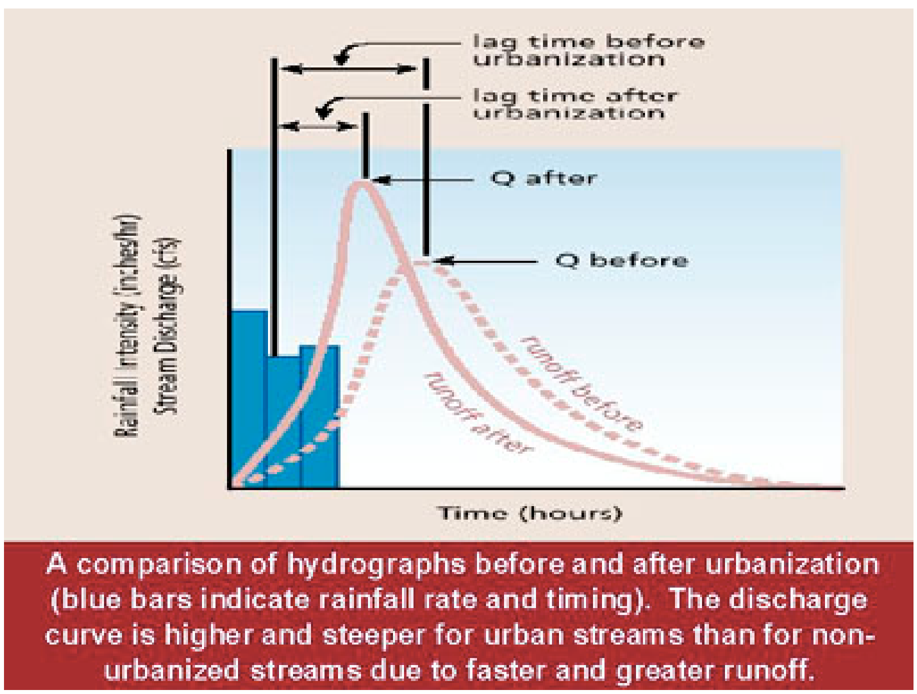


What happens to streams when these changes occur? Increased surface water volumes occur during storms ("peak flows"), leaving less water to infiltrate into the ground and maintain streamflow during dry periods ("baseflow"). See the box on hydrographs. The high "peak flows" and low "base flows" associated with increased development and impervious cover can have many negative effects:

- Increased sediment in streams
- Channel enlargement
- Decline in stream habitat quality
- Increased water temperatures
- Decline in water quality (nutrients, sediment, metals, hydrocarbons, bacteria)
- Decline in fish & aquatic insect diversity; and
- Decline in amphibian communities.
- Decline in habitat diversity

Hydrologists use <u>hydrographs</u> (graphs measuring stream flow over time) to analyze the amount and intensity of water flowing in streams and rivers. The hydrograph below shows the effect of increasing urbanization on streamflows. The dotted line shows runoff levels under natural conditions, and the solid line shows runoff levels after urbanization. Note that the peak of the dotted curve is lower than that of the solid line. This is because peak flows in an undisturbed watershed are lower than in urbanized watersheds. In addition, notice that the solid peak occurs before the dotted peak. Rainfall in urbanized areas concentrates faster, reducing "lag time" and creating more violent flows in streams.

Figure 9: A Hydrograph showing the effects of urban development



A comparison of hydrographs before and after urbanization (blue bars indicate rainfall rate and timing). The discharge curve is higher and steeper for urban streams than for non-urbanized streams due to faster and greater runoff.

Impervious Cover as a Measure of Watershed Health

Various studies have attempted to correlate the amount of a watershed's impervious cover with indicators of stream health. Researchers from across the country have found that levels of impervious cover of between six and fifteen percent negatively affect various indicators (CWP 1998). The range of research is extensive, examining stormwater runoff volumes and intensities, stream channel stability, aquatic habitat, species populations, stream temperature, water quality, wetland plants, sediment loads, and more. Using this research, the

Center for Watershed Protection developed the Impervious Cover Model (CWP 1994) for communities to use in understanding and predicting the watershed impacts from urbanization. This model assumes that watersheds with between 10% and 25% impervious cover will be impacted and watersheds above 25% will be degraded.

It is important to understand that these studies only show associations between impervious cover and stream health. Many important factors, such as the type of stormwater management practices and the natural features of the watershed, are not considered. These factors are specific to an individual watershed and cannot be applied broadly in making watershed management decisions. However, Ellerbe Creek has been, and continues to be, developed using conventional methods that are not sensitive to natural systems. For this reason, the model is useful for general analysis identifying subwatersheds of concern.

Imperviousness vs. Connected Imperviousness

While total impervious surface area is the commonly used indicator of urban stream health, a more effective indicator is the percent of connected, or effective, impervious surface in the watershed. Connected impervious surface refers to impervious areas that are hydraulically connected to the stormwater drainage system (Schueler 2003) or are themselves surrounded by directly connected impervious surfaces (City of Olympia 1995). For example, a parking lot channeling water into a storm drain would be more effective than a residential building directing water onto an adjacent lawn. While research suggests that connected impervious surface is a superior predictor of stream health, it is much more difficult to calculate, and is therefore less commonly used than simple measures of total imperviousness.

Table 3 shows the amount of total impervious area, change in imperviousness and connected imperviousness for the subwatersheds delineated in this study.

Table 3 Ellerbe Creek Total Impervious Area by Subwatershed

Subwatershed	Total Area (Acres)	Percent Impervious 1994	Percent Impervious 1999	Change in Imperviousness (acres lost)	Acres of Connected Imperviousness
1	787	11.4	13.3	15	23.9
2	348	34.6	36.2	5.6	58.1
3	516	17.2	17.9	3.6	20.2
4	729	24.0	24.2	1.5	41.5
5	761	23.7	22.0	+13	68.1
6	141	25.2	25.2	0	15.5
7	438	40.8	41.9	5	52.2
8	809	47.9	47.7	+1.6	104.2
9	424	37.6	40.2	11	79.9
10	1715	22.7	23.1	4	132.6
11	484	41.2	42.0	4	69.3
12	247	41.9	42.5	1.5	35.1
13	1040	29.8	31.1	14	119.1
14	400	18.6	19.1	2	16.6
15	985	21.4	21.8	4	60.5
16	955	9.2	9.3	1	16.3
17	210	11.6	11.9	0.6	3.1
18	1309	10.4	11.0	7.9	15.9
19	1691	3.8	3.9	1.7	0.0
20	765	3.9	3.9	0	0.0
21	1611	4.9	unknown	Unknown	0.0
22	560	3.2	unknown	Unknown	0.0
TOTAL	16,925			97	932

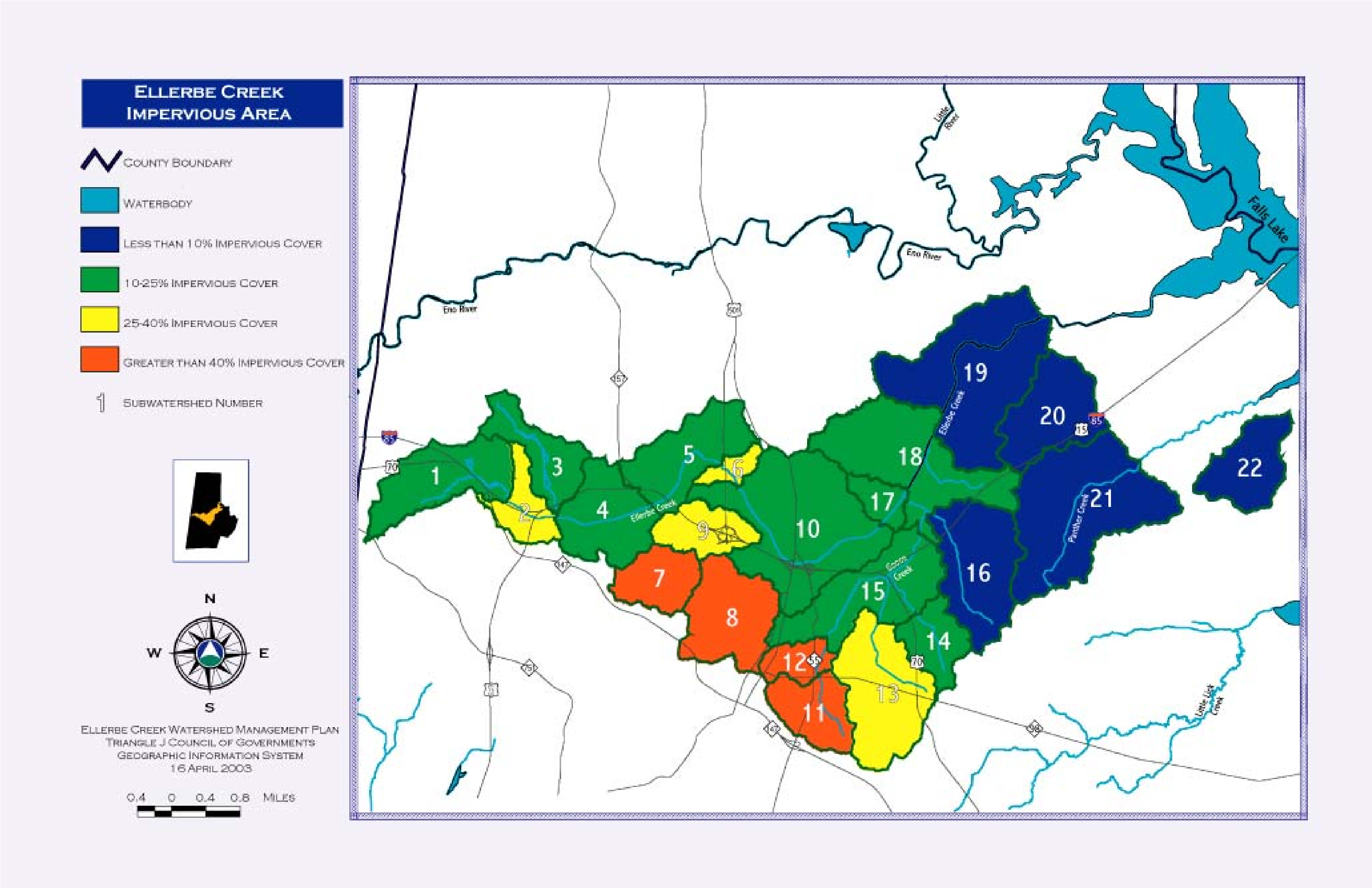


Figure 10: Percent Imperviousness in Ellerbe Creek Subwatersheds

Figure 11: Flooding on Acadia Street, Northgate park neighborhood, Fall 2002

Flooding

Like many urban waterways Ellerbe Creek's high level of imperviousness makes it prone to flooding. Durham 's zoning of the 100-year floodplain (Figure 12 on the next page) makes floodplain development difficult but not impossible. Some structures were built in the floodplain long before current zoning regulations came to pass.

During Hurricane Floyd in 1999, Durham experienced tremendous flooding along Ellerbe Creek. Again in the fall of 2002, after one of the worst droughts in Durham County history, Ellerbe Creek flooded parts of Durham. Floodwaters usually damage homes in Northgate Park at least once a year.

The Roxboro Road/I-85 interchange is an area that often bears the brunt of floodwaters. Here, two main transportation arteries converge along with a several strip malls, a K Mart and large parking lots. Much of this area is in the Ellerbe Creek floodplain, and is just downstream from some of the most developed sections of Durham. Unfortunately, the result is predictable, consistently causing significant property damages to businesses in the area.

Past Impacts -Channelization

In an attempt to alleviate flooding, Ellerbe Creek has been channelized several times in the past. Channelization involves deepening and straightening the stream channel. (At the time people knew nothing about natural channel design). Traditional channelization is a very efficient method for moving water quickly out of an area. Unfortunately, it is a very poor design for sediment transport leading to poor, sandy-bottomed channels lacking the appropriate habitat for most aquatic organisms. Also, channelization didn't alleviate flooding, it just moved the floodwaters downstream. Additionally, channelization creates more shear stress on the sides of the stream. By straightening the stream, the water flow increases, but this increases the pressure on streamsides leading to undercutting and bank collapse, contributing excessive sediment to the stream.

In August 1961, A Corps of Engineering Channel improvement project (channelization) was completed on Ellerbe Creek from the mouth upstream to about Bellevue Avenue. This project provides a major drainage outlet and reduces the stages of the more frequent floods, but has little effect on the 100-year and larger floods (USACE 1978).

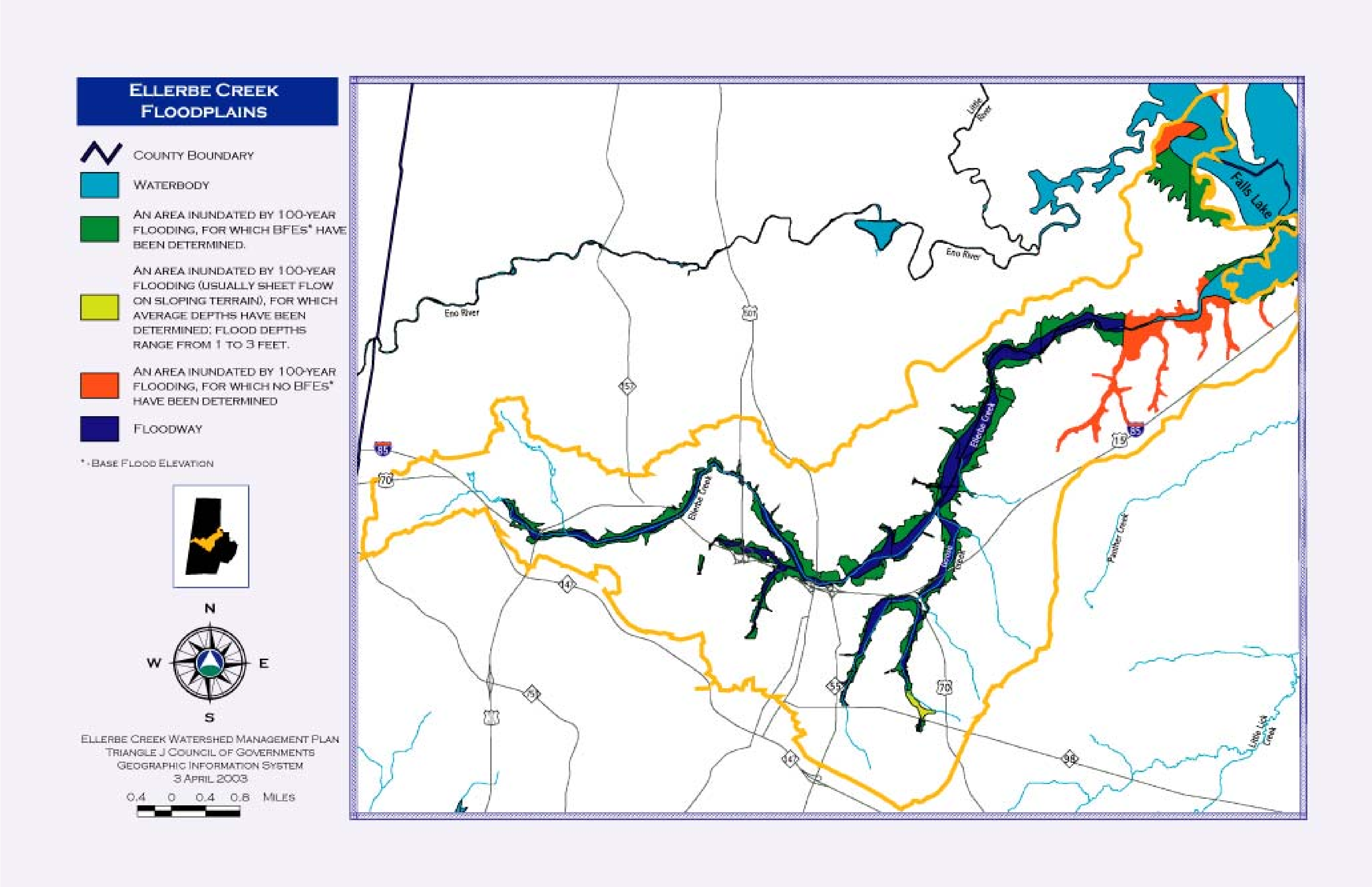


Figure 12: Map of the Ellerbe Creek Floodplains

Impacts on Water Quality

As mentioned in the introduction, Ellerbe Creek is the most impervious watershed draining into Falls Lake. Urbanization and its resulting high imperviousness lead to increased nutrient loads, total suspended sediments, heavy metals, biochemical oxygen demand, and oil and grease (hydrocarbons) in urban streams (May et al. 1997, Lenat and Crawford 1994, Novotny 1991). While specific sources or urban non-point source pollution are difficult to identify, potential sources include street litter, rubber and metal eroded from vehicles, corrosion of galvanized roofing materials, pet wastes, fertilizers and pesticides (Cole et al. 1984, Bannerman et al. 1993). In addition, impervious surfaces serve as a surface for the deposition and accumulation of airborne pollutants from automobile exhaust and other sources that wash off into the creek when it rains (Arnold and Gibbons 1996). Fecal coliform bacteria can also be a problem where there are failing septic and sewer systems or illicit connections to the stormwater system (Schueler 1994). A high percentage of imperviousness also limits opportunities for pollutant absorption. If water is piped directly from an impervious surface, such as a parking lot, into the creek channel there will be no opportunity for the pollutants it is carrying to infiltrate into the ground and be removed.

The water quality monitoring performed by NCDENR and Durham Stormwater Services concludes that Ellerbe Creek suffers from many of the same water quality problems found in urban creeks around the country. Chemical monitoring has shown elevated levels of iron, copper, and zinc (NCDENR 2001). Nutrient concentrations and dissolved oxygen levels at the Fall's Lake monitoring station have improved since 1998 (NCDENR 2001), probably due to improvements at the North Durham Water Reclamation Facility (NDWRF), which discharges into Ellerbe Creek upstream of Falls Lake and immediately downstream of heavily urbanized areas of Durham. However, overall water quality remains problematic and benthic macroinvertebrate samples show only minor differences in biological impairment upstream and downstream of the wastewater treatment plant. Oddly enough, benthic communities downstream of the NDWRF are now actually better than immediately upstream; this is in part due to the diluting effect NDWRF achieves by continually adding treated water to the streams' end line of Durham's urbanized areas. As a result, NCDENR has identified urban non-point source pollution as the most likely source of water quality impairment for Ellerbe Creek. The City of Durham's Stormwater Services has identified non-point sources such as illicit discharges, stormwater runoff and illegal dumping as likely causes. (**See Recommendation 7 and Appendix F**).

Watershed models developed by Tetra Tech, Inc. for the Upper Neuse River Basin Association indicate that Ellerbe Creek currently delivers 37.9 tons of Nitrogen and 4.82 tons of Phosphorous each year into Falls Lake. This will increase to 47.1 tons of Nitrogen and 6.08 tons of Phosphorous when the watershed is built out to the full extent allowable under current regulations in

2025 **(see Appendix A).** These high nutrient loads can cause algal blooms in Falls Lake and may result in eutrophication, a process by which the increased growth and subsequent decomposition of algae leads to low dissolved oxygen levels in the lake. Low dissolved oxygen levels can result in extensive fish kills, such as those that occurred in the Neuse River Estuary in 1995 (NCDENR 1998).

From 1996 to 2002, Durham's Stormwater Services conducted 152 investigations involving sewer leaks and breaks, sanitary sewer overflows, failing septic systems, and unpermitted sand filter systems, 13 laundry wastewater discharges and 71 oil, petroleum product and grease spills in the Ellerbe Creek watershed. During this same time period, they identified 7 illicit connections where sewage drains were hooked up directly to the stormwater drainage system. Stormwater Services has worked to correct these problems as they are identified and fecal coliform counts have decreased substantially in Goose Creek, South Ellerbe Creek, and the main stem of Ellerbe Creek. Ellerbe Creek consistently, though barely, passes the State's water quality standards for fecal coliform bacteria downstream of the NDWRF discharge. The City's monitoring upstream of the discharge indicates that fecal coliform remains a concern in tributaries of Ellerbe Creek (City of Durham, Stormwater Services 2002).

Impacts on Habitat and Aquatic Life

As mentioned in the introduction Ellerbe Creek is on the state's 303(d) list of impaired waters due to inadequate aquatic life support as indicated by a "Poor" bioassessment rating based on benthic macroinvertebrate samples. The NCDENR monitoring station is located downstream of the North Durham Water Reclamation Facility, and this site has shown gradual improvement since 1985 (Neuse River Basin Plan DWQ, 2002). Historically this site has produced ratings of "Poor" but in 2000 the site was rated by the State as "Fair" for the first time, confirming that the stream has potential for improvement. Two locations upstream of the NDWRF have been rated "Poor" by the City of Durham Stormwater Services in annual monitoring of benthic macroinvertebrates.

Stormwater Services and NCDENR have consistently rated the habitat in Ellerbe Creek as extremely degraded. In general, urban streams are characterized by lower species diversity, smaller populations, and the reduced abundance of sensitive species as compared to streams in undeveloped, forested watersheds. The response of aquatic communities to urbanization tends to exhibit a threshold effect, where increased development has little effect up to a certain point, but results in severe degradation to the aquatic community once the threshold is passed. Studies conducted in urban watersheds around the country suggest this threshold generally occurs around 10 to 15 percent of impervious cover (Schueler 1994). These impacts are most likely a result of the combination of habitat degradation, hydrologic impacts, and water quality impacts.

North Carolina's biological assessment methods and ratings (also used by the City of Durham Stormwater Services) were developed based on the pollution tolerance of various organisms. The primary reason that benthic macroinvertebrate communities are sampled is that they provide a better long-term picture of overall stream health than chemical samples, which can only reflect water quality at any one moment in time. Benthic macroinvertebrate communities are sensitive to subtle changes in water quality and as a whole can reflect the cumulative impacts of a wide array of different pollutants (NCDENR 1998).

The diversity of species found at a site is also directly related to the diversity of the aquatic habitat. Natural channels generally have a large number of different micro-habitats within a short segment of stream, including pools, riffles, leaf packs, bank areas with vegetation and roots in the water, etc. Many organisms live in only one type of microhabitat. Therefore a reduction in the diversity of habitat will contribute to a reduction in species diversity.

As discussed in the section on hydrology, urbanization and increases in impervious cover make streams flashier during storm events. The increased runoff from storm events scours streambeds and tends to flush organisms downstream. Efforts to control flooding result in removal of vegetation, snags, leaf packs, and other microhabitats. Urbanization is also accompanied by changes in food supply (as discussed in **Appendix C**).

The changes in hydrology tend to have a significant impact on the diversity of organisms that are being used to assess water quality and the designation of supporting aquatic life. Therefore, improving aquatic life will likely require both improvements in water quality and habitat.

Potential Future Impacts

By the year 2025, The Ellerbe Creek watershed will be built out and urban land use will almost triple from 1249 to 3397 acres and its total imperviousness will increase to 27.5%(**See Appendix A**). As mentioned in the nutrient loading section this will lead to a dramatic increase in nutrient loading.

Road construction scheduled in the next 6 years will impact approximately 6,402 linear feet of stream in the Ellerbe Creek Watershed (Conversation with NCDOT personnel). This is just the direct impact that road construction will have on Ellerbe Creek and does not consider the secondary impacts (additional development, impervious surface, traffic) that will affect the watershed. The vast majority of this construction will occur in the eastern, or less developed part of the watershed.

Many Ellerbe Creek subwatersheds are at or close to build-out, so additional development will not have as great of an impact in these subwatersheds.

Any redevelopment in these subwatersheds presents the opportunity to use more water quality friendly practices such as urban Best Management Practices, Low Impact Development and other techniques.

Current Protection Efforts

Despite many of the problems that plague Ellerbe Creek, it does not lack advocates. One reason that the NCWRP chose to work in Ellerbe Creek was due to the tremendous amount of community concern and grassroots efforts to protect Ellerbe Creek.

Small Area Plans

Durham's City/County Planning Department has produced a series of Small Area plans for different sections of the city. The Northwest Durham plan cites the Ellerbe Creek Headwaters as a focus for preservation. "In addition, West/Northwest Durham is also home to the headwaters of Ellerbe Creek, which flows through Durham and also serves as a refuge for wildlife. The area bounded by Berini Drive, I-85 and Cole Mill Road is the last relatively undeveloped portion of Ellerbe Creek's headwaters, containing a picturesque landscape of woods, native prairies, seepage slopes, ponds and a gorge, with strong neighborhood support for its protection" (page 11 West/Northwest Durham Plan, Durham City County Planning Department, June, 2002)

The North Central Durham Plan states "Water quality sensitive areas are designations made to indicate regions that warrant special attention to development, because of the role that development plays in flooding and pollution of nearby creeks, streams, and reservoirs. Present and future residents may relate to the water body as a source of water supply and recreation, or as a source of flooding and erosion problems. In the case of North Central Durham, the special flood hazard areas and the water quality sensitive areas are the same, following South Ellerbe Creek and Goose Creek, through the planning areas. The designations are outlined in a report by the Department of Planning and Community Development, Durham: Past, Present, Future, 1982. The major concerns with these two environmental designations are minimizing property damage to existing structures in the localities and preventing new development, which would add to property damage and downstream flooding problems. On the positive side, these areas can be seen as opportunities to provide open spaces which address recreation, water quality, and other community concerns" (page 18 North Central Durham Plan, Durham City County Planning Department, 1984).

Durham's Stormwater Services Program

The City of Durham's Stormwater Services' efforts have made for improvements in water quality by locating and eliminating sources of pollution, resulting in the reduction of fecal coliform bacteria and other pollutants as well as increasing dissolved oxygen levels in the streams. These efforts are discussed in greater detail under Recommendations 7 and 8 concerning illicit discharges and stream monitoring

Citizen Advocacy Groups

Three local community groups are constantly working to improve water quality: Friends of South Ellerbe Creek, The Ellerbe Creek Watershed Association, and Durham Central Park.

The Ellerbe Creek Watershed Association (ECWA) is dedicated to improving the relationship between Durham residents and Ellerbe Creek through education, ecosystem restoration, land protection, and the creation of nature trails and preserves for the urban public to enjoy. Since becoming a 501(c)(3) nonprofit in 1999, ECWA has collaborated with state and local governments, neighborhoods, businesses, schools and universities to begin turning a degraded urban creek into an oasis for people and wildlife. ECWA has received awards from the Durham Soil and Water Conservation District and the Headwaters Group of the Sierra Club for its efforts.

Friends of South Ellerbe Creek (FOSEC) is an informal group of citizens committed to the restoration and protection of South Ellerbe Creek. The membership is composed of residents of the neighborhoods through which the creek flows, as well as people who live throughout the Neuse River basin. FOSEC has been active in its efforts to educate the Durham community about the creek's history, its importance to both the community and the broader basin, the threats to its quality, and the ways it can be protected and restored. The FOSEC website contains extensive history, photographs, updates on activities and links to information and other organizations. It works with civic groups and neighborhood schools to organize several creek clean-ups each year. It engages in community education and awareness, periodically sponsoring workshops on topics such as buffer protection, aquatic habitat and xeriscaping, and working with the city of Durham to stencil storm drains. It works closely with neighborhood elementary schools to assist with environmental education and local history classes, and to ensure safe access to the creek for science and ecology classes

Durham Central Park is working to establish the appropriately named downtown urban nature park with an emphasis on environmental education.

Restoration Efforts

In the context of this Local Watershed Plan, the NCWRP identified and has begun implementing a 6000 linear foot stream restoration project on Ellerbe Creek. The project is restoring Ellerbe Creek on the Hillandale Golf course –

just upstream from an Ellerbe Creek Watershed Association tract and just downstream of several high priority headwater tracts targeted for acquisition. With support from the Durham County Matching Grants Program, hundreds of ECWA volunteers have transformed a derelict floodplain woods into a 17 acre urban nature reserve with trails and educational signage. For this work, ECWA received the 2001 Urban Conservationist of the Year award from the Durham Soil and Water Conservation District. ECWA, in collaboration with the NCSU Water Quality Group and Durham city's Stormwater Services Department, recently received a grant from the Clean Water Management Trust Fund to restore an additional half-mile of creek immediately downstream. Together, these two projects represent vital first steps towards reversing the damage channelization wrought decades ago.

ECWA has discovered and inventoried numerous remnants of diverse native flora in the watershed, and is actively promoting the use of these plants in creek- and wildlife-friendly landscaping. Through plant rescues, propagation and creative management of public areas, ECWA is making that natural heritage an enlivening, beautifying presence in constructed wetlands, along city trails and creekbanks, in city parks, on schoolgrounds and in the ECWA Urban Nature Reserve.

Stormwater Retrofitting/Stormwater Management

In an effort to make new development less destructive to Ellerbe Creek, ECWA and FOSEC are working with developers and city planners to promote clustering, better stormwater management and preservation of natural features. Providing new residents with nature-oriented recreational opportunities close to home is an important aspect of this.

In 2000, ECWA collaborated with NC State Extension and the Hillandale Golf Course to construct and plant a stormwater wetland. The facility has demonstrated how otherwise destructive stormwater can be used to beautify the landscape and create habitat.

ECWA actively seeks out and researches opportunities for stormwater retrofits throughout the watershed, and encourages homeowners to redirect roof and driveway runoff into rainbarrels, absorbent swales and miniponds in the yard.

Durham Central Park has been seeking funding to build two bioretention areas within the park. One would treat runoff from Liberty Warehouse and surrounding areas, and the other would treat runoff from the Measurement, Inc, parking lot. Durham Central Park also proposed to restore about 400 feet of Ellerbe Creek. To assist Durham Central Park, the City of Durham has applied for a grant from the NC Division of Water Resources.

Critical Habitat Preservation

ECWA's long-term goals include preservation of Ellerbe headwaters tracts and historic features, establishment of a string of trail-linked nature reserves along the full length of the creek—accessible to neighborhoods and schools—and restoration of the ecological function and beauty of Ellerbe Creek and its adjoining floodplain habitat. Exploring and preserving special areas of the soon-to-be-developed lower valley is also a priority.

FOSEC has been working to secure the acquisition and protection of a critical green space across from an elementary school – one of the last remaining undeveloped tracts of land in the South Ellerbe Creek watershed.

Duke Park Preservation Initiative (DPPI). Though largely inactive in the last few years, DPPI was the first 501(c)(3) nonprofit organized specifically to preserve land in the Ellerbe Creek watershed—in the area of Duke Park. The group drew up a plan for preserving the corridor along a tributary, and acquired several acres through the Durham County Matching Grants program. DPPI awaits a new infusion of volunteer energy to continue its mission.

III Ellerbe Creek Watershed Goals

Protecting Watershed Functions

Watersheds provide a continuum of ecological services to a community. A watershed and its stream provide water for drinking, aquatic habitat for animals, recreation for humans, a finite ability to contain floodwaters, sediment transport and many other functions.

In an undisturbed environment a watershed and stream provide these functions at a high level. Unfortunately, the Ellerbe Creek watershed is not an undisturbed environment, so its ability to perform these functions has been limited. The desired effect of any watershed plan should be to increase these reduced watershed functions.

Goal 1: Improve Aquatic Life

The reason Ellerbe Creek is on the state's 303(d) list of impaired waters is biological impairment. This means that the in-stream habitat has been so altered that the system cannot provide good habitat for aquatic species. One of the most difficult tasks in an urban environment is to sufficiently recreate good habitat for aquatic species

Objectives:
- Reduce water pollution to help protect aquatic life
- Preserve headwater tracts,
- Restore degraded stream sections,
- Reconnect streams to their floodplain (allow flooding where possible),
- Recreate wetlands,
- Build in-stream habitat,
- Target Large Patch size impervious areas to slow down stormwater flow; and
- Retrofit select stormwater systems to improve hydrology.

Goal 2: Reduce Destructive Flooding

Many urban streams have flooding problems - Ellerbe is no exception. As mentioned under the hydrology section in part 2, increasing impervious percentage increases floodwater runoff. Floodplain areas of the watershed will by their very definition always be vulnerable to flooding.

Objectives:
- Find areas where flooding can occur without loss of property and remove structures from the floodplain,
- Promote infiltration of rainwater by creating rain gardens,
- Modify ordinances to promote Low Impact Development,

•Promote stormwater infiltration on individual lots,
•Create stormwater wetlands,
•Allocate more money for leaf pickup - leaves often clog storm drains,
•Create Urban/suburban Best Management Practice on all scales,
•Target Large Patch Imperviousness to increase detention,
•Change city policy to allow portions of parking lots to be flooded,
•Promote parking decks- go up not out,
•Determine where and how instream detention is possible,
•Decrease impervious surfaces where possible; and
•Increase public knowledge and interest in credit manual and other incentive based measures.

Goal 3: Create Recreational Opportunities

Though Ellerbe Creek is a highly urbanized watershed, there still remain comparably large tracts of greenspace along its path. From its headwaters in western Durham down through the city and out through the lower valley to Falls Lake, these green spaces hold tremendous promise for serving the recreational needs of Durham residents. In the city of Durham's 2000 Parks and Recreation plan, number one and two user needs are as follows:

1. A large majority of park users seek informal activities in park landscapes that emphasize closeness to nature and that have high wildlife habitat value; and,
2. The highest priority needs of park users are spaces and facilities for walking.

The remaining green spaces along Ellerbe Creek, along with Durham's plans for a trail along the length of Ellerbe Creek, stand poised to serve an otherwise unmet need. Taken together, they hold the promise of a linear reserve from west to east Durham, a unifying element in the city landscape that will provide residents the opportunity to walk, bike, and observe nature's variety and beauty on a daily basis.

Objectives:

- Restore and increase protection status of existing natural areas,
- Identify areas for walking/greenways,
- Promote community clean-ups.
- Encourage tree planting,
- Work with public safety to make Ellerbe safe,
- Improve access,
- Preserve, manage and expand remnants of native plant diversity,
- Improve channel design to increase habitat and improve public perception and,
- Purchase land for open space

Goal 4: Educate the local community about Ellerbe Creek

Many urban streams are neglected resources; they are perceived in a negative light if at all. A key goal in improving Ellerbe Creek is to educate the residents of the Ellerbe Creek watershed about the nature of urban streams and the neglected resource in their own backyard.

Objectives:
- Educate landowners whose land borders perennial and intermittent streams,
- Target apartment complexes,
- Continue to focus on illicit discharges,
- Educate landowners about water quality on their property,
- Educate the city council,
- Educate the public about what a natural riparian system looks like (and why that's important),
- Use the school system,
- Educate community residents- not just landowners,
- Work with churches,
- Educate people about stormwater management practices they can use; and
- Educate businesses about the stormwater credit manual.

Goal 5: Protect Falls Lake Drinking Water Supply

Of all the watersheds draining into Falls Lake, Ellerbe Creek delivers the highest pollution load. Efforts to clean up Ellerbe Creek will have a positive effect on water quality in Falls Lake, a drinking supply for hundreds of thousands of North Carolinians. Durham's ability to protect a water supply it doesn't use can stand as precedent for other communities that determine the conditions of Durham's water supply reservoirs.

Objectives:
- Reduce nutrient loading into Ellerbe Creek,
- Reduce stormwater runoff from new development,
- Retrofit stormwater systems,
- Create stormwater wetlands,

IV Ellerbe Creek Recommendations

The primary strategy of the Ellerbe Creek Watershed Management Plan is to protect and restore the watershed's functions. The objectives must be to protect and restore such natural processes as infiltration, interception of precipitation by plants, overland sheet flow, and plant transpiration. However, we cannot turn back the clock 300 years to predevelopment conditions. The management recommendations should restore natural processes to the greatest practical extent in developed areas and protect them on currently undeveloped lands.

In the context of this primary strategy, the management recommendations proposed herein are meant to accomplish the five major goals of the plan. These goals are to: improve aquatic life; reduce destructive flooding; create recreational opportunities; educate the local community about Ellerbe Creek; and reduce nutrient loads going into the Falls Lake Water Supply Reservoir. The recommendations to attain these goals are:

1. Critical Area Protection
2. Riparian Area Management
3. Stream and Riparian Buffer Restoration
4. Better Site Design for Stormwater Management
5. Code and Ordinance Review and Revision
6. Stormwater Retrofits
7. Reduce Illicit Discharges and Illegal Dumping
8. Stream Monitoring
9. Strengthening Watershed Education and Stewardship
10. Sediment and Erosion Control

Each strategy is described generally below. Each recommendation is considered in light of both City of Durham and statewide development regulations.

Recommendation 1 Critical Areas Protection

Background

Though highly urbanized, the Ellerbe Creek watershed still contains significant areas of greenspace. The need to improve and sustain water quality is the primary driving force behind protecting riparian and critical areas. Additionally, these largely undeveloped tracts can benefit the ecological and social fabric of Durham—by providing educational and nature-oriented recreational opportunities, preserving beauty and history, and improving the connectivity of habitat and trails. As growth and development continues to displace forest and wetland habitat across the Triangle, the Ellerbe Creek's strip of riparian habitat will become increasingly important as a rest stop for migrating wildlife. The Ellerbe Creek Watershed Association has identified specific tracts.

Protection comes in many forms, and open space can serve multiple, complementary functions while helping to meet goals for water quality and ecological health. Undeveloped headwaters tracts, for instance, reduce downstream flooding while their feeder creeks safely harbor aquatic life to repopulate the main channel after it sustains shocks from floods, heavy sediment loads or pollution. Radio tower properties serve as groundwater recharge areas and habitat for a rich native flora. Historic sites like Bennett Place and Duke Homestead also serve as sanctuaries for wildlife and rare plant communities. Floodplain parks become valuable areas for floodwaters to spill into several times a year. Creekside trails and habitat restoration improve the usefulness of riverine corridors for people as well as wildlife, and thereby insure that more people will be keeping an eye on the creek to quickly report any signs of pollution.

Recommendations

Preserve key headwaters tracts

The headwaters comprise that portion of land from which the main branch of the creek springs, located at the opposite end of the watershed from the creek's outlet into Falls Lake. Ellerbe Creek's headwaters are located west of Cole Mill Road, extending west to the edge of Durham County.

What happens in the headwaters affects the full length of the creek. If highly developed, it threatens the rest of the watershed with floodwater and pollution. If, on the other hand, portions of the headwaters are preserved, the benefits are felt throughout the watershed. These can include reduced downstream flooding, a refuge for aquatic life to repopulate the main channel, and a source of clean water to dilute any pollution that enters downstream. For more information on the importance of headwaters refugia for recolonizing the main channel with aquatic life, (see **Appendix C)**.
Large areas of the Ellerbe Creek headwaters have been zoned industrial, and rapid development of these parcels is burdening Ellerbe Creek with heavy

sediment loads and increased stormwater runoff. This makes preservation of remaining tracts with lower zonings all the more critical.

Identify important subwatersheds of Ellerbe Creek for increased protection

Among subwatersheds, preserving remaining open space in Subwatershed 1 is of the highest priority. Preservation of these remaining areas will benefit all areas downstream, through reduced flooding risk and enhanced recolonization of aquatic life after pollution events.

Figure 13 shows Priority subwatersheds for preservation. Subwatershed 5 contains extensive open space whose protection status needs to be assessed and strengthened. Remaining greenspace areas in Subwatersheds 5, 6 and 10 provide vital links and refuges for wildlife migrating along the Ellerbe Creek corridor between Falls Lake in the east and Duke Forest properties to the west.

Subwatershed 10 contains two important riverine corridors, some publicly owned, some privately owned but with large wetland areas. The protection status and ecological health of these parcels also needs to be assessed and strengthened.

Subwatershed 6 contains portions of greenspace shared with Subwatersheds 5 and 10.

The west branch of Goose Creek also contains several large contiguous undeveloped tracts, in Subwatershed 15. The value of these for water quality and passive recreation should be assessed prior to the design and construction of a road, the Alston Extension, planned to bisect the area.

Development pressure is increasing on remaining undeveloped tracts in Subwatersheds 19, 16, 20, 21, 22, and areas downstream towards Falls Lake. These areas, along with remaining green space in subwatersheds 14 and 18 have been largely unstudied for determination of critical areas.

In addition, a privately owned parcel on Green Street, the last remaining green space on the west branch of South Ellerbe Creek, has been identified by the Friends of South Ellerbe Creek as a priority for preservation.

Work with private landowners and developers to preserve maximum quality greenspace and find economic uses compatible with protecting the land's current water quality functions**.**

Review Durham Trails Masterplan to make sure it extends to as many neighborhoods as possible, and that its unbuilt sections are planned in sufficient detail to take advantage of any opportunities for right-of-way acquisition as they arise.

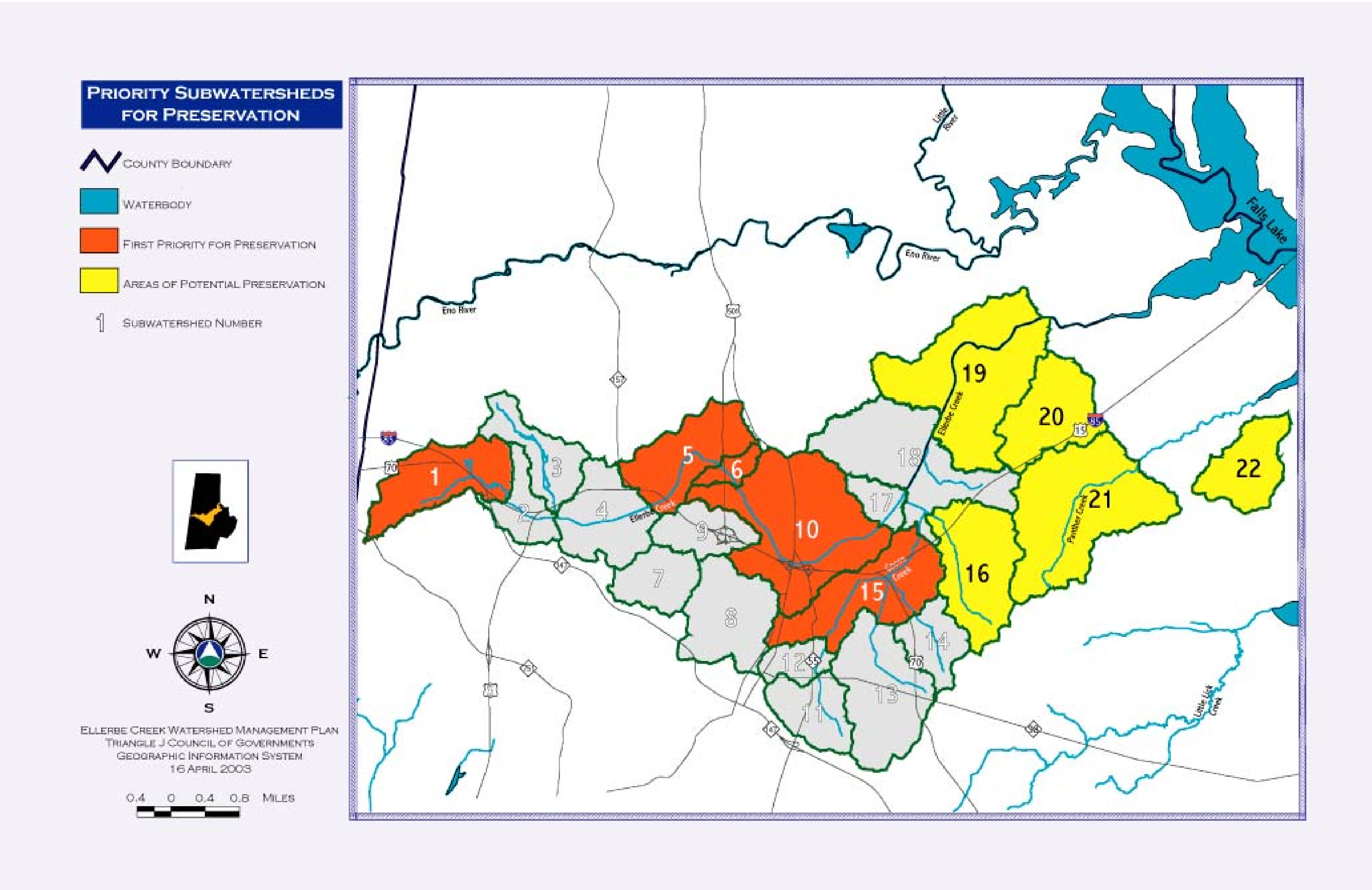


Figure 13: Priority Subwatersheds for Preservation

Recommendation 2 Riparian Area Management

Background

Ellerbe Creek's riparian corridor borders varied human activities. The creek flows through or beside urban trails, golf courses, city parks, radio tower properties, sewer and power line right of ways, public access and people's backyards. Each of these situations has its own requirements for vegetation height, composition and aesthetics.

Improving and restoring riparian areas in Ellerbe Creek will involve planting vegetated buffers along streambanks, building stormwater wetlands and generally finding ways to slow down and filter runoff. To achieve this end, there are a wide variety of durable and attractive native shrubs, wildflowers, grasses, sedges and rushes. But for these plantings to be broadly accepted by the public over the long-term, often juxtaposed with more formal mowed areas, they must be actively and knowledgeably managed to insure that the desired species do not over time become crowded out by invasive weedy species. If vegetated buffers do not meet the requirements mentioned above, an eventual reversion to an intensive mowing regime detrimental to water quality and diversity can be expected.

Active, ongoing management is in general less costly than mowing, and becomes easier with every year, as the desired species become more established and dominant. It does, however, require well-timed periodic removal of vegetation inappropriate to the site, and augmentation of desired species to achieve maximum bloom through the season.

Figure 14: Ellerbe Creek, Northgate Park, **Durham** Notice the eroding soil of the bank that results from complete removal of riparian vegetation on stream banks by mowing and bushhogging.

This approach is a middle ground between total suppression (mowing) and laissez faire, and achieves improved water quality, a dynamic, varied and attractive natural landscape, safer trails and improved wildlife habitat. Though past human alteration of the creek has been destructive, active management to improve aquatic and terrestrial habitat now offers a positive role for people in the watershed.

Recommendations

Active Management
Actively manage the riparian corridor for diverse species native to the Ellerbe Creek watershed.

Volunteer Participation
Through collaboration between government, non-profits, neighborhoods and volunteer organizations, develop a protocol for volunteer participation in active management of riparian areas. Organize restoration workdays, and adoptions of parks and trail sections by groups and individuals.

Training in Plant Identification
Ensure that personnel and volunteers are well trained in plant identification, through collaboration with universities and non-profits.

City Parks
In city parks, many mowed areas remain unused. Determine which areas of parks are best suited for recreation, and which can be used for low-maintenance wildlife habitat and infiltration of runoff. These include stream borders and turfgrass areas that are frequently too wet to mow or use recreationally. Bush hogging of streambanks has had destructive effects on streambank stability and habitat in the past. Streambanks can instead be managed for shrub species that bend out of the way during high flows. A successful demonstration of these approaches can be found in Durham's Indian Trail Park

Urban Trails
Manage urban trails for diverse native vegetation of appropriate height and growth habit.

Right of Ways
Manage power line and sewer right of ways, which form an extensive network of corridors within the watershed, for native flora consistent with the need for low maintenance and periodic access.

Ditches
Convert steep ditches along roadsides and in parks to broader, vegetated swales.

Golf Courses
Encourage golf courses to manage vegetated buffers along waterways for species that meet water quality goals and aesthetic requirements.

Invasive Species
Monitor and limit invasive species in riparian areas. Eradicate invasive species where possible, to reduce long-term maintenance costs.

Recommendation 3 Stream and Riparian Buffer Restoration Projects

<u>Background</u>

Stream restoration is defined as returning a stream to its original hydrology - in Ellerbe Creek that is no small undertaking. Urban streams are often difficult to restore simply because there are so many barriers to restoration. Infrastructure such as: sewer lines, roads, and homes and businesses are not only the reason Ellerbe Creek was channelized in the first place, but also remain impediments to stream restoration today.

Stream restoration has benefits for water quality as well as aquatic life. By reestablishing a stream's meanders, the velocity of the flow is slowed down. Slowing down the water benefits aquatic macroinvertebrates by protecting them and their habitat from scouring – caused by short intense flows of water in urban areas. This slowing of the water also benefits water quality by reducing erosion and sedimentation from the stream walls.

Additionally, if there are any places along the stream that can be allowed to flood this will also accomplish dual goals. When a stream overtops its banks in a vegetated environment two important processes occur:

1. The stream velocity slows down as it spreads over a wide area reducing sedimentation of the stream banks and;
2 The floodwaters nutrients are absorbed by plants on the floodplain (primarily, but not limited to, trees) this cleanses the floodwater

This can also lead to a third important benefit, by allowing a stream to flood in a place it will do no damage (i.e. a golf course or a park without structures) flooding can be reduced in areas where it will cause damage. Remember the water must go somewhere.

Stream restoration works very well with the Ellerbe Creek LWP's stated goals:
1. Stream restoration protects aquatic life
2. Stream restoration can reduce destructive flooding
3. Stream restoration can increase recreational opportunities by restoring floodplains, streambanks and all accompanying wildlife habitat.
4. Stream restoration can serve as an educational tool by reminding people what streams should and could look like.

Stream restoration is ideally done on a minimum of 1500 linear feet (for economic purposes). There are few opportunities in Durham to put meanders (curves) in a stream over such a long stretch. However, Hillandale Golf course presents an opportunity to restore 6000 linear feet of stream that is currently straightened and lacking vegetation. The NCWRP will be restoring this stretch of Ellerbe Creek in the fall of 2003, as well as adding a stormwater wetland on a tributary.

Recommendations

Stream Restoration

1.Hillandale Golf Course
2.Northgate/Jaycee Park
3.Potential sites where stream restoration might be feasible include: The Goose Creek area downtown, and the mainstem of Ellerbe Creek, just north of the landfill.

Riparian Restoration

Even in areas where there would be little advantage to restoring the stream channel, or in areas where it is simply cost-prohibitive, restoration of the riparian buffer is always a benefit to water quality. Many stretched of Ellerbe Creek are adequately buffered with 50 feet or more of forested buffers and the Neuse River buffer rules help protect these areas. However, these buffer rules are not retroactive, they do not mandate that bare or degraded buffers be replanted.

These buffers do not need to be considered wild tangled masses of weedy and exotic species (see Recommendation 3 for Management of riparian lands). Riparian buffers can be actively managed to benefit wildlife or aesthetic tastes. The important issue is that the riparian zone is vegetated to provide the water quality benefits associated with trees.

Focus on Headwaters

As mentioned in the critical lands protection recommendation, headwater areas of Ellerbe Creek's tributaries are particularly important for restoring aquatic life and maintaining water quality. Where headwater streams are too degraded to merit preservation, restoration of headwaters is another mechanism to protect these critical lands.

Recommendation 4 Better Site Design for Stormwater Management

Background

The site design practices used on a new development project can greatly influence the overall effect the site will have on many aspects of the hydrologic cycle. Developing a site changes the amount and quality of stormwater runoff, the amount of groundwater recharge, evaporation and plant transpiration. These hydrologic alterations can greatly affect stream flow downstream from the site, impacting water quality, eroding streambanks, stressing aquatic habitat, and causing floods. For these reasons, hydrologically -sound site design practices form an important component of watershed management in watersheds where some development will occur in the future.

Current Regulations

As shown in Table 4 of the Ellerbe Creek Watershed is land that is undeveloped and currently zoned for some future development. Stormwater management for any new development in the Ellerbe Creek Watershed must meet criteria established under the following regulations:

City of Durham Natural Resource Protection Standards (1999)
Falls Lake Water Supply Watershed Overlay Zoning Districts (1994)
Neuse River Stormwater Management for Nitrogen Controls (2001)

The Stormwater Management standards required for new development in Ellerbe Creek include:

- Manage total nitrogen leaving new development site
- Maintain the peak flow leaving the site at pre-developed level for the 1-year, 24-hour storm,
- Avoid development in floodplains,
- Avoid development on slopes of over 25%,
- Protect at least a 50-foot buffer around streams, wetlands, lakes and ponds,
- Take measures to reduce Total Nitrogen on sites where impervious area exceeds 23%,
- If the site is in the Water Supply Watershed Overlay District, treat runoff on all sites with impervious area exceeding 24%; and
- If the site is in the Water Supply Watershed Overlay District, preserve buffers of 50-150 feet around streams and 250-1000 feet around reservoirs.

In addition, the Draft Upper Neuse Watershed Management Plan recommends that Durham City and County adopt management strategies to improve stormwater management. These recommendations are listed below.

- Create development performance review processes for controlling Nitrogen and Phosphorous leaving any newly developed sites with greater than 10% impervious area.

- Revise development ordinances to encourage Low-Impact Design (LID) techniques. LID is discussed further below.

State of the Art

Several examples of innovative stormwater management practices are useful for guiding site management on new development in Ellerbe Creek. One such approach has been developed by the Department of Environmental Services in Prince George's County, Maryland. This department has developed an EPA-funded manual for innovative stormwater management. *Low-Impact Development Design Strategies* offers site-planning strategies that suggest a change from conventional approaches to stormwater management. These approaches are being used successfully in Prince George's county and other areas around the country. The major objective of the LID Approach is to mimic a site's natural, or pre-development, drainage functions to the greatest extent possible. When runoff is retained and infiltrated on individual sites, the need for costly stormwater conveyance and regional detention systems can be greatly reduced.

LID accomplishes this dispersed method of stormwater management through a host of approaches. For example, designing a site's development envelope based on hydrologic function (i.e., leaving the areas of highest groundwater recharge rates undisturbed to infiltrate more runoff) increase on-site stormwater infiltration. Using multiple integrated management techniques to treat stormwater close to its source helps to avoid concentrating overland flow. Utilizing simplistic, non-structural methods means stormwater control can be easily and attractively integrated into the landscape. The Wake County Watershed Management Plan (CH2M Hill, 2003) identifies five categories of LID practices:

- Runoff Minimization--achieved through porous pavement and green rooftops.

- Rainwater Capture--Cisterns and rain barrels capture rainfall from rooftops for later irrigation or infiltration.

- Landscaping--Bioretention facilities are low areas within a parking lot or a yard that collect rainfall, filter the water through layers of mulch and soil, and then discharge the water, usually through an underdrain system.

- Infiltration--Practices of rainwater capture, landscaping, and conveyance can be altered to maximize infiltration rates.

- Conveyance--LID uses vegetated channels rather than curbs and gutters for transporting stormwater. Vegetated channels filter pollutants allow opportunities for water to slow down and infiltrate.

LID was developed in the coastal plain of Maryland and has also been used in the Puget Sound area of Washington State, both areas with relatively permeable soils. Many LID techniques such as porous pavement and infiltration practices are most effective in permeable soils (Hydrologic Soil Groups “A” or “B”). Because Piedmont soils are slowly draining soils, practices must be adapted for use in our region.

For example, on low permeability soils, bioretention is provided with an under-drain to provide positive drainage. On erodible soils, swale geometry usually can be designed to minimize erosive velocities or lacking that, they can be provided with liner systems to provide channel stability. These practices have recently begun to find application, and design professionals are gaining experience in how to apply them.

Many other management practices that could be applied to LID have not been widely used in the Piedmont. Pilot projects are needed to learn how to apply different LID techniques and to determine what conditions they are suited to, and which are the most cost-effective.

Recommendations

Pilot Projects

The use of innovative stormwater approaches such as these is likely to meet many obstacles such as lack of knowledge about their application and lack of understanding of their benefits for reducing runoff volume and pollutants. It is recommended that the City and County of Durham, along with the Upper Neuse River Basin Association, attempt to encourage pilot projects to implement Low-Impact Development techniques and further study their usefulness in a variety of land use settings.

Revision of State Best Management Practices

Additionally, the state currently does not encourage the use of several of the stormwater management practices recommended in the national Low-Impact Development Manual. For example, large rooftop catchment cisterns can harvest the stormwater from a rooftop for future use in landscaping or even non-potable indoor uses. However, the State does not give credit for use of cisterns. Meanwhile, building codes make reuse of rooftop stormwater for flushing toilets very difficult to implement. It is recommended that the City, County, UNRBA, ECWA, and FOSEC work with the State Division of Water Quality to encourage the inclusion of such practices in the State's Best Management Practices Manual and in building codes. A successful pilot project is a potentially effective method for proving these approaches.

Identify Target areas for Better Site Design

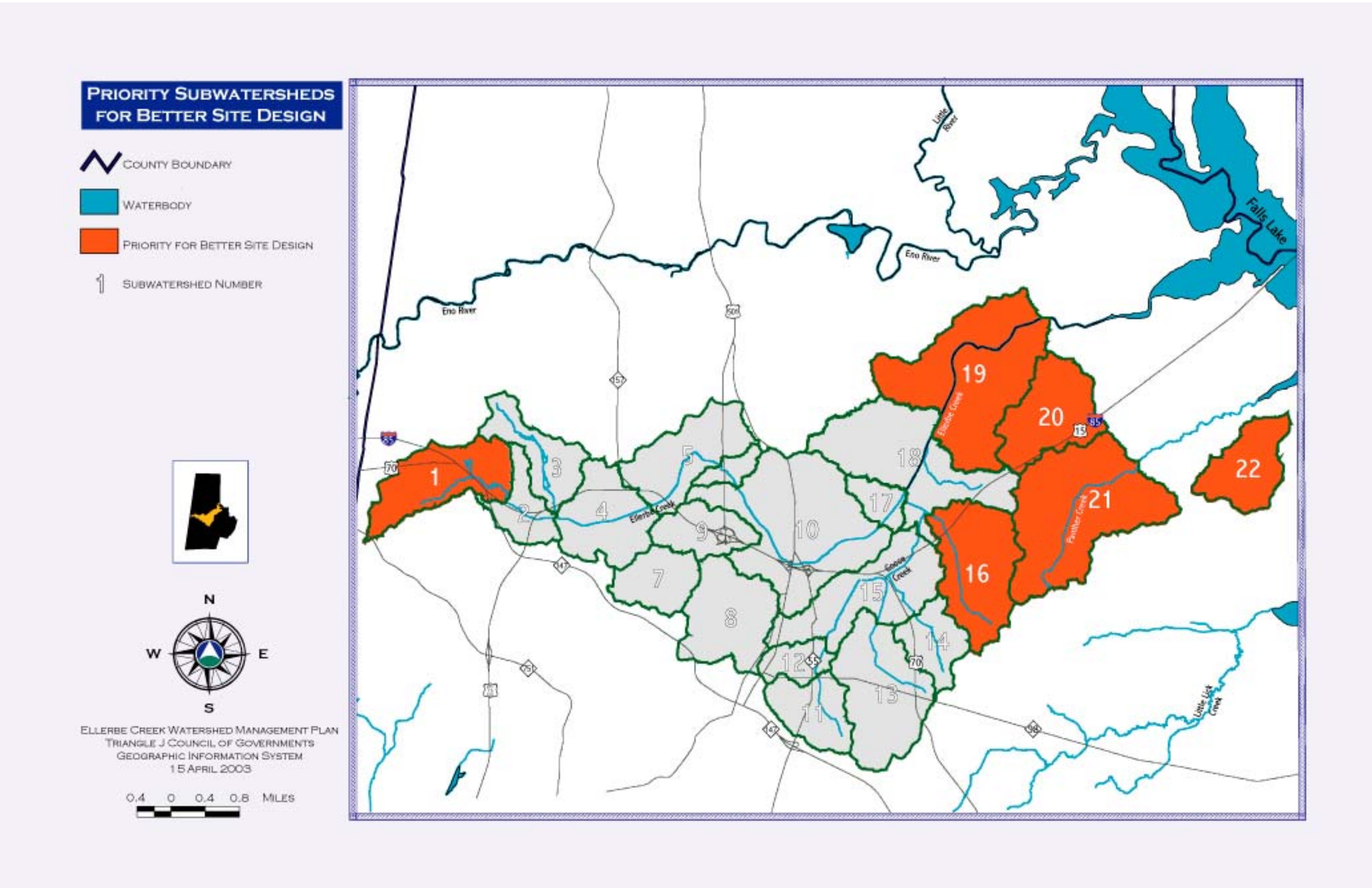
To protect and restore hydrologic function and meet potential future nitrogen or phosphorous reduction goals, the City of Durham should consider attempting better site design specifically in subwatersheds of Ellerbe Creek with areas of high potential for development.

Although this analysis is not meant to be an exhaustive study identifying individual sites, it is useful to examine the need for such an approach at a subwatershed scale. Table 4 shows the total area of potentially developable land in each of Ellerbe Creek's subwatersheds. Geographic Information Systems were used to identify all currently undeveloped parcels in the watershed. From these undeveloped parcels, the lands currently zoned for future development can be identified as 'developable' lands. Figure 15 shows these Priority Subwatersheds for better Site Design. These areas are likely to be developed to higher-intensity uses in the future.

Table 4 Potentially developable land (by subwatershed)

Subwatershed	Total Area Acres	Developable Area (Acres)	Developable Area as Percentage of Total Area
1	787	362.02	46
2	348	243.6	7
3	516	77.4	15
4	729	87.48	12
5	761	167.42	22
6	141	28.2	2
7	438	91.98	21
8	809	88.99	11
9	424	42.4	10
10	1715	291.55	17
11	484	58.08	12
12	247	222.3	9
13	1040	145.6	14
14	400	140	35
15	985	197	20
16	955	496.6	52
17	210	50.4	24
18	1309	340.34	26
19	1691	794.77	47
20	765	627.3	82
21	1611	918.27	57
22	560	453.6	81
TOTAL	16,925	5925.3	35%

Figure 15: Priority Subwatersheds for Better Site Design



Recommendation 5 Code and Ordinance Review and Possible Improvements

<u>Background</u>

As summarized in the Hydrology section (page 16), increasing impervious surface has consistently proven to be detrimental to water quality. Any effort to reduce impervious cover associated with future development in the Ellerbe Creek watershed will help lessen the negative water quality impacts that come with new development.

To that end the Ellerbe Creek Stakeholders group reviewed the City of Durham's response to the Center for Watershed Protection's (CWP) *Code and Ordinance Worksheet*. The Cap's Code and Ordinance Worksheet stems from a series of Model Development Principles. The Model Development Principles and Durham's responses to the worksheet are found in **Appendix D.** For more information about the Center for Watershed Protection, their website can be accessed at www.cwp.org)

Why review local ordinances?

Sustainable development combines economic growth with protection of the natural environment. Communities have long struggled to achieve this goal. However, we often find that our own development codes and standards can actually work against our own efforts to achieve sustainable, "low-impact" development. For example, local codes and ordinances often contain inflexible standards that result in overly wide residential streets, expansive parking lots, and mass clearing and grading of forested areas. At the same time, local codes often give developers little or no incentive to conserve natural areas.

What is the Code and Ordinance Worksheet?

The Code and Ordinance Worksheet (COW) (**Appendix D**) allows an in-depth review of the standards, ordinances, and codes that shape development in our local communities. The COW guides the participant through a systematic comparison of a government's local development rules against a set of model development principles. Institutional frameworks, regulatory structures and incentive programs are included in this review. The worksheet consists of a series of questions that correspond to each of the model development principles. Points are assigned based on how well the existing development rules agree with the site planning benchmarks derived from the model development principles.

What are the Model Development Principles?

The model development principles generally fall into one of three categories: Residential Streets and Parking Lots; Lot Development; and Conservation of Natural Areas. Each principle represents a simplified design objective in site planning. To find more detail on these principles, refer to CWP's *Better Site Design: A Handbook for Changing Development Rules in Your Community* (August 1998).

Applied together, the model development principles can measurably reduce impervious cover, conserve natural areas and reduce stormwater pollution from new development. Application of these principles can enhance both the natural environment and improve the quality of life in local neighborhoods.

Durham City and County Planning used the Code and Ordinance Worksheet to assess the extent to which local codes and ordinances allow or prevent the model development principles from being implemented by developers. Durham scored relatively high on the assessment.

Table 5 Durham's totals for Code and Ordinance Review

Principle	COW points Durham City/County	Maximum Score	Percentage
Residential Streets & Parking lots	24	40	60%
Lot Development	25	36	69%
Conservation of Natural Areas	21	24	88%

Recommendations

Durham scored extremely well in the Conservation of Natural Areas section of the worksheet, showing a pattern of consistently trying to protect open space. Durham's record in this area is to be commended.

However, Durham potentially has opportunities to make development code improvements in several areas listed below. This list is not meant to be a recommendation to the City of Durham, but rather a general guide of possible areas of exploration. This list has not been discussed with city planners.

Minimum right-of-ways
Cul-de-sac sizes
Curb and Gutter Requirements
Parking ratios
Structured parking incentives
Side setbacks
Sidewalk widths and slopes
Flexibility to meet regulatory or conservation restrictions (i.e., transferring development rights, buffer averaging, etc.-some are statewide issues)

Recommendation 6 Stormwater Retrofits

Background

A **stormwater retrofit** is a stormwater management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Stormwater retrofits are typically installed in urban areas that were developed with little or no stormwater management controls. By extending stormwater management controls to existing development, retrofitting complements current City and County regulations that require new development to install stormwater management practices.

By extending stormwater controls to areas that are already largely developed, retrofitting can help to mitigate many existing problems. Stormwater retrofits can reduce nutrient loading to Falls Lake. In some cases, retrofits can be designed to reduce peak flows, thereby reducing erosion of stream banks and improving habitat for aquatic life. Stormwater retrofits can be part of a comprehensive program to restore aquatic life support for communities of benthic aquatic organisms in Ellerbe Creek by generally reducing pollutants.

Controlling runoff from existing urban areas tends to be relatively expensive compared to managing runoff from new developments[1]. In new development projects, the need for stormwater management controls is considered during building layout, grading and design of the stormwater drainage system. Stormwater retrofits for existing development generally must be fit into the existing landscape and drainage system if, and where, space is available. It is generally not feasible or cost-effective to significantly alter surface drainage or to re-direct subsurface piping. Retrofits are further constrained by existing structures, uses and property ownership.

The Problem

The Ellerbe Creek watershed has more than 3,000 acres of impervious surface, most of which was built before the effective date of local Neuse stormwater rules in 2001 or water supply watershed rules in 1994. More than 1,000 acres of impervious surface appear to be directly connected to the stormwater system or to streams. Consequently, most of the impervious surface in Ellerbe Creek, and particularly the large patches of connected impervious area, could be considered a potential candidate for retrofitting.

Developing a Retrofit Prioritization Plan

Developing a retrofit plan can seem like an overwhelming task. There are many possible ways of approaching plan development. According to the Center for Watershed Protection, the key to successful plan development is to have a

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[1] EPA Fact Sheet

structured process to follow. The following ten-step approach has been adapted for Ellerbe Creek from the Center's guidance:

1. **Establishment of goals,**
2. **Evaluation of options,**
3. **Preliminary watershed retrofit inventory,**
4. **Field assessment of potential retrofit sites,**
5. **Prioritize sites for implementation,**
6. **Public involvement,**
7. **Preparation of construction drawings,**
8. **Design review and permitting,**
9. **Construction inspection to ensure that facilities are properly constructed; and,**
10. **Maintenance Plan to ensure that facilities are maintained.**

Appendix E discusses each of these steps and develops recommendations for development of a retrofit plan that supports the goals of the Ellerbe Creek Watershed Management Plan. These goals include protecting Falls Lake by reducing nitrogen and phosphorus loading in stormwater runoff from existing developed areas, improving aquatic life support by reducing pollutant loading and helping to control the one-year storm events that leads to channel instability, and, to the extent possible, reducing destructive flooding by providing detention of large storm events.

The following is a summary of recommendations, in part, from the discussions in the appendix.

1. **The stormwater management practice selected for a given site should be appropriate for the amount of runoff being treated, the available space and topography of the potential retrofit location, and the character and use of the surrounding area.**

2. **Overall, a mix of stormwater management practices should be selected throughout the watershed that together will support the goals of the Ellerbe Creek Watershed Management Plan (protect Falls Lakes, improve aquatic life support, reduce destructive flooding, and educate the public.)**

3. **To protect the Falls Lake reservoir, retrofits should be placed at locations in the Ellerbe Creek watershed where runoff from large areas (20 acres of more) of impervious surface can be treated cost-effectively. In the most highly developed subwatersheds in Ellerbe Creek, there appear to be relatively few locations remaining where large areas of existing impervious surface can be treated cost-effectively; these limited locations should be given high priority for retrofitting before they become committed to other uses.**

Subwatersheds with large amounts of impervious surface and little developable large include: WS-2, WS-8, WS-9, WS-11, and WS-12.

4. **To protect and improve aquatic life, retrofits should be part of an overall program that includes stream restoration and other stormwater management and habitat restoration efforts. To have the best chance of showing improvement in aquatic life support, such retrofits should be located in or near headwaters, upstream of stream restoration projects and in subwatersheds that have between 12 and 40% imperviousness; it will be important to target large patches of impervious surface, heavily used roads, and potential pollution hotspots, like fueling operations. Based on the location of on-going stream restoration projects, subwatersheds WS-1, WS-2, and WS-3 should be target for retrofitting to support the goal of aquatic life restoration. Any stormwater management practice that removes nutrients will also remove other pollutants, and may improve habitat if it can be designed to provide extended detention. If space is limited to control runoff from hotspots, then a hydrodynamic device that removes floating oil and grease and fine suspended solids may be considered.**

5. **Where there is adequate land area, the retrofit should be designed to provide extended detention of the one-year, 24-hour storm to reduce downstream erosion and channel instability.**

6. **Where the retrofit discharges to a tributary that has local flooding problems, and there is a large area available for the retrofit, consideration should be given to increasing the detention volume in order to help control destructive flooding.**

7. **Existing man-made lakes and stormwater ponds should be investigated for cost-effective retrofitting by modification of the outlet structure.**

8. **Publicly owned land will be the easiest to implement the first phase of retrofits and may provide opportunities to educate the public. Where City Parks are undergoing redesign; those locations should be given priority so that retrofitting can be integrated into the park design, reducing overall costs. Parks that will be designed or re-designed include Durham Central Park and Northgate Park.**

Constraints on Potential Sites

Since stormwater retrofit controls must be fit into the existing landscape and drainage system, exiting structures and uses of the land may place constraints on the location of retrofits. Stormwater system ownership also places significant constraints on the location of retrofit locations. Durham County does not own or operate any of the stormwater system in developed portions of the county. The City of Durham owns only that portion of the stormwater system that is in public right-of-way or on other City property. Retrofitting a subwatershed will likely involve looking at potential locations on private property, which will require permission from property owners.

Retrofitting is a long-term strategy that should be implemented through adaptive management. The adverse impacts of stormwater runoff are only partly understood, and **monitoring** will be required to evaluate whether components of the retrofit plan being implemented are having the intended result.

As the technology of stormwater treatment improves, more effective designs will be developed for widely used treatment practices, and new treatment practices will be developed. **It will be necessary to review and revise the any retrofit plan to take into account advances in the start-of-the-art.**

Recommendation 7 Reduce Illicit Discharges

Background

Identifying and eliminating non-stormwater discharges to storm sewers and receiving waters is an important and cost-effective best management practice for improving water quality (US EPA, 1999). Significant non-stormwater discharges include process water, wash-down waters, and sanitary wastewaters. In some cases they are the result of unauthorized or illegal connections of sanitary or process wastewater drains to storm sewer systems. Such illicit connections are common, particularly in older developments, and often go undetected for decades. Illegal dumping is disposal of waste in unpermitted areas, such as a back yard, a stream bank, or even a storm drain or stream.

In early guidance for municipalities developing stormwater programs, EPA indicated the importance of controlling these other sources of pollution:

> "Identification and location of non-stormwater entries into the stormwater system [is essential for] effective investigation of pollution within a stormwater system. Prior research has shown that for many pollutants, *stormwater may contribute the smaller portion* of the total pollutant mass discharged from a stormwater drainage system" (US EPA 1992).

Some of the significant non-stormwater discharges include failing septic systems, sanitary sewer overflows, and wastewater connections to the storm drain system. Illegal dumping often involves yard wastes, used motor oil, and used cooking oil and food wastes.

Some non-stormwater discharges are low risk, requiring control only if identified as significant contributors of pollutants. These low risk discharges include springs, rising groundwater, uncontaminated pumped groundwater, foundation drains, air conditioner condensate, individual residential car washing, dechlorinated swimming pool discharges, and discharges from fire fighting activities.

In brief (refer to **Appendices F and G** for more detail) the City's efforts to control non-stormwater discharges has been evolving over the last seven years. Beginning in 1996 the City's Stormwater Services Division began developing programs to find and eliminate illegal dumping and significant non-stormwater discharges. This effort also investigates reports of 'housekeeping' practices that could result in stormwater runoff carrying pollutants into surface waters.

The effort to find and eliminate these sources (or potential sources) of pollution is based on four components:

- Tools and procedures to identify problems and priority areas
- Tools and procedures for tracing the source of an illicit discharge
- Procedures for removing the source of the discharge
- Procedures for program evaluation and effectiveness

A pollution reporting hotline was established in 1996 to involve citizens in identifying problems. Initially outfall inspection and screening were also used to identify problems and priority areas. While outfall inspection had some success, it was inefficient and did not necessarily target the highest priority areas. To improve efficiency and effectiveness, in 1999 comprehensive outfall inspection was replaced by targeted outfall inspection in priority areas to be identified by intensive weekly monitoring of a section of urban stream over a two month period, focusing on field parameters and fecal coliform bacteria. In 1999, Water and Sewer Maintenance began requesting assistance to determine the extent of contamination from sanitary sewer overflows so that the contaminated water could be fully contained and pumped back into the central collection system.

A number of different methods have been used to assist staff in tracing the source of contamination, including evaluation of various maps, dye testing, field chemical tests, etc. Early on it was anticipated that the use of GIS would overcome the inefficiency of using several different maps, usually at different scales. Databases were developed to be GIS "friendly" and the planned inventory and mapping of the City's stormwater system was planned to include development of GIS tools for managing the maps and data. Other tools used in tracing sources include field-testing of water samples, laboratory testing of water samples, and tracing using fluorescent dyes.

The program has been very successful, conducting 963 investigations during the last six fiscal years, averaging 197 investigations per year for the last three years. Overall, 615 of the investigations found a pollution source, or a potential pollution source. Some of the sources involved discharges that did not reach streams under the dry weather conditions prevailing during the investigation. Others involved dumping of wastes in storm drains or careless storage of materials in a manner that would result in contamination of stormwater runoff during a rain event. However, a significant fraction, 37%, involved direct discharge to a creek or other surface water, usually under dry weather conditions.

Human sewage was involved in a large fraction of the sources found.[2] Privately owned sewage conveyance or treatment facilities (laterals, septic systems) were

[2] The relatively high frequency of sewage as a source is consistent with the Center for Watershed Protection's identification of three basis kinds of non-stormwater discharge sources: septic systems, central

responsible for 163 of the sources, while a slightly larger number was associated with the publicly owned central sewer collection system: 144 central system overflows, 20 breaks and 22 leaks. A significant number of sources, 80, involved petroleum products, and 47 more involved food, cooking grease or paint. Poor housekeeping was found in 56 instances.

Tracking of sources by watershed shows the sources of pollution occur in the most developed areas with the highest population. As the most developed watershed in Durham, Ellerbe Creek accounted for 44% of the sources (270) found during the last six years. The sources found in Ellerbe Creek have included a house and a business each having its sewer lateral connected to the stormwater system rather than the sanitary sewer system. Other sources have included failing septic systems, clogged privately owned sewer laterals (often at apartment complexes), leaky sewers, petroleum spills, dumping of yard wastes, dumping of food wastes and cooking oils, etc.

Identification and elimination of these sources of pollution, some of which have persisted for decades, has resulted in improvements in water quality in the City's urban streams. In Ellerbe Creek, several monitoring locations show reductions in fecal coliform concentrations and increases in dissolved oxygen levels.

Results from the ongoing mapping of the stormwater system are already helping staff to locate sources more efficiently, and the program continues to evolve and to become more efficient. Mapping of potential sources of pollution and of water drainage systems should improve efficiency. Development of additional tools for locating problem and priority areas and for tracing sources will improve the effectiveness of the program.

<u>Recommendations</u>

The following are recommended to further improve the efficiency and/or effectiveness of the City's efforts to find and eliminate non-stormwater discharges that are contributing to water quality impairment:

Increase the frequency of the periodic intensive stream monitoring of the Ellerbe Creek system to once every three years.

Conduct trial of infrared aerial photography as means of locating sources. This should be carried out in the late evening on a clear, cold winter night to maximize the difference between ground temperature and warm water discharges.

Conduct trial of passive monitoring for optical brighteners (laundry detergent additives) as an indicator of human sewage.

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sewer systems, and "other." In fact "other" includes many different kinds of non-stormwater discharges, but individually none of them occur with great frequency.

Complete the ongoing inventory and GIS mapping of the stormwater system.

Develop detailed GIS map of stream hydrology that matches existing, detailed topography.
Develop accurate GIS maps of the sanitary sewer system and of the drinking water distribution system.

Conduct a GIS mapping study to locate areas where the sewer system crosses the stormwater system.

Obtain from the North Carolina Department of Environment and Natural Resources and/or the US Environmental Protection Agency GIS maps showing the location of leaking underground storage tanks, dry-cleaning solvent releases, hazardous waste contamination sites, petroleum spills and other such sites of known contamination.

Obtain from the North Carolina Department of Environment and Natural Resources and/or the US Environmental Protection Agency GIS maps of the location of hazardous waste generators, sites providing toxic release data, Biennial Reporting System data, and other such sites of potential contamination.

Evaluate the possibility of making GIS mapping available to personnel in the field by means of portable computers.

Controlling non-stormwater discharges is the most cost-effective best management practice for improving water quality in the shortest period of time. It is the best method for addressing high bacteria levels in urban streams, and it can help to improve support for aquatic life by improving dissolved oxygen, reducing organic enrichment, and generally helping to reduce anthropogenic impacts on urban streams.

It is difficult to evaluate the relationship between aquatic life impairment and stormwater runoff because both stormwater and non-stormwater discharges are impairing streams. Bringing most of the significant non-stormwater discharges under control will facilitate development of a clearer understanding of the impacts of stormwater runoff, which will enable more effective control of stormwater and more cost-effective restoration of urban streams.

Recommendation 8 Stream Monitoring

Background

Ellerbe Creek is recognized on the State's 303(d) list for impaired waters because of its inability to support aquatic life. Stream monitoring allows us to search for the reasons of impairment in Ellerbe Creek. This may be in the form of habitat degradation or pollutants that have been discharged into the creek. There are two components of the stream monitoring program; benthic monitoring and chemical monitoring. Benthic monitoring is used by the State to determine the quality of a stream and whether it is to be listed as an impaired stream. We also use chemical monitoring to assess any pollutants that may be reaching our streams and causing impairment. Adequate monitoring could not be conducted without both of these sampling methods being present.

Water quality can vary over time, and unless a chemical sample is collected at the exact time of discharge it could be missed. This is where benthic monitoring reflects what the water quality looks like over a period of time, as they are permanent residents within the stream. Chemical monitoring is used to determine what types of pollutants have affected our streams and allows us to take corrective measures to eliminate the source of the problem. It is through monitoring efforts that illicit discharges and non-point source pollution are located and corrected. See Recommendation section covering Non-Stormwater Discharges and Illegal Dumping for more information concerning this topic.

Current Monitoring Efforts

Chemical monitoring in conjunction with benthic monitoring is an excellent way of assessing stream quality. Benthic monitoring allows us to see if streams are supporting life and chemical monitoring allows us to determine the possible causes of degradation. These efforts will allow progress towards the goal of improving aquatic life in the streams. Currently there are seven ambient monitoring sites and four benthic sites within the Ellerbe Creek Watershed. According to Stormwater Services biological monitoring analysis, all the streams in the Ellerbe Creek Watershed are either partially supporting (Fair) or not supporting (Poor) aquatic life.

Why more Monitoring is Needed

NCDWQ has recently completed an Ecoregion map of North Carolina, which illustrates a more complex hydrological/geological condition for Durham than was previously anticipated. There is the potential for Durham to illustrate an increase in water quality by setting up new reference stations in these new geological regions. The Neuse River Basins is split into two distinctive Ecoregion basins, the Slate Belt and the Triassic Basins. The Slate Belt in Durham's' westernmost part is characterized by hard bedrock and consequent gravel and boulders (i.e., more habitat, and possibility for increased dissolved oxygen refer to the Geology section in Ellerbe Creek conditions). Refer to Appendix C on importance of habitat for aquatic organisms. The Triassic Region, in which most of Durham resides, has less in-stream habitat due to geomorphology, regardless of man's influence. Almost all Durham's monitoring sites are in the Triassic Region, whereas all of the reference sites for a comparative analysis are either in the Slate Belt, or primarily draining from the Slate Belt.

Recommendations

Two new benthic monitoring reference sites are needed in Granville County, Neuse River Basin.

The two sites will be third and fourth order Triassic Basin streams that will be more appropriate reference sites for Ellerbe Creek and other Durham sites. In addition to getting better data to compare our city streams, our water quality may show improvement, because we will now be able to compare apples to apples, and not pears. Additional monitoring stations (both ambient and benthic) have been proposed to help restore and protect the Ellerbe Creek Watershed. This will include adding four new benthic monitoring sites, two on Ellerbe Creek and two on Panther Creek, (proposed for the 2003 fiscal year). Chemical monitoring will consist of the collection of ambient samples along with sites designated for fecal coliform bacteria-only collection. Refer to Figure 16 Ellerbe Creek Monitoring Stations for the locations of proposed collection sites. Appendix G contains a complete list of sampling locations and explains in greater detail which parameter will be collected at each site. In the appendix there is a description of each type of monitoring site listed in this section.

Table 6 Table of Proposed Monitoring Sites in Ellerbe Creek Watershed.

Subwatershed Number	Site Name	Ambient	Benthic	Fecal Only
1	EL11.4EC	X	X	
3	EL10.7ECUT	X		
4	EL9.5EC	X		
5	EL8.2EC		X	X
9	EL7.3SEC	X		
10	EL5.6EC		X	X
11	EL8.1GC	X		
12	EL7.5GC	X		
13	EL6.9GCTA	X		
14	EL6.9GCUT	X		
16	EL5.6GCUT	X		
20	EL1.8ECUT	X		
21	PA2.8PC	X	X	
22	PA0.7FLT	X	X	

In order for the City to conduct a more intensive monitoring effort in the Ellerbe Creek Watershed, Stormwater Services Division will have to add an additional day and staff time for sample collection. To handle the excess in workload it will require additional qualified staff to help in sample collections.

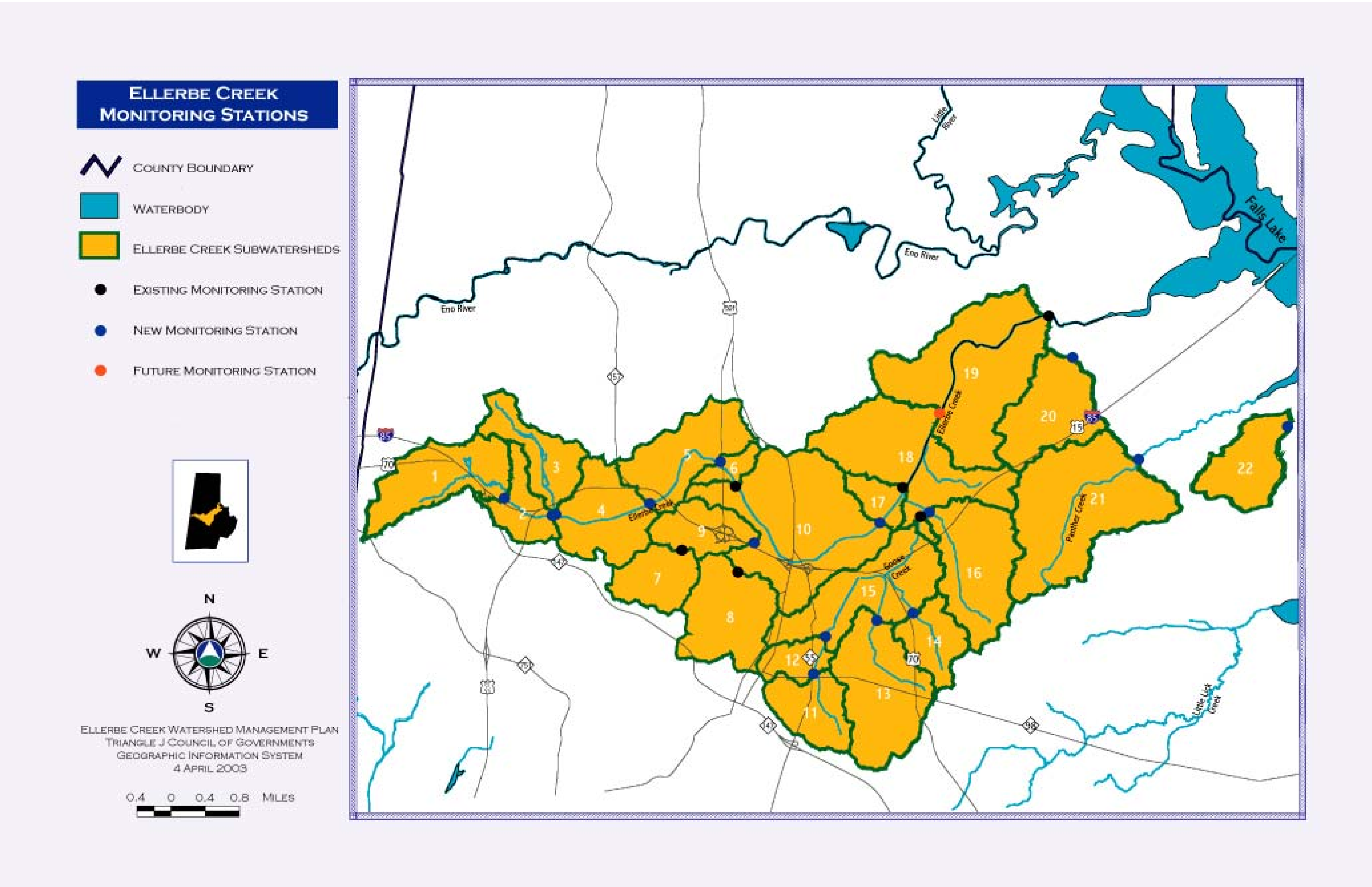

Figure 16: Stream Monitoring Locations

Recommendation 9 Strengthen Watershed Education and Stewardship Programs

Background

One on the five goals of the Ellerbe Creek Local Watershed Plan is to educate the local community about Ellerbe Creek. Though Ellerbe Creek has many enthusiastic supporters, many people still view it in a negative light or don't think about it at all. Critical to restoring Ellerbe Creek's water quality is the effort to educate people to the resource right in their backyard. A knowledgeable citizen is a caring citizen, and caring citizens will remain active in their efforts to protect their creek and their watershed.

Current Educational Use of Ellerbe Creek

There are currently many educational efforts that make use of Ellerbe Creek. Such efforts include:

- Durham's Stormwater Education Program marks Ellerbe Creek storm drains and visits area schools,

- School classes and Durham City Parks educators use the ECWA Urban Nature Reserve,

- NC State University created an educational stormwater wetland on Hillandale, Golf Course.

- The Museum of Life and Sciences uses Ellerbe Creek and some of its tributaries for nature programs,

- Classes at Duke University study restoration efforts along Ellerbe Creek; and,

- Many volunteer and neighborhood groups have been very active in creek cleanups as well as leading periodic plant and bird identification tours.

Recommendations for Additional Educational Use

Because Ellerbe Creek flows through a densely populated urban area, it is uniquely situated to serve as a convenient environmental education resource for Durham. Ellerbe Creek's educational potential can be further realized in the following ways.

Establish and/or upgrade urban nature reserves convenient to schools.
Nature reserves within walking distance of schools make field trips possible without the expense of busing or the investment of long travel times. Many urban natural areas in the watershed are already in public or nonprofit hands. Most are near parks with existing water and toilet facilities, but need official designation, trails for accessibility and habitat improvement to enrich their educational

offerings. Such areas are also useful to nearby residents for walking and wildlife viewing as well as educators that can access them when and how they see fit. There are also some very good sites for urban stream education along Ellerbe Creek that could be improved with small investments of time and money and made more useful as environmental education sites. Such locales include:

Bennett Place - next to Triangle Day School
Actions needed: Some management for biological diversity

Green Street Woods - Across the street from E.K. Powe School
Actions needed: Acquisition, trails, habitat restoration

Woods next to Northgate Park - close to Club Blvd. Elementary
Actions needed: Trails, habitat restoration

Goose Creek Floodplain - borders Eastway Elementary
Actions needed: restoration of channel and floodplain

Durham Landfill and borrow area - Glenn School, Chewning Middle School

Actions needed: trails, access, habitat restoration

Provide educational signage in urban nature preserves and along urban trails for self-guided walks by residents and students

Communicate with schools and teachers about nature study locations being developed close to their schools, and include their input in the design and management of these locations.

Expand educational outreach programs by Durham's Department of Stormwater Services

Include information on Durham's Stormwater Services website that explains how homeowners can have a creek-friendly yard and other concepts about minimizing imperviousness and increasing infiltration and detention of stormwater

Create a brochure describing habitat restoration and creek-friendly landscaping techniques including such techniques as rainwater gardens and swales.

Recommendation 10 Erosion and Sediment Control

Background[3]

Sediment is one of the leading causes of stream impairment in the United States and Ellerbe Creek is no exception. Ellerbe Creek's subwatersheds that have the potential for more development also have the likelihood of delivering large sediment loads to Ellerbe Creek. Poor aquatic habitat results from this sediment loading from construction sites. Data indicate that sediment loading from a construction site can be over 100 times the sediment load from a forested site. Data collected in Carpenter Village in Cary show that 8,700 pounds per acre (lb./acre) of sediment are discharged to sediment traps (CH2M Hill 2003). There is tremendous variability concerning the efficiency of sediment traps.

Data collected from a site near the I-540 indicate that mulching and seeding reduce erosion rates by approximately 95 percent. The average plot on bare soil had an erosion rate of 9,741 kg/ha (8,692 lb./acre), while those that were mulched and seeded had an average erosion rate of 438 lb./acre (CH2M Hill 2003). Thus, controlling sediment at its source is one of the most effective ways to address erosion from construction sites. The time when soil is left bare should be minimized.

Existing Regulations

The North Carolina Division of Land Resources (DLR) is the lead state agency for the sediment and erosion control program in North Carolina. DLR has delegated authority of this program to the Durham City and County. The Durham City/County Sediment Control Program requires a permit for all land disturbing activities exceeding 12,000 square feet. The only activities exempt from this rule are agricultural activities, publicly funded projects, projects exercising eminent domain powers, and forestry operations that follow and approved plan and utilize the forest practice guidelines. If the disturbed area exceeds 12,000 square feet, sediment and erosion control plans must be submitted and approved.

Appropriate Control measures include:

- Control measures must protect from peak runoff from 10-year storm,
- Must establish permanent ground cover within 15 working days or 90 calendar days whichever is shorter,
- Must notify agency that issued plan of the date land disturbing activity will begin,
- Preconstruction conference required; and,
- Agriculture and silviculture are exempt.

[3] Much of the language of this recommendation was taken directly from the Wake County Watershed Management Plan (see references)

Agriculture must meet agriculture BMP requirements, and forestry must comply with Forest Practices Guidelines. While plan is required for only those projects that exceed one acre in size, the law applies to all projects.

NPDES stormwater currently covers construction activities on sites greater than 5 acres. Phase II will cover sites 1 acre and greater. NPDES fines can be as high as $10,000 /day.

Recommendations:

Ensure there is adequate erosion and sediment control staff to carefully review plans

Update design manual to include new, more effective technologies

Provide funding and resources to local erosion and sediment control programs to provide environmental education classes geared to developers, contractors, site designers, and citizens. The State developed a Clear Water Contractor education program in which a one-day workshop is provided to the contracting community. Durham can use the State's education materials as a basis, modify them if desired and conduct training workshops.

Fines should be imposed on those that do not meet the local requirements. Fines should be large enough to encourage good erosion and sediment control practices.

Conclusion

The purpose of the recommendations laid out in this plan is to further the stated goals of improving aquatic life, reducing destructive flooding, enhancing recreational opportunities, protecting drinking water supplies, and educating the Durham community about Ellerbe Creek's valuable watershed resources. The desired effect of achieving these goals is to increase Ellerbe Creek's ability to perform essential watershed functions for the benefit of the Durham community. However, watershed restoration and management is an ongoing process, and it is the hope of the stakeholder community that this Local Watershed Plan serve as a blueprint for an ongoing adaptive management process that will help to guide future decision-making in the Ellerbe Creek Watershed. The recommendations in this plan provide a framework for the development of partnerships between local governments, citizen, non-profit organizations, and state and federal agencies aimed at fostering long-term restoration and management of the Ellerbe Creek Watershed. As new strategies are developed and new information becomes available that improves our ability to move towards the goals of this Local Watershed Plan, new recommendations should be developed to reflect our greater understanding of the most efficient and affective ways of achieving these goals. Thus, while the development of this Watershed Plan marks the end of the first stage of problem identification, prioritization, and strategy development for the Ellerbe Creek watershed, it is our hope that it is only the beginning of an on-going process aimed at the protection and improvement of the valuable water resources that serve our community.

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Appendix A

Imperviousness and Nutrient Loads for Ellerbe Creek

For the Upper Neuse River Basin Watershed characterization, TetraTech Inc. analyzed existing land use in the Ellerbe Watershed (23,528 acres or 36.76 square miles). Aerial photography was used to determine the current impervious area and growth rates from transportation analysis zones and current zoning were used to determine imperviousness in the year 2025. The Ellerbe Creek watershed is expected to reach "build out" or a state of full development allowed under current regulations by the year 2025.

Table A-1:Landuse (acres) in the Ellerbe Creek Watershed

Scenario	Forest	Agriculture	Residential	Urban
Year 2000	3676.2	298.3	4364.7	1245.8
Year 2025	1686.8	90.4	4480.0	3396.6

Table A-2: Imperviousness in the Ellerbe Creek Watershed

Scenario	Percent Impervious
Year 2000	22.4
Year 2025	27.5

By determining existing land use and predicted land use, phosphorous and nitrogen loads can be determined for a specific watersheds. Certain land uses deliver a particular load of a given nutrient. By determining land use within the watershed, a standard calculation was then used to determine total nutrient load.

Table A-3: Total Nitrogen Load (tons/year) in the Ellerbe Creek Watershed

Scenario	Forest	Agriculture	Residential	Urban
Year 2000	0.7	1.2	19.0	17.0
Year 2025	0.4	0.4	19.3	27.0

Table A-4: Total Phosphorus Load (tons/year) in the Ellerbe Creek Watershed

Scenario	Forest	Agriculture	Residential	Urban
Year 2000	0.06	0.13	2.52	2.11
Year 2025	0.04	0.05	2.56	3.43

Appendix B

Correlation of Pollutant Loads with Impervious Areas

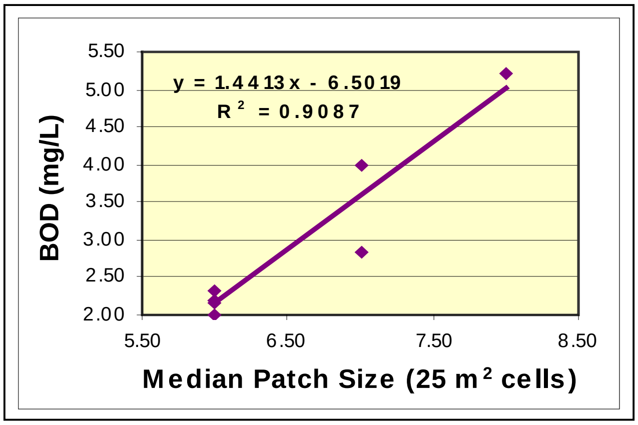
Duke University Master's Student Melissa Vernon studied the impact of impervious cover on several different water quality parameters within the Ellerbe Creek watershed. One of the most interesting results of looking at the water quality data was the correlation between water quality and median impervious area size. Traditionally, percent impervious surface area has been used to model pollutant loading in urban watersheds (See the TetraTech study above). The results of this study indicate that a predominance of large, contiguous impervious surfaces within a watershed may be more important in driving water quality than the overall amount of impervious surface area.

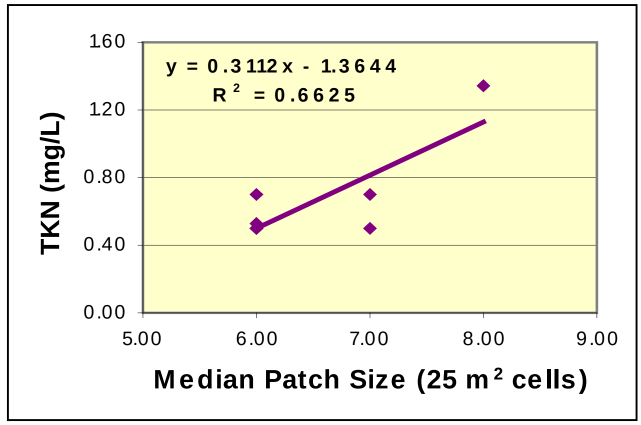
The importance of contiguous impervious surface in urban watersheds is likely related to the probability that any particular impervious surface is directly linked to the stormwater sewer system and thus directly to the stream providing no opportunity for pollutant removal or infiltration. The following page has graphs describing the correlation between median patch imperviousness size and several pollution parameters.

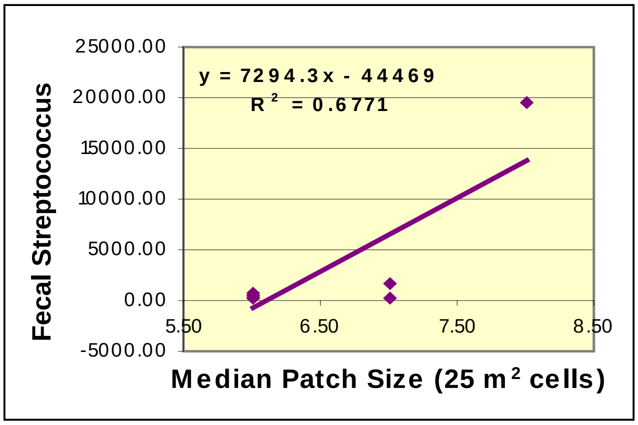
Abstract

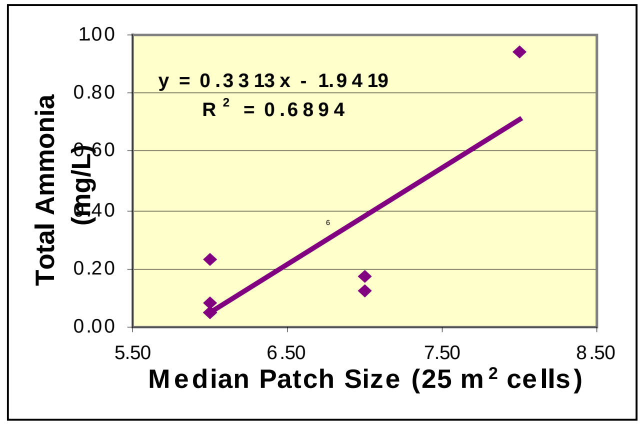
Urban runoff is a significant source of non-point source pollution degrading waterways in the United States. Past studies have linked percent impervious surface area to deteriorating water quality in urban watersheds. The objective of this study was to quantify this relationship by considering the spatial distribution of impervious surfaces within the Ellerbe Creek watershed, a small urban stream in Durham, North Carolina. Five spatial impervious surface variables – percent impervious, impervious surface weighted by distance to the stream, mean impervious surface patch size, median impervious surface patch size, and road and parking lot density were calculated for each of nine nested subwatersheds delineated for the Ellerbe Creek watershed. These spatial impervious surface variables were then regressed against mean spring ambient water quality variables to investigate how impervious surfaces might be driving water quality in urban watersheds.

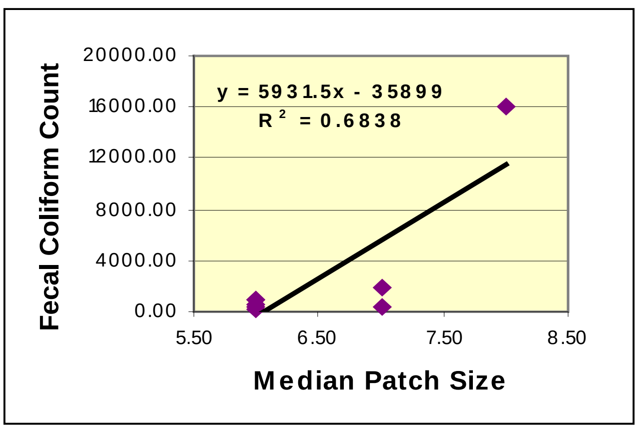
The results indicate that median impervious surface patch size may be more significant in predicting certain water quality parameters in urban watersheds than percent impervious surface area. In addition, distance-weighted impervious surface area did not improve the correlation to water quality variables, suggesting that location of impervious surfaces within the watershed is less important than the total amount of impervious surfaces. Based on these results, traditional methods of addressing non-point source pollution such as stream buffer and wetland restoration may be less effective in an urban watershed such as Ellerbe Creek than alternative watershed restoration strategies such as stormwater best management practices and in-stream restorations that deal directly with runoff from large contiguous impervious surfaces.

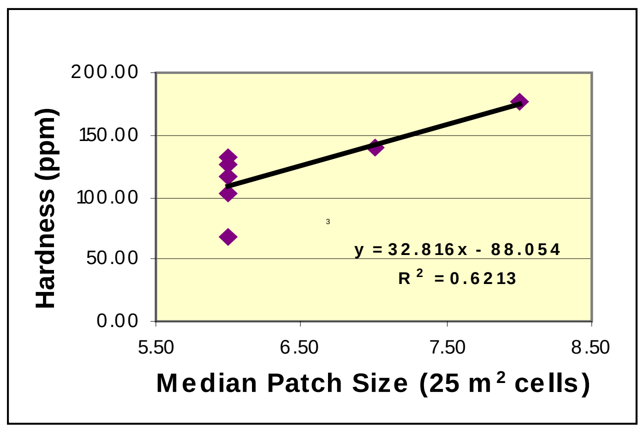

y = 1.4413x - 6.5019
R 2 = 0.9087
BOD (mg/L)
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
5.50
6.50
7.50
8.50
Median Patch Size (25 m 2 cells)

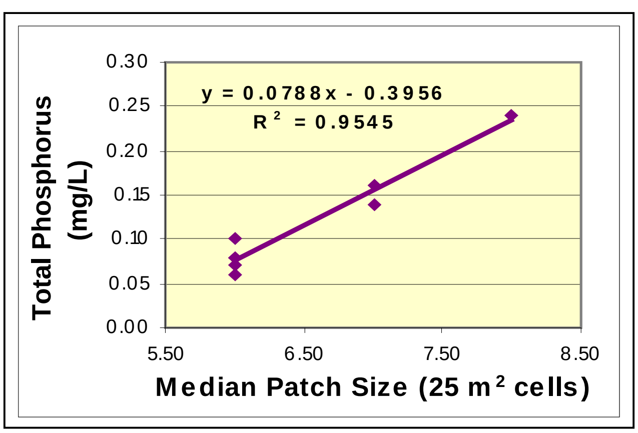

y = 0.3112x - 1.3644
R 2 = 0.6625
TKN (mg/L)
160
120
0.80
0.40
0.00
5.00
6.00
7.00
8.00
9.00
Median Patch Size (25 m 2 cells)


y = 7294.3x - 44469
R 2 = 0.6771
Fecal Streptococcus
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
-5000.00
5.50
6.50
7.50
8.50
Median Patch Size (25 m 2 cells)


y = 0.3313x - 1.9419
R 2 = 0.6894
Total Ammonia (mg/L)
100
0.80
0.60
0.40
0.20
0.00
5.50
6.50
7.50
8.50
Median Patch Size (25 m 2 cells)


y = 5931.5x - 35899
R 2 = 0.6838
Fecal Coliform Count
20000.00
16000.00
12000.00
8000.00
4000.00
0.00
5.50
6.50
7.50
8.50
Median Patch Size


y = 32.816x - 88.054
R 2 = 0.6213
Hardness (ppm)
200.00
150.00
100.00
50.00
0.00
5.50
6.50
7.50
8.50
Median Patch Size (25 m 2 cells)


y = 0.0788x - 0.3956
R 2 = 0.9545
Total Phosphorus (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5.50
6.50
7.50
8.50
Median Patch Size (25 m 2 cells)

Appendix C

Importance of Habitat and Primary Refugia for Aquatic Organisms

Aquatic organisms (benthic macroinvertebrates) require food, oxygen, water, and shelter—just as humans do. The types and diversity of aquatic organisms present can convey much information on the overall health of the stream in which they live. Some are tolerant to pollution and the conditions it creates (low dissolved oxygen, metals, sewage, and hazardous chemicals), while others are very sensitive to these factors. We can surely understand the importance of clean, unpolluted water for the health of not just people, but also organisms that live in or depend on the stream for water. One often overlooked and misunderstood aspects of ecological harmony is the idea of habitat.

Habitat is where an organism lives and what it relies on for food or shelter. For aquatic organisms, it is especially important to have a diversity of habitats, as many organisms are suited only for specialized habitats. Stream edges and root mats are particularly rich in species diversity. This type of habitat is best represented by tree roots and aquatic vegetation partially submerged in the water. This habitat serves as a food source for both herbivores and predators, but also offers protection and refuge during high flow and storm conditions. Submerged logs, rocks, sand, gravel, and silt can all provide excellent habitat for different types of organisms. It is important that all of these types of habitats be represented in the proper ratio. If one habitat dominates the stream, the overall diversity of the stream is reduced.

Man-made impacts on a stream, particularly those aimed at reducing flooding, can negatively affect much of the natural and healthy functions of the stream by excluding or destroying habitat. A common problem with many urban streams is that they have been channelized to reduce flooding. This creates problems with the flow regime of the stream. Steep, deeply cut stream banks offer no support for vegetation to grow. The tree roots along the edge cannot grow deep enough to be submerged year round. Channelization also creates problems with the velocity of the water traveling in a stream. A healthy stream has varying velocities of water within the stream at all times. The fast moving water tends to be in the middle of the stream, while along the banks, the rootmats and bends in the stream will help slow the water down. This provides a diverse benthic community because some species require rapidly flowing water while others require slower moving water.

Because many species live on, under, and between the spaces of substrates in the stream, they can't tolerate much sediment and silt from erosion. Erosion within a stream, due to poor control measures or man-modified design, and flash-flood rain events, is perhaps one of the biggest obstacles to overcome in urban streams. This excessive silt and sediment buries the substrate and covers the insects' gills, literally smothering them to death. The submerged logs, leaves, and rocks are covered with sediments, leaving aquatic organisms without food and shelter. This hydrological dysfunction can lead to stagnant water, low dissolved oxygen, increased bacterial activity, and promote favorable conditions for pests such as mosquitoes and leeches.

Another important aspect of habitat is that of quality of food sources. Aquatic organisms are in one way or another dependent on leaves and other vegetative material that make their way into the stream, whether it is a direct food source or as a food source for their prey. Aquatic organisms are also dependent on the shade riparian vegetation provides, as tall trees, shrubs and bushes. Here it is important to think outside the bank, in the riparian area. The riparian area provides the food source that "drives" the system. Many areas bordering streams in urban areas either lack vegetation, or at least the majority consists of non-native vegetation. Native vegetation is often overlooked when planning stream restorations and green space plantings. Many aquatic herbivores are specifically adapted to the type of native vegetation found in their particular range, so using non-native vegetation can dramatically alter their ability to utilize it as a viable food source. These inedible food sources can then lead to lower dissolved oxygen levels via bacterial decomposition and algal blooms. In highly visible urban areas riparian plantings and maintenance must have a balance between ecological harmony and attractive and easily maintained vegetation, which can be easily accomplished.

So many of our heavily urban streams like Ellerbe Creek have already been damaged to the point that stream restoration and protection of critical areas is the only hope in increasing their health. Note that improving water quality is also a requirement (see Appendix E and F). Interesting questions that are often brought up are "what happens if all the sensitive organisms are already gone from a stretch of stream?" and "How can we get them back?" This leads to a discussion on the importance of refugia.

Refugia can simply be thought of as a shelter or area of protection from which a population can spread out and repopulate a stream after a catastrophic event (i.e., pollution flume, or major storm event). This is where diverse, stable habitat and protected areas are of a major importance. If habitat and refugia are absent, any disturbance in an unprotected or unstable stream will wipe out or flush organisms downstream. If they are present, they provide a refuge where organisms can survive the event. After the event has passed the organisms can fan out into the areas left vacant.

While there is some degree of recolonization from downstream to upstream, it is limited in its' ability to repopulate the upper reaches of a stream because, as we all know, water flows downstream. Most often, recolonization is accomplished when organisms in the upper reaches float downstream. This demonstrates the major importance of protecting the upper reaches of a stream, especially high quality sites. Another important aspect of recolonization is that of adult aerial dispersal. This too is limited in our urban setting due to bright light interfering with adult dispersal and mating, and also the underground piping of stream sections. It can be argued that a protected upper reach of a stream could provide lateral movement of aerial dispersal of adults to recolonize other streams short distances nearby. Therefore, it is doubly important to protect the healthiest streams and stream sections so that they may serve as a repopulation center for nearby streams after stream restoration has occurred.

Appendix D

The Center for Watershed Protection's Model Development Principles and The City of Durham's Response

The model development principles generally fall into one of three categories: Residential Streets and Parking Lots; Lot Development; and Conservation of Natural Areas. Each principle represents a simplified design objective in site planning. To find more detail on these principles, refer to *CWP's Better Site Design: A Handbook for Changing Development Rules in Your Community* (August 1998).

Residential Streets and Parking Lots

These principles focus on those codes, ordinances, and standards that determine the size, shape, and construction of parking lots, roadways, and driveways in the suburban landscape.

1.Design residential streets for the minimum required pavement width needed to support travel lanes; on street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume.

2.Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.

3.Wherever possible, residential street right-of-way widths should reflect the minimum required accommodating the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located within the pavement section of the right-of-way wherever feasible.

4.Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required accommodating emergency and maintenance vehicles. Alternative turnarounds should be considered.

5.Where density, topography, soils, and slopes permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.

6.The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to see if lower ratios are warranted and feasible.

7.Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.

8.Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas.

9.Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.

10.Wherever possible provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Lot Development

Principles 11 through 16 focus on the regulations which determine lot size, lot shape, housing density, and the overall design and appearance of our neighborhoods.

11.Advocate open space development that incorporates smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

12.Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.

13.Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.

14.Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.

15.Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.

16.Direct-rooftop runoff to pervious areas such as yards, open channels or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Conservation of Natural Areas

The remaining principles address codes and ordinances that promote (or impede) protection of existing natural areas and incorporation of open spaces into new development.

17.Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and freshwater wetlands.

18.The riparian stream buffer should be preserved or restored with native vegetation that can be maintained throughout the delineation, plan review, construction, and occupancy stages of development.

19.Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.

20.Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas to promote natural vegetation.

21.Incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value. In addition, off-site mitigation consistent with locally adopted watershed plans should be encouraged.

22.New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

City of Durham's Response to Model Development Ordinance Worksheet

1. Street Width
What is the minimum pavement width allowed for streets in low-density residential developments that have less than 500 average daily trips (ADT)?

*If your answer is between **18-22 feet**, give yourself **4** points.* **4 points**

At higher densities are parking lanes allowed to also serve as traffic lanes (i.e., queuing streets)? YES/**NO**
*If your answer is **YES**, give yourself **3** points* **0 points**

2. Street Length
Do street standards promote the most efficient street layouts that reduce overall street length? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 Point**

3. Right-of-Way Width
What is the minimum right of way (ROW) width for a residential street? 50 feet
*If your answer is **less than 45 feet**, give yourself **3** points* **0 points**

Does the code allow utilities to be placed under the paved section of the ROW? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

4. Cul-de-Sacs
What is the minimum radius allowed for cul-de-sacs? **46.5** feet
*If your answer is **less than 35 feet**, give yourself **3** points*
*If your answer is **36 feet to 45 feet**, give yourself **1** point* **0 points**

Can a landscaped island be created within the cul-de-sac? **YES** / NO *If your answer is **YES**, give yourself **1** point* **1 point**

Are alternative turn arounds such as "hammerheads" allowed on short streets in low density residential developments? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

5. Vegetated Open Channels
Are curb and gutters required for most residential street sections? **YES** / NO
*If your answer is **NO**, give yourself **2** points* **0 points**

Are there established design criteria for swales that can provide stormwater quality treatment (i.e., dry swales, biofilters, or grass swales)? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

6. Parking Ratios
What is the minimum parking ratio for a professional office building (per 1000 ft2 of gross floor area)? **4** spaces
*If your answer is **less than 3.0 spaces**, give yourself **1** point L* **0 points**

What is the minimum required parking ratio for shopping centers (per 1,000 ft2 gross floor area)? **5**
*If your answer is **4.5 spaces or less**, give yourself **1** point* **0 points**

What is the minimum required parking ratio for single family homes (per home)? **2** spaces
*If your answer is **less than or equal to 2.0 spaces**, give yourself **1** point*
1 point

Are your parking requirements set as maximum or median (rather than minimum) requirements? YES / **NO**
*If your answer is **YES**, give yourself **2** points* **0 points**

7. Parking Codes
Is the use of shared parking arrangements promoted? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Are model shared parking agreements provided? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Are parking ratios reduced if shared parking arrangements are in place?
YES / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

If mass transit is provided nearby, is the parking ratio reduced? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

8. Parking Lots
What is the minimum stall width for a standard parking space? **<u>8.5</u>** feet
*If your answer is **9 feet or less**, give yourself **1** point* **1 point**

What is the minimum stall length for a standard parking space? **<u>18</u>** feet
*If your answer is **18 feet or less**, give yourself **1** point* **1 point**

Are at least 30% of the spaces at larger commercial parking lots required to have smaller dimensions for compact cars? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Can pervious materials be used for spillover parking areas? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

9. Structured Parking
Are there any incentives to developers to provide parking within garages rather than surface parking lots? YES / **NO**
*If your answer is **YES**, give yourself **1** point* **0 points**

10. Parking Lot Runoff
Is a minimum percentage of a parking lot required to be landscaped? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Is the use of bioretention islands and other stormwater practices within landscaped areas or setbacks allowed? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Table D-1Total Score Residential Streets and Parking Lots

	Durham City/County	Maximum Score	Percentage
Residential Streets & Parking lots	24	40	60%

11. Open Space Design
Are open space or cluster development designs allowed in the community? **YES** / NO *If your answer is **YES**, give yourself **3** points* **3 points**

Is land conservation or impervious cover reduction a major goal or objective of the open space design ordinance? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Are the submittal or review requirements for open space design greater than those for conventional development? YES / **NO**
*If your answer is **NO**, give yourself **1** point* **1 point**

Is open space or cluster design a by-right form of development? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Are flexible site design criteria available for developers that utilize open space or cluster design options (e.g., setbacks, road widths, lot sizes) **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

12. Setbacks and Frontages
Are irregular lot shapes (e.g., pie-shaped, flag lots) allowed in the community?
YES / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

What is the minimum requirement for front setbacks for a **one half (½) acre** residential lot? **35 feet**
*If your answer is **20 feet or less**, give yourself **1** point* **0 point**

What is the minimum requirement for rear setbacks for a **one half (½) acre** residential lot? **25 feet**
*If your answer is **25 feet or less**, give yourself **1** point* **I point**

What is the minimum requirement for side setbacks for a **one half (½) acre** residential lot? **12 feet**
*If your answer is **8 feet or less**, give yourself **1** points* **0 points**

What is the minimum frontage distance for a **one half (½) acre** residential lot?
100 feet

*If your answer is **less than 80 feet**, give yourself **2** points* **0 points**

13. Sidewalks
What is the minimum sidewalk width allowed in the community? **5 feet**
*If your answer is **4 feet or less**, give yourself 1 point* **0 points**

Are sidewalks always required on both sides of residential streets? YES / **NO**
*If your answer is **NO**, give yourself **1** points* **1 point**

Are sidewalks generally sloped so they drain to the front yard rather than the street? YES / **NO**
*If your answer is **YES**, give yourself **1** point* **0 points**

Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

14. Driveways
What is the minimum driveway width specified in the community? **10 feet**
*If your answer is **9 feet or less (one lane) or 18 feet (two lanes)**, give yourself **2** points* **0 points**

Can pervious materials be used for single family home driveways (e.g., grass, gravel porous pavers, etc)? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Can a "two track" design be used at single family driveways? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Are shared driveways permitted in residential developments? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

15. Open Space Management
Does the community have enforceable requirements to establish associations that can effectively manage open space? **YES**/NO
*If your answer is **YES**, give yourself **2** points L* **2 points**

Are open space areas required to be consolidated into larger units?
YES / NO *If your answer is **YES**, give yourself **1** point* **1 point**

Does a minimum percentage of open space have to be managed in a natural condition? YES / **NO** *If your answer is **YES**, give yourself **1** point* **0 points**

Are allowable and unallowable uses for open space in residential developments defined? **YES** / NO *If your answer is **YES**, give yourself **1** point* **1 point**

Can open space be managed by a third party using land trusts or conservation easements? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

16. Rooftop Runoff
Can rooftop runoff be discharged to yard areas? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Do current grading or drainage requirements allow for temporary ponding of stormwater on front yards or rooftops? **YES** / NO
If your answer is **YES**, give yourself **2** points **2 points**

Table D-2 Score for Lot Development

	Durham City/County	Maximum Score	Percentage
Lot Development	25	36	69%

17. Buffer Systems
Is there a stream buffer ordinance in the community? **YES** / NO
*If your answer is **YES**, give yourself **2** point* **2 points**
If so, what is the minimum buffer width? **<u>50 feet</u>**
*If your answer is **75 feet or more**, give yourself **1** point* **0 points**
Is expansion of the buffer to include freshwater wetlands, steep slopes or the 100-year floodplain required? YES / **NO**
*If your answer is **YES**, give yourself **1** point* **0 points**

18. Buffer Maintenance
Does the stream buffer ordinance specify that at least part of the stream buffer be maintained with native vegetation? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Does the stream buffer ordinance outline allowable uses? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Does the ordinance specify enforcement and education mechanisms?
YES / NO *If your answer is **YES**, give yourself **1** point* **1 point**

19. Clearing and Grading
Is there any ordinance that requires or encourages the preservation of natural vegetation at residential development sites? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Do reserve septic field areas need to be cleared of trees at the time of development? YES / **NO**
*If your answer is **NO**, give yourself **1** point* **1 point**

20. Tree Conservation
If forests or specimen trees are present at residential development sites, does some of the stand have to be preserved? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Are the limits of disturbance shown on construction plans adequate for preventing clearing of natural vegetative cover during construction?
YES / NO *If your answer is **YES**, give yourself **1** point* **1 point**

21. Land Conservation Incentives
Are there any incentives to developers or landowners to conserve non-regulated land (open space design, density bonuses, stormwater credits or lower property tax rates)? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Is flexibility to meet regulatory or conservation restrictions (density compensation, buffer averaging, transferable development rights, off-site mitigation) offered to developers? YES / **NO**
*If your answer is **YES**, give yourself **2** points* **0 points**
22. Stormwater Outfalls
Is stormwater required to be treated for quality before it is discharged? **YES** / NO
*If your answer is **YES**, give yourself **2** points* **2 points**

Are there effective design criteria for stormwater best management practices (BMPs)? **YES** / NO
*If your answer is **YES**, give yourself **1** point* **1 point**

Can stormwater be directly discharged into a jurisdictional wetland without pretreatment? YES / **NO**
*If your answer is **NO**, give yourself **1** point* ***1 point***

Does a floodplain management ordinance that restricts or prohibits development within the 100-year floodplain exist? **YES** / NO
If your answer is **YES**, give yourself **2** points **2 points**

Table D-3 Score for Conservation of Natural Areas

	Durham City/County	Maximum Score	Percentage
Conservation of Natural Areas	21	24	88%

Table D-4 Totals for Code and Ordinance Review

Principle	COW points Durham City/County	Maximum Score	Percentage
Residential Streets & Parking lots	24	40	60%
Lot Development	25	36	69%
Conservation of Natural Areas	21	24	88%
Totals	70	100	70%

TOTAL
SCORING (A total of **100** points are available):
See Page 10 to determine where your community's score places in respect to the site planning roundtable Model Development Principles:

Your Community's Score
90- 100 L Congratulations! Your community is a real leader in protecting streams, lakes, and estuaries. Keep up the good work.

80 - 89 L Your local development rules are pretty good, but could use some tweaking in some areas.

79 - 70 L Significant opportunities exist to improve your development rules. Consider creating a site planning roundtable.

60 - 69 L Development rules are inadequate to protect your local aquatic resources. A site planning roundtable would be very useful.

Less than 60 L Your development rules definitely are not environmentally friendly. Serious reform of the development rules is needed.

Appendix E

Stormwater Retrofit Prioritization Process

Step 1 – Establish Goals

Retrofitting is a long-term strategy. Experience in the national 319 non-point source grant program indicates that confining restoration efforts to relatively small watersheds can makes it much easier to see benefits, whereas distributing projects over a large area makes it difficult to discern changes. For this reason initial efforts at retrofitting should be focused on selected subwatersheds within Ellerbe Creek.

Selection of the target watersheds should be based on potential to show improvements and on total cost of retrofitting the watershed. Initial retrofits also should be focused where they can have a significant impact – subwatersheds with little development will accrue little benefit, while subwatersheds that are large or highly developed will require substantial retrofitting to achieve measurable benefits. Subwatersheds with between 12 and 30% imperviousness may be better candidates to focus initial efforts. Similarly, a subwatershed that has other subwatersheds draining to it is less likely to show improvement than a subwatershed that is a headwaters of the creek or one of its tributaries.

Locating retrofits where they can work with other strategies will have substantially better success at showing improvement in sensitive biological assessment monitoring. Aquatic life impairment is the result of multiple stressors, and removing only a few stressors may not resulting significant improvements. Retrofitting a subwatershed where riparian buffers are being reestablished or where the watershed is tributary to a stream restoration project is more likely to show improvements by a wider variety of stressors.

To simplify the task of developing a retrofit plan, initial efforts will primarily focus on reduce the loading of nitrogen and phosphorus. The ability of several stormwater management practices to remove nitrogen and phosphorus has been studied well enough to estimate their expected removal performances. Management practices that are effective at controlling nutrients should be somewhat effective of other pollutants of concern. Where it is not possible to implement nutrient control because space is too limited, it may be necessary to consider practices that will remove floating oil and grease (FOG) and fine suspended particles as much as possible in an effort to control hydrocarbons and total metals.

Some treatment practices can be designed to mitigate increases in peak flow and runoff volume by temporarily storing, and slowly releasing the retained flow. Such enhanced designs should be employed wherever space is available. Control of flow and volume can also be cost-effective where the outlet structure of an existing pond or detention basin can be retrofitted to provide improved control and management of the one-year storm. However, full control of flow and volume in Ellerbe Creek would be very expensive.[4] In general, the problems created by increased stormwater runoff can be addressed through a combination of partial runoff management and channel restoration. Supplemental control of flow and volume should be targeted to selected areas upstream of channel sections identified as having high velocities (to be identified in drainage modeling) and that are not suitable for channel restoration.

Impervious surfaces tend to collect large amounts of nitrogen (from automobiles and atmospheric deposition) and also to contribute somewhat higher loading of phosphorus than lawns. Impervious surfaces also collect hydrocarbons from auto exhausts, and metals from brake pad wear and tire wear. With more than 3,000 acres of impervious surface in Ellerbe Creek, a system for ranking which impervious surfaces have the greatest impact can help make the best use of limited resources?

Not all impervious surfaces have the same impact. As discussed above, research by Melissa Vernon and Patrick Halpin of Duke University indicates that large patches of impervious area are generally more closely associated with water quality impacts than any other measure of development evaluated, including total imperviousness. Theory and practice indicates that directly connected impervious areas have greater impacts on stormwater flow and volume than disconnected impervious areas, and disconnecting roof leaders is often included as a strategy in retrofit plans.

The following summarizes the order of preference for targeting the retrofits:

1. Large patch impervious areas;
2. Directly connected impervious surfaces with high automobile use;
3. Other directly connected impervious surfaces; and
4. Indirectly connected impervious areas that sheet flow a short distance over pervious areas before reaching a gutter, inlet, ditch or other part of the drainage system.

Step 2 – Evaluation of Potential Options

[4] Runoff from the one-year, 24-hour storm from Ellerbe Creek in the City of Durham has increased on the order of 300,000,000 gallons as a result of development. It would be prohibitively expensive to mitigate this increase by even 1/10 if rain barrels are used. Uninstalled costs for cisterns ranges from $.70 to $.90 per gallon, and for rain barrels it is more than $1.00 per gallon. Assuming owner installation (and neglecting the cost of installation) and assuming the rain barrels are empty at the beginning of the rain event, the cost of the rain barrels would be on the order of $30,000,000.
For comparison, installed cost for detention basins is typically $.07 to $.14 per gallon of storage (CWP, 1998). Detention basins excavated on publicly owned land would cost on the order of $3,000,000 for a similar level of control.

The state of the art of stormwater treatment is advancing rapidly, and there is a growing list of options. These options vary considerably in cost, space requirements, maintenance requirements, and ability to remove various pollutants, where that information is available (adequate treatment performance results exist for only a handful of treatment practices).

The table below is a partial list of some of the options available for stormwater retrofits. The listed options vary considerably in cost, space requirements, maintenance requirements, and ability to remove various pollutants of concern. The reported efficiencies should be taken as a rough guide. Treatment efficiency for a given device will vary wildly from storm to storm.

Table E-1 Selected Stormwater Management Practices

Practice	Area Required[1] Design/[Total]	Slope (%) or Elev. Diff. ('Head") [7,8]	Nitrogen Removal	Phosphorus Removal	Application Suitability	Cost for One Acre Impervious [2]	Notes
Wet Ponds (Retention Basin)	1.1% – 4% [6,7] [3% - 9%]	2 - 4 feet	25% [3]	35% (1") 40% (1½") 50% (2") 65% (2" w/ aquatic shelf) [4]	Suitable for most apps except hotspots and ultra-urban areas.[7]	$3,000 to $14,000[6]	$$ 1, 5, 6, 7, 8, 9.
Constructed Stormwater Wetland	1.5% - 2%[6,7] [3.5 – 4.5%]	2 - 4 feet	40%[3]	30%[4]	See Wet Ponds	$3,900[6] to $7,000	$$ 1, 5, 6, 7, 8, 9.
Sand Filter (perimeter Delaware-type, or underground traffic loading)	1.2% - 2% [6,2] [0% - 2%] (underground may be 'zero' space)	3– 6 feet	40%[8] for 1 inch storm; (50% for Alexandria modified)	65% for 1 inch storm[4]	Ideal where space is limited; parking lots, ultra-urban[7]	$14,000 to $50,000[6]	$$$ 2, 4, 10.
Bioretention with underdrain	2.5% - 7% [3% - 10%]	4 – 6 feet	40%[9] for 1 inch storm	50% for ½ inch storm; 65% for 1 inch storm[4]	Ideal for parking lots, used for roads & residential; maybe for pervious areas [7]	$10,000 to $12,000[6,8]	$$ 2, 3, 11.
Grassed Swale	[5% - 7%] (100 ft length /acre treated)	2 - 3% slope or add check dams	30% [3]	15%[4] - 25%[5]	For roads & residential [7] where space is available	$400	$ 2, 3, 13, 14.

Practice	Area Required[1] Design/[Total]	Slope (%) or Elev. Diff. ('Head") [7,8]	Nitrogen Removal	Phosphorus Removal	Application Suitability	Cost for One Acre Impervious [2]	Notes
Dry Filtration Swale w/ underdrain	6% - 8% [10% - 15%[7]]	1.25 – 3% slope	30%	50%[5]	Ideal for roads & residential; possibly parking lots [7]	$4,800 to $7,200	$$ 2, 3, 10/11, 13, 14.
Vegetated filter strip with level spreader	[11% - 14%]	1 to 2 feet	20%	10%[4]	For roads & residential areas[7]	$1,200 to $2,500	$ 2, 4, 12, 15, 16.
50 ft forested riparian buffer with sheet-flow	See vegetated filter strip		20%	10%	Where space allows		$ 2, 4, 12, 15, 16.
Manufactured Hydrodynamic Structures	<1%	1 ft	<5%	15% - 20%	For ultra-urban areas		$$$ 2, 3, 17, 18.

[1] "Area Required" is ratio of the size of the treatment practice to drainage area (SA/DA) expressed as a percent for treatment of the first inch of runoff for imperviousness in the range 30% to 100%; first set of ranges is the design surface area, while the second set [in brackets] is approximate total area, including embankments, etc. Where space is very limited a retrofit practice may need to be downsized to treat the first ½ inch of runoff.
[2] Costs are construction cost and do not include design or land costs. Add 30% to account for design, permitting, contingencies, etc.
[3] Neuse River Basin: Model Stormwater Program for Nitrogen Control, North Carolina Division of Water Quality, 1999.
[4] Virginia Stormwater Management Handbook, 1999
[5] Georgia Stormwater Manual, 2001
[6] The Economics of Stormwater BMPs in North Carolina, Ada Wossink and Bill Hunt, (in press 2003).
[7] Center for Watershed Protection, 2000.
[8] City of Durham Stormwater Management Plan for the Neuse River Nutrient Sensitive Waters Strategy, 2001
[9] Stormwater Best Management Practices, North Carolina, April 1999.
[10] Tar-Pamlico Stormwater Management Program, per Bill Hunt, personal communication, January 10, 2003

Notes for Table E-1 - Selected Stormwater Management Practices

$ Moderate cost
$$ Expensive
$$$ Very expensive

1. Can be designed to manage peak flow.
2. Requires separate detention capability to manage peak flow.
3. Suitable for small drainage areas
4. Not appropriate for drainage areas larger than 3 to 5 acres.
5. Suitable for larger drainage areas
6. Larger facilities of this type have significant economies of scale.
7. Large facilities of this type lend themselves to placement in low-lying areas, and may require mitigation.
8. Mitigation for impacts to streams and wetlands usually can be incorporated into the design.
9. Works well on local impervious surfaces.
10. For treating runoff from impervious surfaces - facility of this type highly susceptible to clogging by local, erodible clay soil.
11. Moderately subject to clogging from clay soil, may require pretreatment if drainage area will have erodible clay soil.
12. Requires one or more level spreaders to provide sheet flow.
13. For low slopes. Slopes <2% unless channel liner installed.
14. Side slopes must be stabilized to prevent clogging. Erosion control matting is strongly recommended.
15. For slopes <4%.
16. Provide with a by-pass or design as off-line facility with flow splitter.
17. May be subject to clogging from trash.
18. Space-saving, small footprint.

- -

It is common for efficiency measurements on a series of storms to vary from –20% to 80%. Even attempts to measure overall, long-term efficiency can be confounded by the fact that measured efficiency increases as the quality of the water being treated declines.

Practices also vary considerably in suitability for specific applications. Where space is limited, flow splitters may be required to divert only a portion of the flow (i.e. the first flush) into a treatment practice.

Cost expressed in the table above does not reflect economies of scale for practices that are suitable for treating larger drainage areas. The table below provides preliminary formulas for calculating cost based on the size of the watershed being treated, based on a study (in press) by Ada Wossink and Bill Hunt.

Table E-2 Stormwater Treatment Practice and Cost

Stormwater Treatment Practice	**Construction Cost*** (C = cost in dollars, x = area in acres)
Wet Pond	$C=13{,}909\ x^{0.672}$
Stormwater Wetland	$C=3{,}852\ x^{0.484}$
Sand Filter	$C=47{,}888\ x^{0.672}$
Bioretention (in clay soils)	$C=10{,}162\ x^{1.088}$

** Add 20 to 30% to account for design costs and other capital costs.*

Using the formulas in the table above, the cost of treating a one-acre site using bioretention is estimated to be $10,200, which is slightly less than the cost of using a wet detention pond at $13,900.

Wet detention ponds and stormwater wetlands benefit from economies of scale in a way that bioretention does not. Bioretention is generally limited to smaller drainage areas, as indicated in the Table E-2 notes. Table E-3 below shows how economies of scale impact treatment costs for a twenty-acre site. :

Table E-3 Stormwater Treatment Practice and Comparable Cost for Treating a 20 acre site.

Stormwater Treatment Practice	**Construction Cost*** **For Treating 20 Acre Site**
Wet Pond	$104,100
Stormwater Wetland	$16,400
Sand Filter	$672,600
Bioretention (in clay soils)	$264,500

When used in larger size practices, constructed stormwater wetlands are the most cost-effective management practices for removal of nitrogen. Employing a few large facilities of either type in place of multiple small facilities can reduce the cost per treated acre through economies of scale.

The opportunities to locate large facilities will be limited by the lack of available undeveloped area. In some cases large facilities can be designed so that they reduce flooding downstream. However, depending upon how they are designed and constructed, such facilities tend to back water up. Care must be used in locating and designing large facilities so that backwater conditions will not cause flooding. Durham cannot approve a large facility unless it can show that it will not contribute to, or exacerbate, an existing flooding problem ("no rise.")

Large facilities lend themselves to placement in low lying areas, and depending upon the size and location may impact existing intermittent or perennial streams and/or wetlands. Because regulators recognize that retrofitting existing development is much more difficult than designing stormwater for new development, regulatory hurdles are slightly lower under some circumstances.

Table E-4 Guidelines for Evaluating Large and Regional Facilities.

Stream type	Drainage Area	Pipe Discharges	Open Channels
Ephemeral	<20-25 acres	Generally no restrictions.	Generally no restrictions.
Intermittent	5 to250 acres	On-line BMPs at the mouth of piped systems require approval but are generally approved.	Depends upon conditions – on-line BMPs may be approved for existing development – wetlands systems easier to permit than systems with permanent pools
Perennial	>40 acres	401/404 permitting requires analysis of alternatives and will require mitigation, if approved.	401/404 permitting requires analysis of alternatives and will require mitigation, if approved. Non-permanent pool systems easier to permit. Will not address water quality upstream of the facility, so very large facilities are limited in effectiveness.

A retrofit plan for a subwatershed must explore a wide variety of available options, and must review a variety of alternatives. Opportunities for placing large facilities are likely to be limited by land cost and/or lack of appropriately located public land.

Some additional strategies that have been used elsewhere and may be suitable for Durham:

- Disconnection of roof rainwater downspout from the storm (or sanitary sewer) system to reduce peak flows (and control sanitary sewer overflows). Effectiveness at controlling peak flow depends upon availability of a landscaped area to which flow can be directed. Cost is approximately $50 per house.
- Replanting dry detention basins with wild flowers rather than turf grass to improve settling and nutrient capture.
- Encourage use of cisterns to capture sufficient rainwater to supplement irrigation (600 to 1,200 gallons per house, depending upon irrigation needs.).

<u>Step 3 - Preliminary watershed retrofit inventory.</u>

This involves identifying as many potential sites as rapidly as possible. According to the Center's guidance, "The best sites fit easily into the existing landscape, are located at or near major drainage or stormwater control facilities, and are easily accessible. For example, almost every urban area has some type of existing pond or other existing feature adaptable for retrofitting. In many newer neighborhoods, dry stormwater detention facilities were constructed for flood control. In older neighborhoods there are often aesthetic ponds, or other water features which can make suitable retrofits."

There are many areas to look at to assess whether they offer suitable opportunities for retrofits including: publicly owned open spaces, existing stormwater management practices, road culverts, storm drain outfalls, parking lots, and street right-of-ways. Hotspots like gas stations, garbage compactors, and garbage dumpsters (especially those serving restaurants and apartment complexes).

Table E-5 Location and best type of Retrofit

Location	Type of Retrofit
Existing ponds, stormwater detention facilities	Usually involves conversion to a wet pond or stormwater wetland capable of multiple storm frequency management, including the one-year event. A dry detention basin that cannot be converted to a wetland or pond can be replanted with vegetation having higher pollutant removal rates.
Immediately upstream of road culverts	When the area adjacent to the road is undeveloped, sometimes it can be retrofitted as a wet pond, wetland, or extended detention facility capable of multiple storm management.
Immediately below or adjacent to existing storm drain outfalls	Usually water quality only practices such as sand filters, vegetative filters or other small storm treatment facilities.
Directly within urban drainage channels or flood control channels	Usually small scales weirs or other flow attenuation devices to facilitate settling of solids.
Highway rights-of-way and cloverleaves	Can hold a variety of practices, but usually ponds or wetlands.
Within large open spaces such as golf courses and parks	Can hold a variety of practices, but usually ponds or wetlands capable of multiple storm management.
Within or adjacent to large parking lots	Usually water quality only facilities such as sand filters or other media filters (e.g. bioretention).

Potential sites can be identified using topographic maps, and storm drainage maps, and other such resources. For each potential site, the area draining to it (DA) must be delineated, the imperviousness (%I) determined, and treatment volume quantified. The site's available surface area (SA) for placing the treatment practice must be determined. The volume available at the site can be approximated by multiplying two-thirds the surface area times the estimated depth[5], and the volume should be large enough to capture at least the first ½ inch of runoff, with a 1 inch capture being preferred. Effective use of the City of Durham's Geographic Information Systems (GIS) resources will improve the

[5] Center for Watershed Protection recommendation,

efficiency of mapping the potential sites, delineating and quantifying drainage to them, and assessing the available area at the site.

Constraints on Potential Sites

While stormwater retrofit controls must be fit into the existing landscape and drainage system, exiting structures and uses of the land may place constraints on the location of retrofits. Stormwater system ownership also place significant constraints on the location of retrofit locations. Durham County does not own or operate only of the stormwater system in developed portions of the county. The City of Durham owns only that portion of the stormwater system that is in public right-of-way or on other City property. Retrofitting a subwatershed will likely involve looking at potential locations on private property, which will require permission from property owners.

<u>Step 4 - Field assessment of potential retrofit sites</u>

A field assessment of each potential site must be conducted to verify which sites are feasible and appropriate. It can be difficult to ascertain the way a site is currently being used using only GIS or topographic maps - a field assessment should evaluate whether an open space area has an incompatible use that cannot be relocated. GIS topographic maps are usually adequate for initial assessments, but a site survey may be required to verify whether site elevations and slopes will allow conveyance of stormwater runoff to and from the proposed treatment practice. If infiltration practices are proposed based on soil survey maps, a field assessment is required to determine the infiltration rates the soil can support. If excavation is proposed, the depth to bedrock should be determined to make sure that blasting or other expensive construction practices would not be necessary to facilitate excavation.

<u>Step 5 – Public involvement</u>

A critical part of the retrofit planning process is explicit outreach efforts to inform and educate stakeholders, and to solicit their involvement. Placing new stormwater management facilities in existing neighborhoods is likely to generate a lot of questions regarding the need, alternatives evaluated, appearance, public safety, public health, property values, and other issues. The Center for Watershed Protections suggests using workshops or charrettes early in the planning process to involve and solicit comments from adjacent property owners and other members of the public. A 30% design (conceptual design) can often provide sufficient detail to provide a useful, realistic picture for communicating with members of the public. In some cases it may be necessary to develop 30% designs for several alternatives.

Step 6 – Prioritize sites for implementation

Each subwatershed within Ellerbe Creek will require multiple retrofits in order to effectively improve water quality. Ranking is necessary to determine which projects to pursue first. Site should be ranked based on specified criteria. The following criteria are suggested:

- Pounds of N removed
- Pounds of P removed
- Impervious area treated
- Type of impervious area (large patch, directly connected, highways, etc.)
- Channel protection volume treated
- Water quality volume treated
- Project cost
- Land ownership and availability
- Ease of access
- Future maintenance burden
- Impact on utilities
- Forest & tree preservation
- Wetlands preservation
- Community acceptance
- Potential for project success

Step 7 – Final design and preparation of construction drawings for retrofits.

Based on the ranking, selected retrofit sites would be carried through to development of construction drawings and specifications.

Step 8 – Design Review and Permitting

The 30% design stage may be able to serve as the necessary submission for the first stage of Durham's two-stage review process. The site plan review stage involves layout, topography and erosion and sediment control plans. Construction drawings would be submitted for review and approval after the site plan drawings had been approved.

In cases where a large facility or a regional facility is proposed for retrofitting, the planned facility may involve impacts to streams, wetlands, or floodplains. The Center for Watershed Protection indicates, "Many of these impacts are either unavoidable or necessary to achieve reasonable storage targets. The primary issues that the permitting agencies are looking for is to ensure that the impacts have been minimized to the maximum extent practicable and that the benefits of the proposed project are clearly recognizable. It may be a prudent step to introduce permit agencies to proposed retrofits early on in the process, to avoid proceeding too far on a project that never had a chance of being permitted. Field visits are often the best way to get a general indication from regulators as to the permitability of a proposed project."

Step 9 Construction Inspection

Unforeseen conditions often occur on construction projects involving existing development. Existing utilities may not be fully identified, soil, groundwater conditions, shallow bedrock, and other factors may occur. Questions may arise as to the meaning of specifications in construction documents. Contractors may be tempted to substitute equivalent construction materials that will not function as well in this application as the material specified. Inspection during construction is necessary to efficiently resolve questions and ensure that the project has the greatest chance for success.

Step 10 - Maintenance Plan

Development and implementation of maintenance plan to ensure that the retrofits continue to operate for their expected life of twenty years.

Appendix F

Illicit Discharges and Illegal Dumping

Federal regulations require identification of categories of non-stormwater discharges that may be a low risk, requiring control only if identified as significant contributors of pollutants. Durham has identified several categories of non-stormwater discharges that are risk, requiring control only if identified as significant contributors of pollutants. These low risk discharges include springs, rising groundwater, uncontaminated pumped groundwater, foundation drains, air conditioner condensate, individual residential car washing, dechlorinated swimming pool discharges, and discharges from fire fighting activities.

Illicit discharges and illegal dumping can usually be tracked back to single discharge point, a single activity, or a single responsible party. It is usually easier and more cost-effective to control a single activity or discharge points than to control truly diffuse pollution. If a source must continue, it can be regulated through NPDES permitting. These non-stormwater discharges are point sources that just have not been identified because they are hidden among the diffuse, non-point sources that pollute stormwater runoff. These hidden point sources are a large part of urban stream impairment, and they must be addressed as quickly as possible so that we can evaluate the impact of the truly diffuse non-point source pollution in urban areas.

In 1996 the City of Durham's Stormwater Services Division began to develop and implement an active program to detect and eliminate significant non-stormwater discharges into either directly into receiving waters or indirectly via the stormwater system. The program includes four components:

- Tools and procedures to identify problems and priority areas
- Tools and procedures for tracing the source of an illicit discharge
- Procedures for removing the source of the discharge
- Procedures for program evaluation and effectiveness

A number of different methods have been used to assist staff in tracing the source of contamination, including evaluation of various maps, dye testing, field chemical tests, etc. The program continues to improve the tools and procedures used to detect and eliminate significant non-stormwater discharges, and the program continues to evolve.

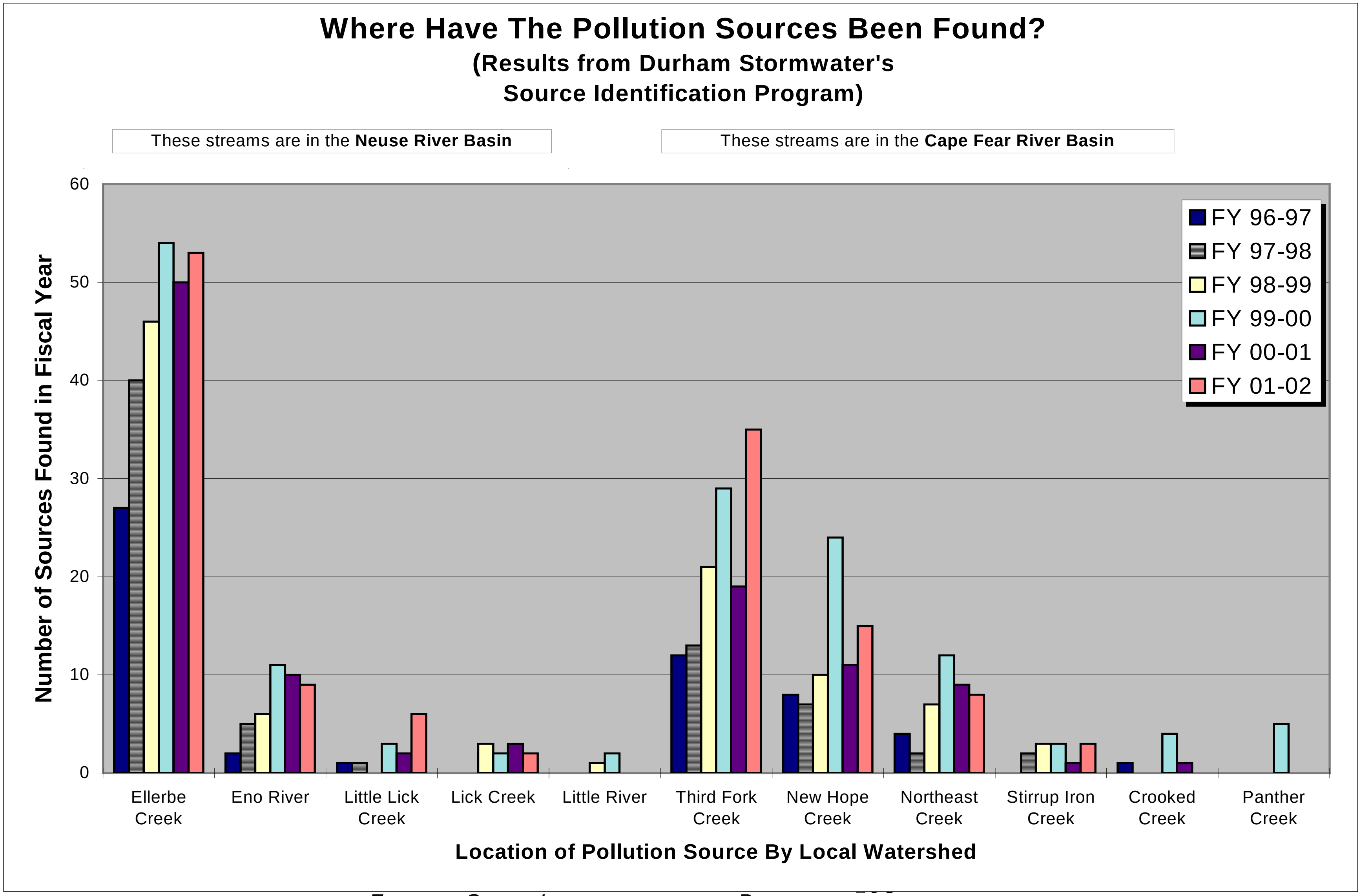
Initially, efforts at locating the source of contaminated flows used topography maps, utility maps, field investigations, field testing of water samples, laboratory testing of water samples, dye testing, and other techniques. Early on it was anticipated that the use of GIS would overcome the inefficiency of using several different maps usually at different scales. Databases were developed to be GIS "friendly." Inventory and mapping of the City's stormwater system was planned to include development of GIS tools for managing the maps and data. The program has modified the suite of analytical chemistry tests it can perform in the field to evaluate where water is likely to be contaminated, and continues to look methods that can improve sensitivity, increase accuracy, and reduce the time it takes to trace a source of pollution.

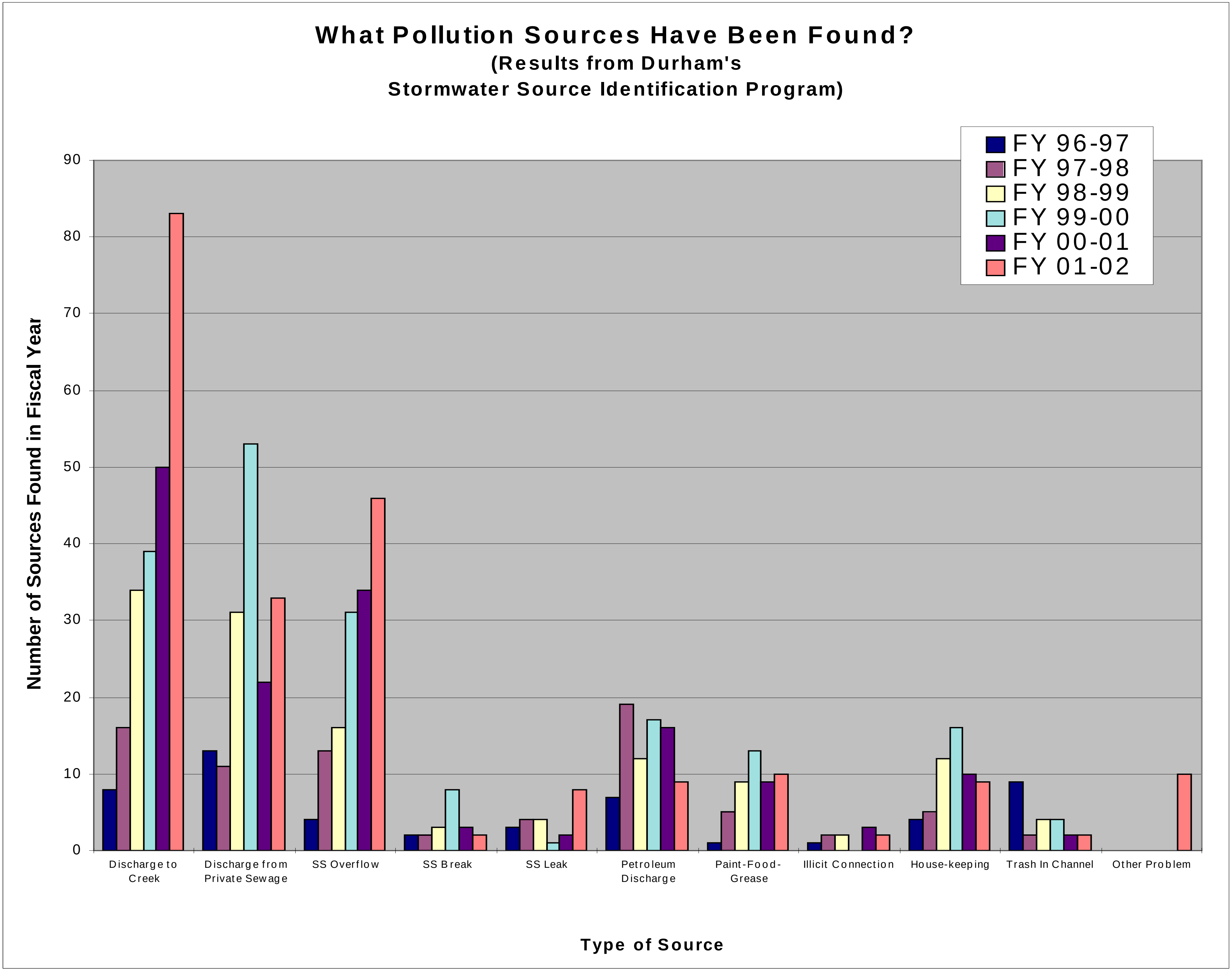
Highlights include:

- Establishment of a pollution reporting hotline in 1996
- Discovery that calls from citizens would increase briefly after each effort to publicize the hotline.
- Development of a highly responsive program to investigate potential sources of pollution.
- Completion of a program to inspection of more than 850 stormwater outfalls and test dry weather flows from those outfalls for pollution, conducted twice for each outfall.
- Updating of the City's 200 ft per inch scale topographic maps by the Engineering Division of Public Works.
- Establishment of several stream monitoring programs including what is referred to as *intensive stream monitoring* intended to work in a small watershed over a two month period and identify priority areas in which to screen for pollution sources.
- Establishment of a program to assist the Water and Sewer Maintenance Division to identify the extent of contamination from sanitary sewer overflows so that they can be more fully contained and polluted water pumped back into the collection system.
- Continuing development of GIS mapping layers by the City's Geographic Information Systems Division and Durham County, including land parcel ownership, streets, sanitary sewer schematic, etc.
- Ongoing inventory and mapping of the stormwater system; most of the inventory has now been completed, and the contractor is developing the maps.
- Ongoing mapping of potential sources of pollution within the City
- Training stormwater field investigators in the use of GIS mapping tools.
- Evaluation of alternative field screening methods, including alternative field chemistry tests and field instruments to increase sensitivity and improve speed of testing.
- Completion of 963 investigations over the six years of the program's existence.
- Staff handles a much larger number of investigations per year than earlier in the program, now averaging 197 per year for the last three years.
- Location of 615 sources or potential sources of pollution; 37% involved direct discharge to a stream. Elimination of these sources has resulted in a measurable improvement in water quality compared to the period 1993-96.

Tracking of sources by watershed shows the sources of pollution occur in the most developed areas with the highest population.

As the most developed watershed in Durham, Ellerbe Creek accounted for 44% of the sources (270) found during the last six years.




What Pollution Sources Have Been Found?
(Results from Durham's
Stormwater Source Identification Program)
FY 96-97
FY 97-98
FY 98-99
FY 99-00
FY 00-01
FY 01-02
Number of Sources Found in Fiscal Year
0
10
20
30
40
50
60
70
80
90
Discharge to Creek
Discharge from Private Sewage
SS Overflow
SS Break
SS Leak
Petroleum Discharge
Paint-Food-Grease
Illicit Connection
House-keeping
Trash In Channel
Other Problem
Type of Source

The sources found in Ellerbe Creek have included a house and a business each having its sewer lateral connected to the stormwater system rather than the sanitary sewer system. Other sources have included failing septic systems, clogged privately owned sewer laterals (often at apartment complexes), small leaks in sewer lines, petroleum spills, dumping of yard wastes, dumping of food wastes and cooking oils, etc.

Identification and elimination of these sources of pollution, some of which have persisted for decades, has resulted in improvements in water quality in the City's urban streams. In Ellerbe Creek, several monitoring locations show reductions in fecal coliform concentrations and increases in dissolved oxygen levels.

Results from the ongoing mapping its stormwater system are already helping staff to locate sources more efficiently, and the program continues to evolve and to become more efficient. Mapping of potential sources of pollution and of water drainage systems should improve efficiency. Development of additional tools for locating problem and priority areas and for tracing sources will improve the effectiveness of the program.

Some of the other findings and lessons learned are summarized below:

- The state of the art is advancing rapidly.
- Many non-stormwater discharges are intermittent, making them more difficult to locate.
- The easiest sources to find may also be some of the larger ones. After eliminating the larger sources, there are often many, many small sources.
- As easy-to-find sources are eliminated, it will be necessary to modify the tools, tactics and sophistication of the program in order to find intermittent or less obvious sources.
- Human sewage was involved in a large fraction of the sources found.[6] Privately owned sewage conveyance or treatment facilities (laterals, septic systems) were responsible for 163 of the sources, while a slightly larger number was associated with the publicly owned central sewer collection system: 144 central system overflows, 20 breaks and 22 leaks.
- A significant number of sources, 80, involved petroleum products, and 47 more involved food, cooking grease or paint. Poor housekeeping was found in 56 instances.
- Inspection and screening of 850 outfalls found a small number of difficult-to-locate sources of pollution, but 85% to 90% of the time and effort was spent on outfalls with no flow or standing water, and more than half of

[6] The relatively high frequency of sewage as a source is consistent with the Center for Watershed Protection's identification of three basis kinds of non-stormwater discharge sources: septic systems, central sewer systems, and "other." In fact "other" includes many different kinds of non-stormwater discharges, but individually none of them occur with great frequency.

those that had water showed no evidence of pollution. The efficiency of widespread screening was low for the effort expended.

- Mapping is an essential component of illicit discharge tracking. For efficient and effective illicit discharge control it is essential to have maps of streams, of the system of underground stormwater pipes, of ditches, swales, and the entire stream system including ephemeral, intermittent and perennial streams. It is also essential to have up-to-date topographic maps, as well as maps of the sanitary sewer system and other potential sources.
- Geographic Information Systems (GIS) can help overcome the inefficiency of using different maps usually at different scales.
- Databases for tracking water quality investigations and for storing stream-monitoring data should be developed to be GIS "friendly."
- The use of 50 acres as the size of watersheds to identify the 850 outfalls appears to be a reasonable compromise. However, if stream monitoring has identified likely presence of dry weather sources, more detailed sampling should be used.
- A few intermittent discharges were found as a result of sampling during a discharge - follow-up sampling to locate the source found no flow, and the sources were located only by dye testing all potential sources.
- Development and use of several different tools and techniques is likely to be required to locate all intermittent sources.
- Investigator knowledge and training is essential for success of this effort. Some illicit discharges take considerable persistence and methodical elimination of possibilities by well-trained investigators in order to locate the source.
- In looking for non-stormwater discharges, the indicators that are selected should be sufficiently sensitive and preferably somewhat selective; however, these same screening tests are also used in the process of tracing sources, often in a series of tests with the results on one set of tests dictating where the next set are collected, and the speed with which the test results can be obtained are as important as any other aspect of the test. Field tests that require 20 minute of longer reaction time should be avoided if possible.
- The six field test parameters required by EPA for screening dry weather flows and standing water at stormwater outfalls turned out to be less effective than ammonia, which City of Durham Stormwater Services added to its suite of tests in 1998. Ammonia has been the best single field test indicator of contaminated outfalls, failing septic systems, leaking sanitary sewers, and extent of contamination from sanitary sewer overflows. Ammonia is present in raw sewage and septic systems at 25 to 60 mg/l, and is rarely found in stormwater runoff or unpolluted streams at more

than 1 to 1.5 mg/l. Because ammonia undergoes transformations it is most useful relatively near the source (i.e. near in time and/or space)

- Ammonia and the other nitrogen species are generally poor indicators in stream sampling because nitrogen undergoes reversible transformations (nitrification, denitrification, ammonification) as well as dilution and complex interactions with stream sediments.
- Ammonia is useful in screening for the extent of contamination from a sanitary sewer overflow and has been shown to be much more sensitive than color, turbidity and odor.
- Multi-parameter instruments are expensive and difficult to maintain in comparison to well-selected instruments that target one of a few closely related parameters.
- The first generation of instruments and/or sensors for measuring ammonia do not have sufficient sensitivity and require too frequent calibration to be useful.
- Stream monitoring for fecal coliform bacteria is a cost cost-effective method for identifying priority areas in which to find illicit discharges. It is necessary to collect a number of samples over a period of time in order to be able to statistically identify priority areas because of the large variability in any single sample and because of the variability introduced by intermittent discharges.
- Active efforts to find illicit discharges through outfall inspection and stream monitoring generally find a small number of sources, but these sources tend to be larger or more persistent and therefore have a large impact on water quality.
- Reactive efforts to find illicit discharges through public involvement tend to find a very large number of sources, that tend to be smaller and that may be otherwise difficult to find. Pursuing these sources often represents an excellent opportunity to educate the public regarding the impact of their activities.
- Involving the public has been a very successful strategy, complementing active efforts.
- It is necessary to conduct periodic campaigns to publicize the hotline in order to maintain high levels of public involvement in the process of finding and eliminating sources of pollution.

Appendix G

The City of Durham's Stream Monitoring Plan

Biological Monitoring

Benthic macroinvertebrate ratings are based on the ability of waterways to support aquatic life. This is the bottom-line view for legislative concerns. Biologists prefer the five-step classification (Excellent, Good, Good-Fair, Fair, and Poor), because this classification can be more precise in tracking trends in upgrading or downgrading stream quality. A Fair rating is partially supporting and anything below Fair is "impaired". An impaired site, which scores a Fair or Poor rating, should be closely monitored. Unfortunately for legislators, the support vs. non-support view can lead to under-rating or over-rating stream health. Described below is a brief summary of the City of Durham Stormwater Services' benthic monitoring program.

Benthic macroinvertebrate samples are collected between June and September. Our monitoring consists of annual summer samples and biennial winter samples. It should be kept in mind that many of Durham's sampling locations are in an urban setting and not large magnitude streams (2nd and 3rd order streams). The City of Durham currently has 15 benthic macroinvertebrate monitoring stations, four of which are reference locations. We currently monitor the two river basins located in Durham, the Cape Fear River and Neuse River Basins. In addition, we have broken down these two basins into 13 subwatersheds in the City of Durham, seven of which are monitored for benthic macroinvertebrates. Due to expanding City annexation and land use changes, three subwatersheds need to be added. Lick and Panther Creek subwatersheds will need to have two new benthological monitoring stations each. Data has been collected since 1998, although full-scale identification work was not introduced until 1999.

The additional proposed sites are a direct result of the newly acquired information published by NCDWQ and our longstanding practice of a proactive philosophy. When speaking with NCDWQ, they were very interested in seeing our monitoring program grow and have requested that we further our program by obtaining a Laboratory Identification Certification and adding these new stations, as the state is very enthusiastic about our data for their utilization. We will get their final approval on newly proposed sites, so that our data will be the most significant for comparison. Laboratory ID Certification is slated for the 2003 fiscal year.

Durham's biological (benthic) monitoring stations are located at the same stations used by NCDWQ for their basin-wide assessments, and are also upstream and downstream of some of their sampling stations. Currently the City of Durham and NCDWQ share benthic monitoring stations in the Neuse River

Basin. The data we collect therefore reflects a potentially more detailed picture of the health of benthic communities than NCDWQ's, because of our ability to provide more intensive monitoring. Our biological monitoring stations are also evaluated for habitat, pebble-count, and chemical parameters.

According to NCDWQ standards, the 3rd order streams and greater in the Piedmont Region of NC must have a value of 8+ EPT Taxa Richness (at least eight different EPT species per Qual 5 Sample), and a Biotic Index Value of <7.48 per 10-sample Qualitative Sample, to be considered as supporting or partially supporting aquatic life. EPT's are three highly sensitive Orders of aquatic insects (Ephemeroptera – mayflies, Plecoptera – stoneflies, and Trichoptera – caddisflies).

The Qualitative 5 Sample Procedure (DENR, DWQ, 2001), used in Durham and by North Carolina Division of Water Quality (NCDWQ), includes 10 composite samples: consisting of two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leaf pack sample, and visual collections from microhabitats not already sampled (i.e., picking from large rocks and logs). Organisms are assigned abundance values depending on how many of those taxa are collected: Rare (1-2 specimens) = 1, Common (3-9) = 3, and Abundant (10-10+) = 10. Organisms are also assigned tolerance values by NCDWQ according to their sensitivity to pollution (0 = most sensitive, 10 = most tolerant). See Table F2 for a complete list of aquatic invertebrates found in Ellerbe Creek by the City of Durham's Stormwater Services and Table F3 for the Fishes found in Ellerbe Creek at the end of this section.

North Carolina Biotic Index = [Sum of (Tolerance Value of each unit) multiplied by (Abundance Value of each unit)] divided by the [Sum of all units' Abundance Values]. A unit is an individual taxon (i.e., *Stenonema modestum*). The NC Biotic Index and EPT Taxa Richness Index are then averaged to provide an overall biotic stream classification. In the event of a bioclassification conflict between the EPT Rating and the Biotic Index Rating, the EPT Rating is used for the final site rating (rounding up or down for the final rating).

According to Stormwater Services biological monitoring analysis, all the streams in Ellerbe Creek watershed are either partially supporting (Fair) or not supporting (Poor) aquatic life.

Chemical Monitoring

As an initial assessment of the Ellerbe Creek watershed, 25 sites were monitored as part of an intensive monitoring phase. This consisted of each site being tested once a month for a three-month period. There are seven sites that are part of the ambient monitoring program. These sites are sampled once every three months.

Intensive monitoring utilizes the following standard field parameters: DO (%), DO (mg/L), temperature, specific conductivity (SC), pH and turbidity. A portable YSI 95 dissolved oxygen meter is used for DO (%), DO (mg/L) and temperature. Oakton waterproof field pens are used for measuring pH, and SC. Turbidity is measured using a 2100P Hach Turbidimeter. Field conditions are also noted concerning the water level, abnormal appearance to the water, and if any rainfall had been recorded before the sampling event. Intensive monitoring locations were tested using the field parameters listed and fecal coliform bacteria. Field parameters are collected at ambient monitoring locations and through laboratory testing are analyzed for: copper (total and dissolved), zinc (dissolved), TSS, BOD, TKN, NO2 + NO3, total ammonia, total organic nitrogen, total phosphorus, dissolved phosphorus, titrated hardness, fecal coliform, and fecal streptococcus.

As part of the Ellerbe Creek Watershed plan, the City of Durham would like to expand our stream monitoring efforts within this subwatershed. In addition to four new benthic monitoring locations, there would be an increase in the number of ambient stream monitoring locations. There would be an additional 11 ambient locations and three fecal coliform only added to the existing seven locations. Some of these locations are sites that were part of the intensive monitoring program. Two of the newly proposed stations, located on Panther Creek, have not previously been monitored. Samples would be collected every third month to give a synoptic view of the streams' water quality. At the time of sample collection field measurements would be taken along with samples for laboratory analysis. Certain ambient stations will be located at the same sites where benthic monitoring is to be done. This will allow us to track the causes of any changes in the benthic community.

Our laboratory is only able to process a limited volume of ambient samples per sampling event. Keeping this in mind, certain locations will be monitored for fecal coliform bacteria only. These locations are at points on the creek that allow another station downstream to be monitored for ambient parameters to ensure that nothing is missed.

Table G1 illustrates which sites have been designated for ambient, benthic or fecal only sampling. The column labeled current / proposed shows which locations will be additional locations to those that are already being sampled. Several sites will be monitored for more than one parameter.

Table G-1: List of Sampling Locations for Monitoring in Ellerbe Creek Watershed

Map Number	Site Name	Ambient	Benthic	Fecal Only	Current/Proposed Sampling Site
1	EL11.4EC	X	X		P
2	EL10.7EC			X	P
3	EL10.7ECUT	X			C / P
4	EL9.5EC	X			P
5	EL8.2EC		X	X	P
6	EL7.9EC	X	X		C
7	EL8.5SEC			X	C
8	EL7.6SECT	X			C
9	EL7.3SEC	X			P
10	EL5.6EC		X	X	C / P
11	EL8.1GC	X			P
12	EL7.5GC	X			P
13	EL6.9GCTA	X			P
14	EL6.9GCUT	X			P
15	EL5.5GC	X	X		C
16	EL5.6GCUT	X			P
17	EL5.0EC	X			C
18	EL4.1EC				P*
19	EL1.9EC	X	X		C
20	EL1.8ECUT	X			P
21	PA2.8PC	X	X		P
22	PA0.7FLT	X	X		P

Due to accessibility, this site will not be sampled at the start of this project. Our hope is that in the near future this site will be accessible, via a newly proposed road, and data will be collected.

In an effort to track the watersheds' quality consistently it will be advantageous to place a continuous monitoring location at a downstream point, such as EL1.9EC. The station would be able to record such data as flow rate, pH, dissolved oxygen (mg/L and %), temperature and conductivity. Flow level markers will be placed within the watershed at key locations to assess flow levels during dry periods and at the time of rain events. Composite samples will be collected at this location over the course of a rain event and taken to the lab for analysis.

Ambient monitoring locations will be collected during what is classified as a dry period, which is indicative of less than 0.1 inch of rainfall within a 24-hour period before samples are collected. To be able to show comparative data, EL1.9EC would be collected as an ambient site, as well as used for our continuous monitoring location. This site will also have a composite sample collected during a rain event to show the differences in concentrations from stormwater runoff.

Table G-2: List of Aquatic Invertebrates Collected in Ellerbe Creek Watershed by Durham Stormwater Services

List of Aquatic Invertebrates Collected In Ellerbe Creek by the City of Durham Stormwater Services From 1999 - 2002				
Order	**Family**	**Genus**	**Species**	**Tolerance Value**
Coleoptera	Dryopidae	Helichus	Helichus spp.	4.63
Coleoptera	Dytiscidae	Dytiscus	Dytiscus spp.	99*
Coleoptera	Dytiscidae	Laccophilus	Laccophilus spp.	10.00
Coleoptera	Dytiscidae	Neoporus	Neoporus spp.	8.62
Coleoptera	Elmidae	Ancyronyx	A. variegatus	6.49
Coleoptera	Elmidae	Stenelmis	Stenelmis spp.	5.10
Coleoptera	Hydrophilidae	Berosus	Berosus spp.	8.43
Coleoptera	Hydrophilidae	Enochrus	Enochrus spp.	8.75
Coleoptera	Hydrophilidae	Hydrochus	Hydrochus spp.	6.55
Coleoptera	Hydrophilidae	Tropisternus	Tropisternus spp.	9.68
Coleoptera	Noteridae	Hydrocanthus	Hydrocanthus spp.	7.14
Coleoptera	Staphylinidae	--	--	99*
Crustacea	Palaemonidae	Palaemonetes	P. paludosus	7.07
Diptera	Chironominae	Chironomus	Chironomus spp.	9.63
Diptera	Chironominae	Cryptochironomus	Cryptochironomus spp.	6.40
Diptera	Chironominae	Dicrotendipes	D. modestus	8.73
Diptera	Chironominae	Dicrotendipes	D. neomodestus	8.10
Diptera	Chironominae	Dicrotendipes	D. nervosus	9.76
Diptera	Chironominae	Dicrotendipes	D. simpsoni	9.95
Diptera	Chironominae	Microtendipes	Microtendipes spp.	5.53
Diptera	Chironominae	Polypedilum	P. aviceps	3.65
Diptera	Chironominae	Polypedilum	P. flavum	4.93
Diptera	Chironominae	Polypedilum	P. halterale grp.	7.31
Diptera	Chironominae	Polypedilum	P. illinoense	9.00
Diptera	Chironominae	Polypedilum	P. scalaenum	8.40
Diptera	Chironominae	Rheotanytarsus	Rheotanytarsus spp.	5.89
Diptera	Chironominae	Stenochironomus	Stenochironomus spp.	6.45
Diptera	Chironominae	Tanytarsus	Tanytarsus spp.	6.76
Diptera	Orthocladiinae	Cricotopus	C. triannulatus/sp. 5	9.04
Diptera	Orthocladiinae	Orthocladius	Orthocladius sp. 3	9.11

Order	Family	Genus	Species	Tolerance Value
Diptera	Orthocladiinae	Cricotopus	C. annulator	7.62
Diptera	Orthocladiinae	Cricotopus	C. patens	99*
Diptera	Orthocladiinae	Orthocladius	Orthocladius sp. 3	9.11
Diptera	Orthocladiinae	Rheocricotopus	R. robacki	7.28
Diptera	Orthocladiinae	Rheocricotopus	Rheocricotopus spp.	7.30
Diptera	Orthocladiinae	Thienemanniella	Thienemanniella spp.	5.86
Diptera	Ptychopteridae	Bittacomorpha	Bittacomorpha spp.	99*
Diptera	Simulidae	Simulium	S. venustrum	7.06
Diptera	Simulidae	Simulium	Simulium spp.	6.00
Diptera	Tanypodinae	Ablabesmyia	A. mallochi	7.19
Diptera	Tanypodinae	Clinotanypus	C. pinguis	8.74
Diptera	Tanypodinae	Conchapelopia	Conchapelopia grp.	8.42
Diptera	Tanypodinae	Natarsia	Natarsia spp.	9.95
Diptera	Tanypodinae	Procladius	Procladius spp.	9.10
Diptera	Tipulidae	Tipula	Tipula spp	7.33
Ephemeroptera	Baetidae	Baetis	B. flavistriga	6.58
Ephemeroptera	Baetidae	Baetis	B. intercalaris	4.99
Ephemeroptera	Baetidae	Baetis	Baetis spp.	99*
Ephemeroptera	Caenidae	Caenis	Caenis spp.	7.41
Ephemeroptera	Heptageniidae	Stenonema	S. modestum	5.50
Ephemeroptera	Tricorythidae	Tricorythodes	Tricorythodes spp.	5.06
Gastropoda	Physidae	Physella	Physella spp.	8.84
Gastropoda	Planorbidae	Helisoma	H. anceps	6.23
Hemiptera	Belostomatidae	Belostoma	Belostoma spp.	9.80
Hemiptera	Corixidae	--	--	9.00
Hemiptera	Nepidae	Ranatra	Ranatra spp.	7.82
Megaloptera	Corydalidae	Chauloides	C. rastricornis	8.42
Megaloptera	Corydalidae	Corydalus	C. cornutus	5.16
Odonata	Aeshnidae	Basiaeschna	B. janata	7.35
Odonata	Aeshnidae	Boyeria	B. vinosa	5.89
Odonata	Calopterygidae	Calopteryx	Calopteryx spp.	7.78
Odonata	Coenagrionidae	Argia	A. sedula	8.46

Order	Family	Genus	Species	Tolerance Value
Odonata	Coenagrionidae	Argia	Argia spp.	8.17
Odonata	Coenagrionidae	Enallagma	Enallagma spp.	8.91
Odonata	Coenagrionidae	Ischnura	I. posita	9.52
Odonata	Corduliidae	Epicordulia	E. princeps	5.60
Odonata	Corduliidae	Somatochlora	Somatochlora spp.	9.15
Odonata	Corduliidae	Tetragoneuria	T. cynosura	8.57
Odonata	Gomphidae	Progomphus	P. obscurus	8.22
Odonata	Gomphidae	Stylogomphus	S. albistylus	4.72
Odonata	Libellulidae	Erythemis	E. simplicicollis	9.72
Odonata	Libellulidae	Libellula	Libellula spp.	9.64
Odonata	Libellulidae	Perithemis	P. tenera	9.85
Odonata	Libellulidae	Sympetrum	Sympetrum spp.	7.29
Pelecypoda	Corbiculidae	Corbicula	C. fluminea	6.10
Plecoptera	Perlidae	Acroneuria	A. abnormis	2.06
Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche spp.	6.22
Trichoptera	Hydropsychidae	Hydropsyche	H. betteni	7.78
Trichoptera	Hydroptilidae	--	--	99*

Tolerance Values were assigned by NCDWQ Bioassessment Unit
Tolerance Value ranges from 0 to 10 – 0 is the most sensitive, 10 is the most tolerant to pollution
* A 99 Tolerance Value has no actual value, because this organism was collected too rarely to assign a value

Table G-3 List of Fishes of the Ellerbe Creek Watershed and Tolerance Rankings

Taken from Ed Menhick's book, Freshwater Fishes of NC (1991), and Chad Hallyburton's unpublished report for the Ellerbe Creek Watershed Association, *Ellerbe Creek Survey of Fishes* (2000). Tolerance Rankings were taken from NCDWQ Bioassessment Unit's Website.

Family	Species	Tolerance Ranking	Common Name
LEPISOSTEIDAE	*Lepisosteus oseus*	Tolerant	Longnose Gar
AMIIDAE	*Amia calva*	Tolerant	Bowfin
CLUPEIDAE	*Dorosoma cepedianum*	Intermediate	Gizzard Shad
CYPRINIDAE	*Cyprinus carpio*	Tolerant	Common Carp*
CYPRINIDAE	*Netemigonus crysoleucas*	Tolerant	Golden Shiner
CYPRINIDAE	*Nocomis leptocephalus*	Intermediate	Bluehead Chub
CYPRINIDAE	*Nocomis raynei*	Intermediate	Bull Chub
CYPRINIDAE	*Cyprinella analostana*	Tolerant	Satinfin Shiner
CYPRINIDAE	*Notropis hudsonius*	Intermediate	Spottail Shiner
CYPRINIDAE	*Notropis procne*	Intermediate	Swallowtail Shiner
CYPRINIDAE	*Luxilus albeolus*	Intermediate	White Shiner
CYPRINIDAE	*Notropis photogenis*	**Intolerant**	Silver Shiner
CYPRINIDAE	*Notropis amoenus*	Intermediate	Comely Shiner
CYPRINIDAE	*Lythrurus matutinus*	**Intolerant**	Pinewoods Shiner
CYPRINIDAE	*Pimephales promelas*	Tolerant	Fathead Minnow*
CYPRINIDAE	*Semotilus atromaculatus*	Tolerant	Creek Chub
CATASTOMIDAE	*Erimyzon oblongus*	Intermediate	Creek Chubsucker
CATASTOMIDAE	*Moxostoma anisurum*	Intermediate	Silver Redhorse
ICTALURIDAE	*Ictalurus punctatus*	Intermediate	Channel Catfish*
ICTALURIDAE	*Ameiurus catus*	Tolerant	White Catfish
ICTALURIDAE	*Ameiurus natalis*	Tolerant	Yellow Bullhead
ICTALURIDAE	*Ameiurus nebulosus*	Tolerant	Brown Bullhead
ICTALURIDAE	*Noturus insignis*	Intermediate	Margined Madtom
FUNULIDAE	*Fundulus rathbuni*	Intermediate	Speckled Killifish
POECILIIDAE	*Gambusia holbrooki*	Tolerant	Eastern Mosquitofish
MORONIDAE	*Morone americana*	Intermediate	White Perch*
CENTARCHIDAE	*Centrarchus macropterus*	Intermediate	Flier
CENTARCHIDAE	*Lepomis marginatus*	Intermediate	Dollar Sunfish
CENTARCHIDAE	*Lepomis cyanellus*	Tolerant	Green Sunfish*
CENTARCHIDAE	*Lepomis auritus*	Tolerant	Redbreast Sunfish
CENTARCHIDAE	*Lepomis gulosus*	Intermediate	Warmouth
CENTARCHIDAE	*Lepomis macrochirus*	Intermediate	Bluegill*
CENTARCHIDAE	*Lepomis gibbosus*	Intermediate	Pumpkinseed
CENTARCHIDAE	*Micropterus salmoides*	Intermediate	Largemouth Bass*
CENTARCHIDAE	*Pomoxis nigromaculatus*	Intermediate	Black Crappie
PERCIDAE	*Perca flavescens*	Intermediate	Yellow Perch*
PERCIDAE	*Etheostoma vitreum*	Intermediate	Glassy Darter

- Denotes non-native species

Appendix H

Ellerbe Creek Cultural History

Ellerbe Creek is a small, predominately urban watershed located within the upper Neuse River Basin in Durham County, North Carolina. Its headwaters and half of its 23,526-acre watershed are located within Durham's city limits. Approximately 47,540 people currently reside within the Ellerbe Creek watershed, and based on current population trends, this number will increase to 58,000 by 2020 (Ellerbe Creek Watershed Association). Land use within the watershed is a mixture of medium to high-density residential and commercial development. Outside of the city the Ellerbe Creek watershed is dominated by bottomland hardwood forests and loblolly pine forests, with a limited amount of agricultural activity. In all, over 60 % of the watershed is comprised of potentially polluting urban and agricultural land uses – over 20 % of the watershed is currently impervious.

Ellerbe Creek bubbles up just west of Cole Mill Road and flows through what was mostly forest and farmlands to Falls Lake. From there, the Neuse River begins its journey past Raleigh, Smithfield, Goldsboro, Kinston, New Bern, Pamlico Sound and into the Atlantic Ocean.

The history of these creeks is as colorful as its names. A transcript from a 1737 surveyor's journal called South Ellerbe Creek "Deep Creek." Before 1752, when this territory was still part of Granville County, Ellerbe Creek was called "South Eno." In the late 18th century, South Ellerbe Creek was called "Watery Branch." The course of South Ellerbe and Ellerbe follows the history of Durham itself. South Ellerbe was more Blue collar in its origins while Ellerbe held more middle class origins. All these creeks flow through some of the Bull City's most historic urban neighborhoods.

Old West Durham was built for workers in the textile mills; Walltown for workers in the tobacco industry, Watts-Hillandale for shop owners and doctors and, Trinity Park for merchants and teachers at the new college that would eventually changed its name to Duke University.

Ellerbe Creek begins its path through the Hillandale Golf Course and the neighborhood of Watts-Hospital-Hillandale. When Watts Hospital was moved to Broad Street from Trinity Park, many doctors and merchants built their homes along West Club Boulevard (beginning around 1908).

Ellerbe then flows through areas that were farms until the 1950s. Ranch houses now stand in what was a large green belt separating Durham and Bragtown. The creek flows through Northgate Park and continues past the Avondale Road K-Mart, Camden Avenue asphalt plant and the old City dump. Ellerbe's last miles are its most serene as it flows along a quiet stretch of bent trees and into

Falls Lake at an old wooden railroad bridge (less than a mile south of where the Eno River flows into the lake).

Numerous grist mills along its banks have disappeared from the records. Over by the City dump, Ellerbe Creek was channelized, choked with industrial effluent and leachate (which a writer has called "garbage juice"). At the turn of the last century, the local wags were already calling it “Allergy Creek.”

South Ellerbe’s headwaters rise next to what was once the settlement of Pinhook, which served as a traveler's rest on the dirt road between the colonial capital of Hillsborough and the new state capital of Raleigh. Beginning near Greystone Baptist on Hillsborough Road, South Ellerbe Creek flows for three miles through some of Durham's oldest and most densely developed neighborhoods.

Today, the first mile of the creek is surrounded by various auto and muffler shops, large surface parking lots, a plumbing shop, funeral home, photo studio, small apartment complex, the Southern Railroad, Highway 70/Business, a Duke warehouse, an old gas station, and a number of quiet back yards. Its path will take it past three schools: EK Powe Elementary, Brogden Middle and Club Boulevard Elementary.

In 1892, the Rigsbee family sold a northern stretch of its farm to make room for the Erwin Mills and some of the surrounding mill village near Ninth Street. Also in 1892, Trinity College moved next door – to Blackwell's Fairgrounds (eventually becoming Duke's East Campus).

25 years later, the rest of the Rigsbee farm was sold and became Duke's West Campus. Many of the Italian stonecutters who built Duke Chapel and the hospital lived near South Ellerbe. Duke's football stadium was built in the ravine where the Rigsbee's kept their pigs (site of the 1942 Rose Bowl, moved to Durham after Pearl Harbor).

Crossing the northern edge of the old Erwin Cotton Mills, South Ellerbe Creek was channelized and used to dump warm dyes from the mills. At the dawn of the new millennium, many of the mill families still in Old West Durham simply call it the “ditch.”

Long-time residents of the mill village recall that a sawmill was placed in the middle of the woods to cut the planks to build the first mill houses -- along the creek. In the early days, the entire neighborhood smelled like a Laundromat -- from the hot, soapy water being discharged by the textile mills into South Ellerbe.

Hall of Fame and Grammy-award winning composer John D. Loudermilk (who wrote 'Tobacco Road') grew up on the banks of South Ellerbe. During the Prohibition, a house on Virgie Street was one of the most popular destinations in all of West Durham. In the back yard were two doors. One was prominent and led nowhere. A second was small and mostly hidden. Visitors would pass through the smaller door to enter a large room filled with floor-to-ceiling cabinets -- each with a small padlock. Inside the private cabinets was a collection of favorite spirits.

According to long-time residents, White Lightning was the brew of choice. Consumption only allowed off-site. One resident recalls a scandalous morning in the 1930swhen a body was found in South Ellerbe Creek across the street. This scared the neighborhood kids half to death. Turns out he was fine -- just an avid consumer of local moonshine. Today, this area forms the heart of the National Registry Historic District in Old West Durham and the proposed site for an urban green space.

In the late 1880s, a young African-American man named George Wall followed his job with Trinity College to Durham. Wall bought a wooded plot of land just north of what is now East Campus. Walltown became a neighborhood for workers moving into the Bull City for the growing tobacco industry. The narrow shotgun houses and small residences provided easy access to the tobacco factories. The east-west streets were numbered and the north-south streets were lettered (which explains why Ninth Street is called Ninth Street).

From Walltown, South Ellerbe Creek flows under Guess Road; the massive surface parking lots at Northgate Mall, and Interstate 85. According to the Durham Architectural and Historic Inventory, rapid growth during the 1950s transformed the forests and farmlands into neighborhoods like Northgate Park.

Another branch of South Ellerbe flows north from downtown through Trinity Park -- joining its sister streams near West Club Blvd Elementary. Although many of Trinity Park's early settlers were connected with Trinity College (now Duke); the majority were merchants, businessmen and professionals.

In contrast to Durham's late 19th-centuryneighborhoods, a smaller proportion of Trinity Park's residents were directly associated with tobacco and textiles. They were part of the broader local economy produced by their families' successes in Durham's leading industries. These younger generations chose not to live in the older neighborhoods where they grew up close to Durham's industries.

Standing along this branch of South Ellerbe are the Durham Athletic Park (South Ellerbe flows under the pitcher's mound), Durham Central Park (bisected by the creek) and the South Ellerbe bike trail (which will eventually become part of the “urban AppalachianTrail” – a bike path connecting towns from Maine to Florida).

Along some wooded stretches, these streams quietly flow through areas as scenic as any in North Carolina. Elsewhere, the Ellerbe watershed deserves its status among state’s most polluted creeks. Flowing past history and through Durham's neighborhoods, Ellerbe's creeks absorb the city's ills as the waters run to the sea.