# TREES TO OFFSET STORMWATER

## Case Study 03: Wilmington, North Carolina

July 2018

*Cover photo by City of Wilmington.*
*All other images in the report are by the City of Wilmington and by the Green Infrastructure Center Inc. (GIC).*

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# Project Overview

This project, called Trees to Offset Water, is a study of Wilmington's forest canopy and the role that trees play in up taking, storing and releasing water. This study was undertaken to assist Wilmington in evaluating how to better integrate trees into their stormwater management programs. More specifically, the study covers the role that trees play in stormwater management and shows ways in which the city can benefit from tree conservation and replanting. It also evaluated ways for the city to improve forest management as the city develops.

## PROJECT FUNDERS AND PARTNERS

This is a pilot project for a new approach to estimate the role of trees in stormwater uptake. North Carolina is one of six southern states that received funding from the USDA Forest Service to study how trees can be utilized to meet municipal goals for stormwater management. The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of North Carolina, South Carolina, Virginia, Alabama, Georgia and Florida. The NC Forest Service administered the pilot studies in North Carolina. Wilmington was selected to be one of the two test cases in North Carolina for the project. The other municipality selected was Apex, North Carolina.

The GIC created the data and analysis for the project. The project was spurred by the on-going decline in forest cover throughout the southern United States. Causes for this decline arise from multiple sources including land conversion for development, storm damages and lack of tree replacement as older trees die. Many localities have not evaluated their current tree canopy, which makes it difficult to track trends, assess losses or set goals to retain or restore canopy. As a result of this project, Wilmington now has baseline data against which to monitor canopy protection progress, measures of the stormwater and water quality benefits of its urban forest, as well as to prioritize restoration of canopy where it is needed.

*A redeveloping downtown welcomes walkers with beautiful landscapes.*

## OUTCOMES

This report includes those findings and recommendations that are based on tree canopy cover mapping and analysis, the modeling of stormwater uptake by trees, a review of relevant city codes and ordinances, and citizen input and recommendations for the future of Wilmington. More specifically, the following deliverables were included in the pilot study:

- Analysis of the current extent of the urban forest through high resolution tree canopy mapping,
- Possible Planting Area analysis to determine where additional trees could be planted,
- A method to calculate stormwater uptake by the city's tree canopy,
- A review of existing codes, ordinances, guidance documents, programs and staff capabilities related to trees and stormwater management, and recommendations for improvement,
- Two community meetings to provide outreach and education,
- Presentation of the results of the pilot studies as a case study at the National Partners In Community Forestry Conference, and
- A case booklet and PowerPoint presentation detailing the pilot study methodology, as well as lessons learned and best practices.

The project began in September 2016 and Wilmington staff members have participated in project review, analysis and evaluation. The following city divisions were involved in the project planning and review as the Technical Review Committee (TRC): Community Services, Parks and Urban Forestry; Public Services, Stormwater Division, and GIS; Planning, Development, and Transportation; and Engineering.

*Trees are central to the city's character.*

## COMMUNITY ENGAGEMENT

Two community meetings were held. The first meeting held in July 2017 provided an overview of the project and an opportunity to gather community input and concerns regarding tree conservation and to review the maps of canopy cover. The second meeting held in November 2017 provided recommendations (listed below) for the city and elicited feedback. All individual comments from both meetings were provided to the city.

Residents offered specific requests for where to plant trees, as well as requesting advice for how to properly plant and nurture street trees to maximize survivability. Residents emphasized the importance of planting native trees, focusing on saving existing large trees during development, more education for citizens about tree care, beginning a regular citywide tree maintenance schedule, having an adopt-a-tree program, citizen tree mapping, increasing tree removal fines, quantifying benefits of significant trees such as the 'Sonic Oak,' shading bus stops with trees and much more. There was both concern for tree loss from new development and for tree protection and replacement, which were considered central to the small city character and historic identity of Wilmington.

Community members were presented with seven specific code/ordinance or practice changes which GIC recommended to the City of Wilmington. Meeting attendees were asked to choose the top three changes they felt would most benefit the urban forest. The policy or code changes are listed below in priority order (most to least popular).

- Increase the urban forestry management budget.
- Assign a GIS person (mapping) to Parks/Forestry.
- Maintain canopy (48.2 percent in the historic district and 50% in the city).
- Increase enforcement staff to fulfill ordinance.
- Require tree risk assessments of public trees.
- Allow credit for tree planting to reduce stormwater utility fee.
- Allow/install roadside bioswales with trees.
- Develop an emergency plan to replant trees after storms.



**Wilmington can use this report and its associated products to:**

- *Set goals and develop a management plan for retaining or expanding its tree canopy by watershed.*
- *Improve management practices so trees will be well-planted and well-managed.*
- *Educate developers about the importance of tree retention and replacement.*
- *Motivate private landowners (residential, commercial, and institutional) to protect their trees.*
- *Support grant applications for tree conservation projects.*

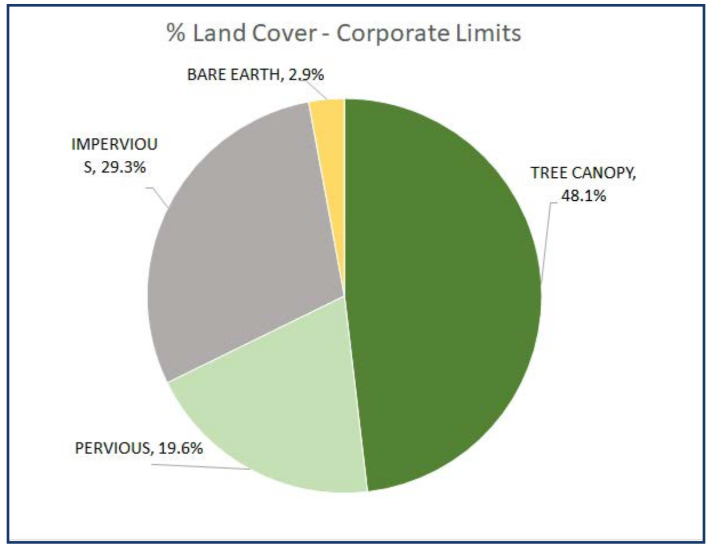
## Summary of Findings

Satellite imagery was used to classify the types of land cover in Wilmington (for more on methods see page 18). This shows the city those areas with vegetative cover that allow for the uptake of water and those that are impervious and more likely to have stormwater runoff. High-resolution tree canopy mapping provides a baseline of tree canopy cover that is used to assess current tree cover and to evaluate future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS shape files produced during the study was provided to Wilmington for its future use.

*One mature tree can absorb thousands of gallons of water per year. Citywide forest cover is 48 percent.*

The goal of this study was to identify ways in which water entering the city's municipal separate storm sewer system (MS4) could be reduced by using trees. Tree canopy serves as green infrastructure that can provide more capacity for the city to support grey infrastructure (i.e. stormwater drainage systems). It also can be used to show how the city can reduce potential pollution of its surface waters, which can have an impact on Total Maximum Daily Load (TMDL) requirements and Basin Management Action Plans (BMAPs).

This project created a detailed land cover analysis to evaluate how much water is taken up by the city's trees in various scenarios. This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed. Tree canopy was found to be 48.1 percent. While this is a high number for an urban landscape, canopy coverage is much less in the downtown districts.




*City tree canopy is 48 percent.*

*During an average high volume rainfall event in Wilmington (a 10-year storm), over 24 hours the town's trees take up an average of **240 million gallons of water**.*

***That's 363 Olympic swimming pools of water!***

## Wilmington: Fast Facts & Key Stats

- County: New Hanover
- Port town in southeastern North Carolina.
- 2017 Census Population Estimate: **117,525** People

City Area

- Total area: **52.81** sq. mi.
- Land: **49.51** sq. mi
- Water: **1.58** sq. mi.

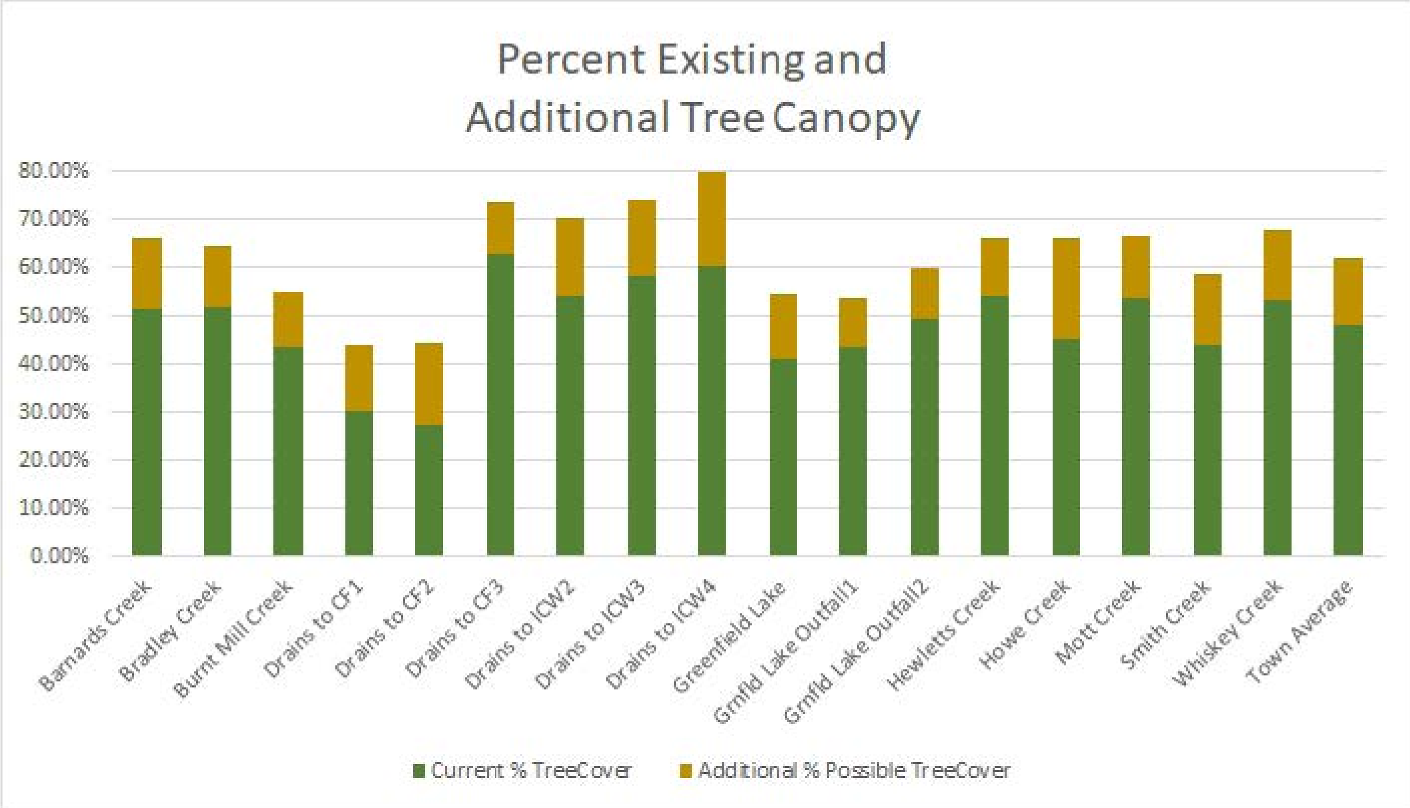
Natural Resources

Major Drainage Basins:
Cape Fear River and drainage directly to the Atlantic Ocean

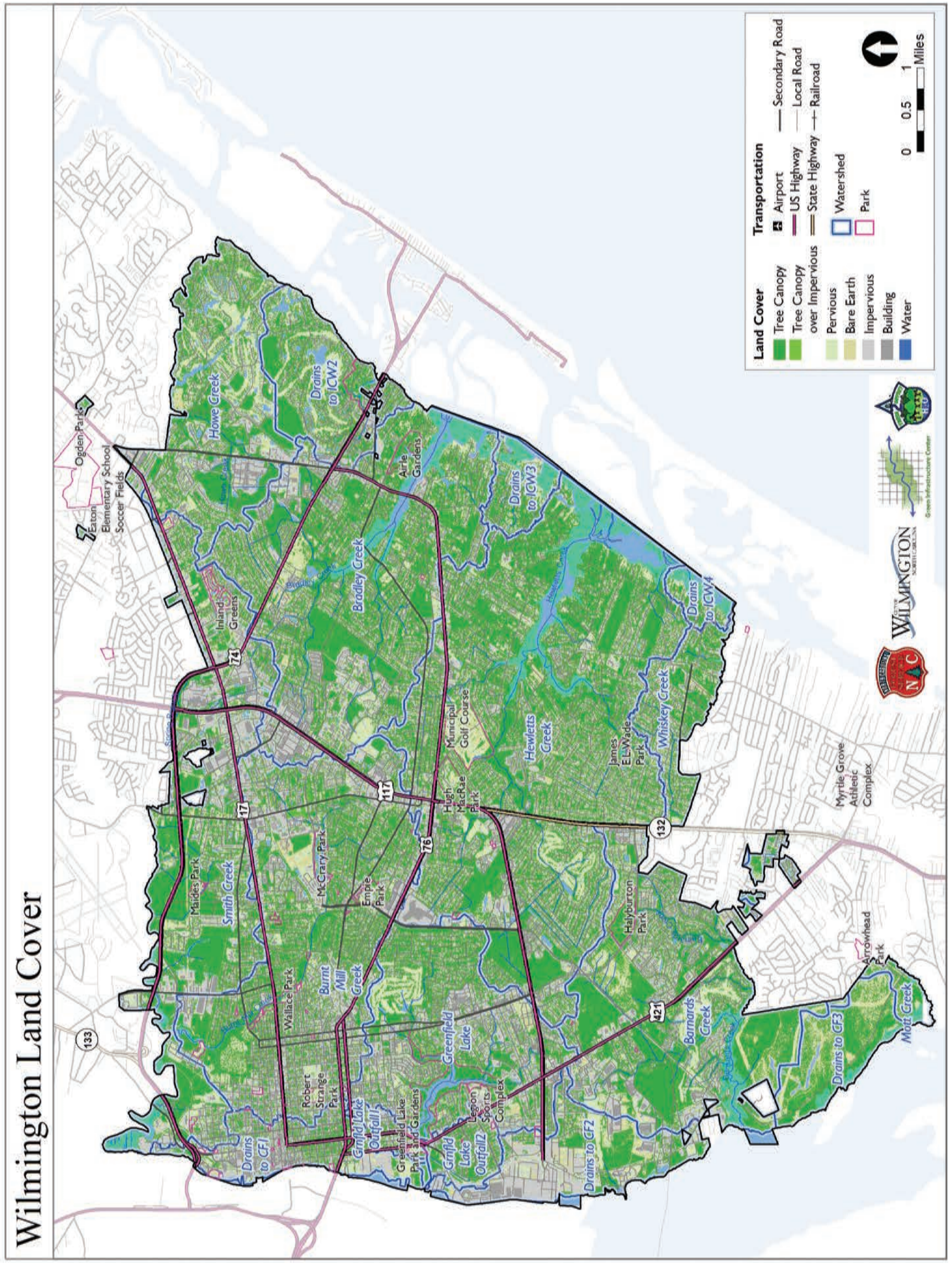
Miles of Stream: **50.34** miles

Acres of Lakes: **199.35**

Tree Canopy: **999** acres




*Percent Tree Cover and Possible Planting Area by Watershed*




*This map shows the tree canopy of the city, which covers 48 percent of the area.*

# Why Protect Our Urban Forests?

As areas develop, natural land cover changes to urban land cover and forested land cover decreases. Today, municipalities are losing their trees at an alarming rate, estimated at four million trees annually nationwide (Nowak 2010). This is due, in large part, to population growth. This growth has brought with it pressures for land conversion to accommodate both commercial and residential development. Cities are also losing older, established trees from the cumulative impacts of land development, storms, diseases, old age and other factors (Nowak and Greenfield 2012). However, at 46 percent canopy Wilmington has a large extent of urban forest cover.

Cities such as Wilmington have lost their natural forest cover and may continue to see losses unless planting and urban forest care are better funded. As older trees die (or before they die), younger trees need to be planted to restore the older canopy. For example, canopy coverage in the central business district is only 10.2 percent. However, 14.3 percent more area downtown could possibly be planted based on an analysis of existing open space. For recommendations for how the city can better protect and manage its urban forests, see the Codes and Ordinances section of this report.

The purpose of this report is not to seek a limit on the city's growth, but to help the city better utilize its tree canopy to manage its stormwater. Additional benefits of improved canopy include:

- fostering a healthful and vibrant community,
- cleaner air,
- aesthetic values,
- reduced heating and cooling costs,
- decreased urban heat island effects,
- increased wildlife habitat,
- fostering walkability and multimodal transportation, and,
- increased revenue from tourism and retail sales.

Newly Planted Tree in Wilmington

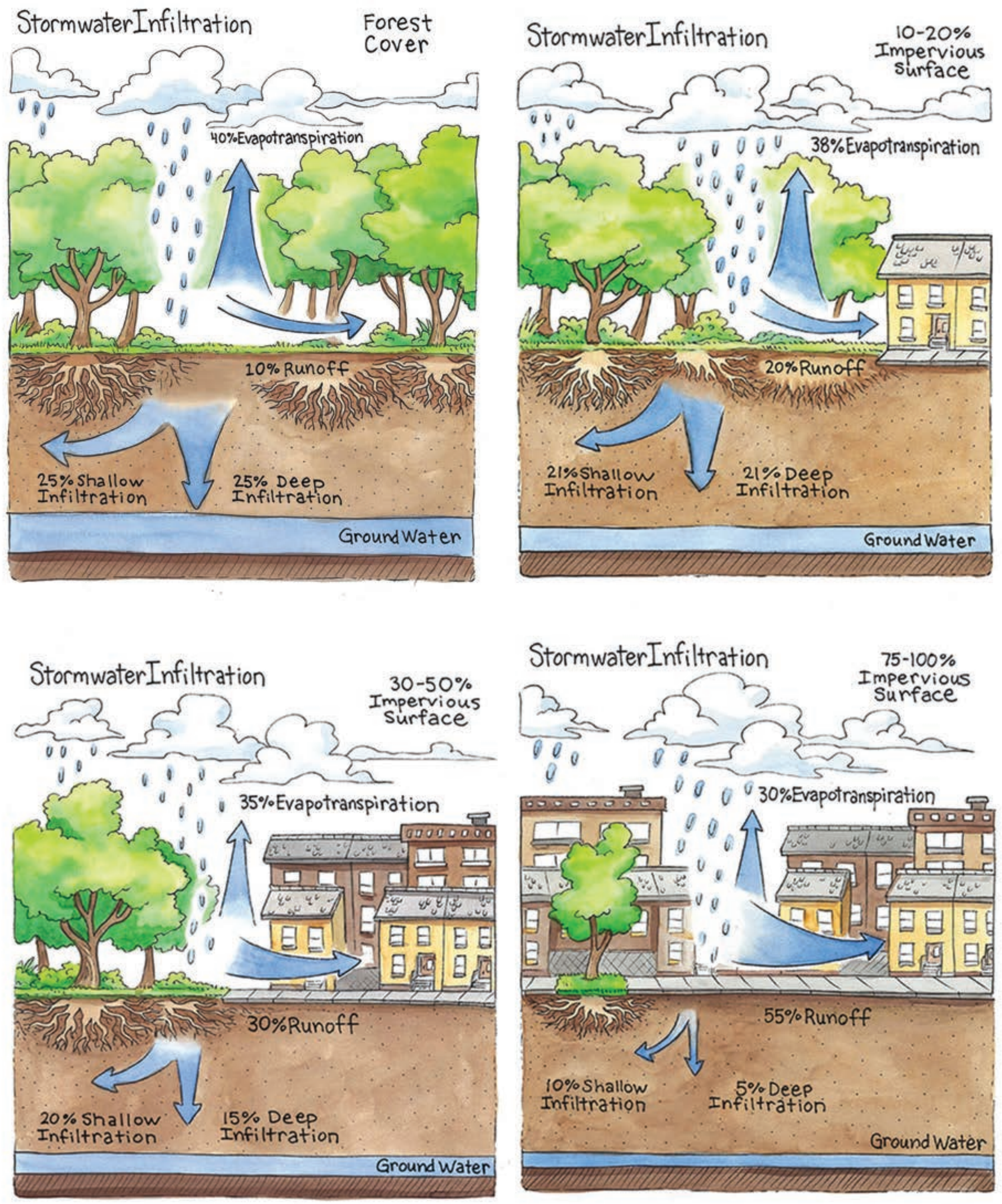
As forested land is converted to impervious surfaces, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving streams, increased potential for pollution of surface and ground waters and greater potential for flooding. According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters and causes increased flooding and property damages, as well as public safety hazards from standing water. The EPA recommends a number of ways to use trees to manage stormwater in the book *Stormwater to Street Trees.*

Imperviousness is one consideration; another concerns the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff. As their urban forest canopies declined, municipalities saw increased stormwater runoff. Unfortunately, many cities and counties did not have a baseline analysis of their urban forests or strategies to replace lost trees.

In the past several years, many powerful storms have affected the Southeastern United States leading to high levels of tree loss. This study was funded to address this problem by helping municipalities monitor, manage and replant their urban forests and to encourage cities to enact better policies and practices to reduce stormwater runoff and improve water quality.

Assessment and inventory of trees is key to ensuring a healthy forest.






Runoff increases as land is developed. Information source: U.S. EPA

It is not just development and storms that contribute to tree loss. Millions of trees are also lost as they reach the end of their life cycle through natural causes. For every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can all lead to tree canopy loss. It is also important to realize that an older, well-treed neighborhood of today may not have good coverage in the future unless young trees – the next generation – are planted.

Urbanizing counties and cities are beginning to recognize the importance of their urban trees because they provide tremendous dividends. For example, urban canopy can reduce stormwater runoff anywhere from two to seven percent (Fazio 2010). According to Penn State Extension, during a one-inch rainfall event, one acre of forest will release 750 gallons of runoff, while a parking lot will release 27,000 gallons! This could mean an impact of millions of gallons during a major precipitation event. While stormwater ponds and other management features are designed to attenuate these events, they cannot fully replicate the pre-development hydrologic regime. In addition, parts of Wilmington are older and may lack stormwater management practices that are required for new developments.

*Excess impervious areas cause hot temperatures and runoff. Some older paved areas predate regulations requiring stormwater management.*

Trees filter stormwater and reduce overall flows. So planting and managing trees is a natural way to mitigate stormwater. Estimates from Dayton, Ohio study found a 7 percent reduction in stormwater runoff due to existing tree canopy coverage and a potential increase to 12 percent runoff reduction as a result of a modest increase in tree canopy coverage (Dwyer et al 1992). Conserving forested landscapes, urban forests, and individual trees allows localities to spend less money treating water through the municipal storm systems and reduces flooding.

Each tree plays an important role in stormwater management. For example, based on the GIC's review of multiple studies of canopy rainfall interception, a typical street tree's crown can intercept between 760 gallons to 3000 gallons per tree per year, depending on the species and age. If a community were to plant an additional 5,000 such trees, the total reduced runoff per year could amount to tens of millions of gallons. This means reduced flooding in neighborhoods and reduced stress on waste water treatment plants as well as less runoff into the city's rivers and lakes.

Another compelling fiscal reason for planning to conserve trees and forests as a part of a green infrastructure strategy is minimizing the impacts and costs of natural disasters. By retaining trees and forests, it is possible to reduce the likelihood of extensive flooding.

In urban areas, tree canopy should be assessed and realistic goals established to maintain or expand it. Geographic Information Systems (GIS) software is used to map the extent of the current canopy as well as to estimate how many new trees might be fitted into an urban landscape. A Possible Planting Area (PPA) map estimates areas that may be feasible to plant trees. A PPA map helps communities set realistic goals for what they could plant (this is discussed further on page 16).

### Buffering surface waters from pollution

*Urban forests are also critical to buffering surface waters from pollution. However, at certain levels of urban development and related imperviousness, aquatic life begins to decline. The rate of decline is affected by factors such as land cover, lot sizes and types of land use, as well as the locations of imperviousness within the watershed. Excessive urban runoff results in pollutants such as oil, metals, lawn chemicals (e.g., fertilizer and herbicides), pet waste and other contaminants reaching surface waters. High stormwater flows result in channel and bank scouring, releasing sediments that smother aquatic life and reduce stream depth and clog ditches, leading to yet more bank scouring and flooding, as channel capacity is lost.*



*These turtles appreciate cleaner water in Wilmington.*

## ADDITIONAL URBAN FOREST BENEFITS

### Quality of Life Benefits

During North Carolina's hot summers, more shade is always appreciated. Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, and more pleasant for walking or biking. Multiple studies have found significant cooling (2-7 degrees) and energy savings from having shade trees in cities (McPherson et al 1997, Akbari et al 2001). In addition, trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Shaded pavement also has a longer lifespan so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick 2005).

Children who suffer from Attention Deficit Hyperactivity Disorder (ADHD) benefit from living near forests and other natural areas. One study showed that children who moved closer to green areas have the highest level of improved cognitive function after the move, regardless of level of affluence (Wells 2000). Thus, communities with greener landscapes benefit children and reduce ADHD symptoms. Trees also cause people to walk more and walk farther. This is because when trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk than if streets and walkways are well treed (Tilt, Unfried and Roca 2007).

*Well treed areas encourage people to walk and bike.*

## Economic Benefits

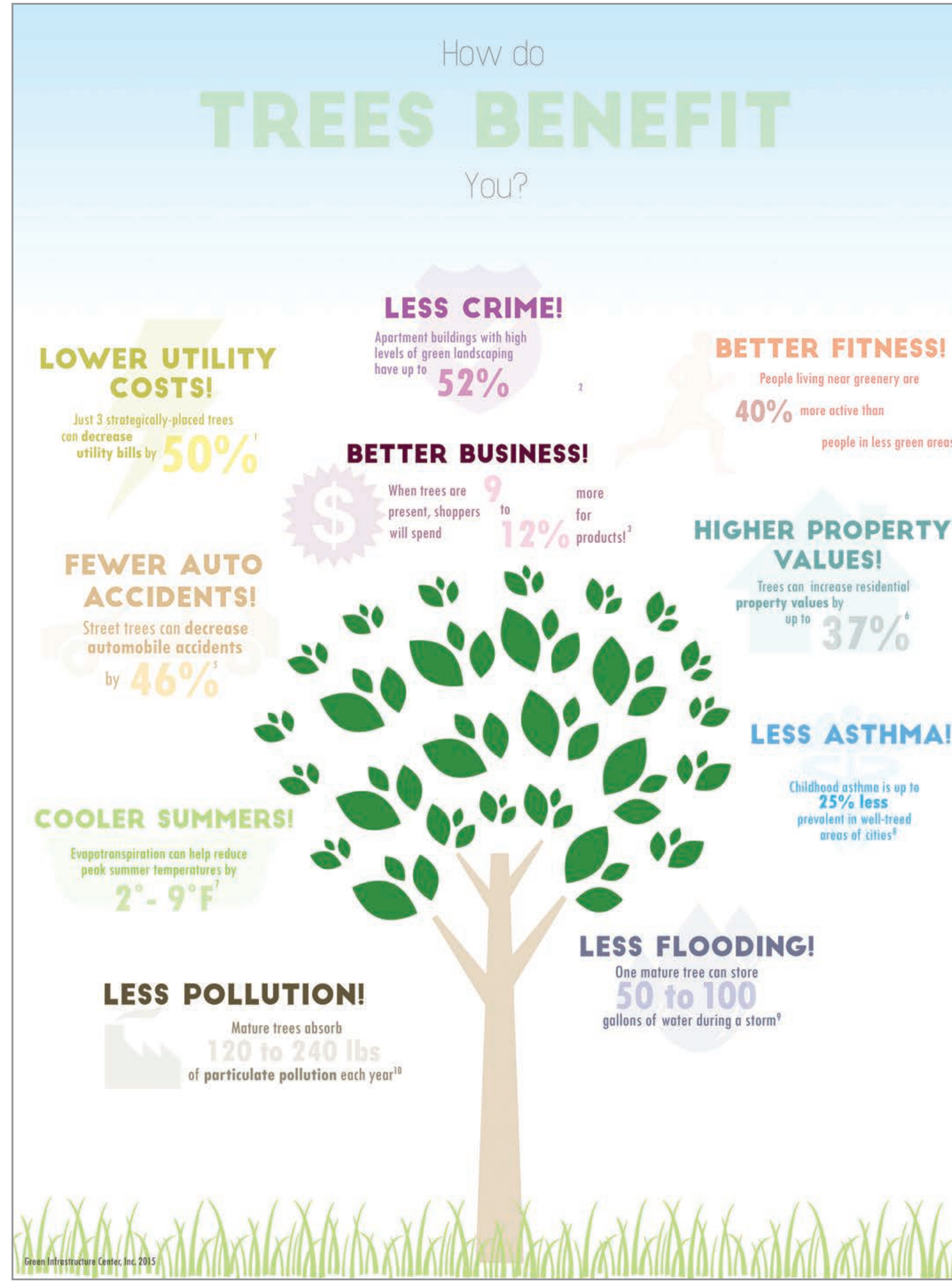
Developments that include green space or natural areas in their plans sell homes faster and for higher profits than those that take the more traditional approach of building over an entire area without providing for community green space (Benedict and McMahon 2006).

A study by the National Association of Realtors found that 57 percent of voters surveyed were more likely to purchase a home near green space and 50 percent were more willing to pay 10 percent more for a home located near a park or other protected area. A similar study found that homes adjacent to a greenbelt in Boulder, Colorado were valued 32 percent higher than those 3,200 feet away (Correll et al. 1978).

## Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires North Carolina to have standards for water quality. When waters are impaired they may require establishment of a Total Maximum Daily Load (TMDL) standard and a clean-up plan (i.e., Best Management Action Plan or BMAP) to meet water quality standards. Since a forested landscape produces higher water quality by cleaning stormwater runoff (Booth et al 2002), increasing forest cover results in less pollutants reaching the city's surface and ground waters. Forest cover also reduces the cost of drinking water treatment. The American Water Works Association found that a 10 percent increase in forest cover reduced chemical and treatment costs for drinking water by 20 percent (Ernst et al. 2004).

*Trees could be added downtown for shade and beauty.*



# Natural Ecology in Urban Conditions – Changing Landscapes

Natural history, even of an urbanized location, informs planting and other land-management decisions. Prior to conversion from natural or agricultural land cover to urban, it was Wilmington's climate and geographic location that determined its flora and fauna.

Wilmington is located in the Coastal Plain province which covers 45 percent of North Carolina's eastern coast (and Piedmont Ecoregion), characterized by a relatively flat landscape of sediment types are sand and clay, although a significant amount of limestone occurs in the southern part of the Coastal Plain.

## HISTORIC LAND COVER

The city is bordered by the Cape Fear River to the west and the Atlantic Ocean to the east. Incorporated in 1739, Wilmington became a city in 1866 and by 1840 it was the largest town in the state until the early 1900s. Wilmington began to boom following the construction the ports along the Cape Fear River and later the Wilmington and Raleigh Railroad (later named the Wilmington & Weldon Railroad), which in 1840, was the largest continuous railroad track in the world.

*Tugboat in Cape Fear River*

Today, Wilmington's downtown is booming with new rental units, housing rehabilitation and arts facilities and restaurants as well as newer suburban neighborhoods that have grown with the city's expansion. The city is recognized for its many unique quality of life aspects in rankings by Livability, Forbes, USA Today and other ratings touting its small city charm, riverfront, affordability, business friendly environment and vibrant downtown district, which scored highly for 'al-fresco' dining. City parks such as Halyburton Park and Greenfield Lake Park and the Cape Fear River walks are popular places to experience nature in the city and add to the city's livability scores.

*A little blue heron appreciates the tree cover and water in Wilmington, NC*


*A redeveloping downtown welcomes walkers with beautiful landscapes.*



## GROWTH & DEVELOPMENT CHALLENGES

Demands for space to meet the needs for housing, commercial, business, industrial uses and transportation put strains on both the city's grey and green infrastructure. As an older city, there are areas that pre-date the 1987 Clean Water Act Amendments which required localities to treat stormwater runoff. Adding stormwater treatment for these older areas is achieved by either retrofitting stormwater best management practices into the landscape or adding them as properties are re-developed. Adding more trees is a best management practice that provides other benefits beyond stormwater uptake, such as shade, air cleansing and aesthetic values. Recommendations for improvements to better utilize trees to manage stormwater and to reduce imperviousness are found in the section on page 20.

## WILMINGTON'S GREEN FUTURE

Wilmington is working to develop in ways that support a quality lifestyle for residents and visitors alike, while also meeting state and federal mandates for protecting air and water. The city boasts 746 acres of parks and 32 miles of walking trails.

The city also celebrates and promotes its location along the Cape Fear River with a 1.75-mile river walk in which they have invested 33 million dollars along for safety features, the boardwalk, furniture and lighting. Wilmington is also a Bee City USA. The Bee City program endorses a set of commitments for creating sustainable habitats for pollinators, and encourages city leaders to raise awareness of the contribution bees and other pollinators make to the city. For more see https://www.wilmingtonnc.gov/departments/community-services/bee-city Wilmington is also a Tree City USA (this is discussed in a later section.)

# Analysis Performed

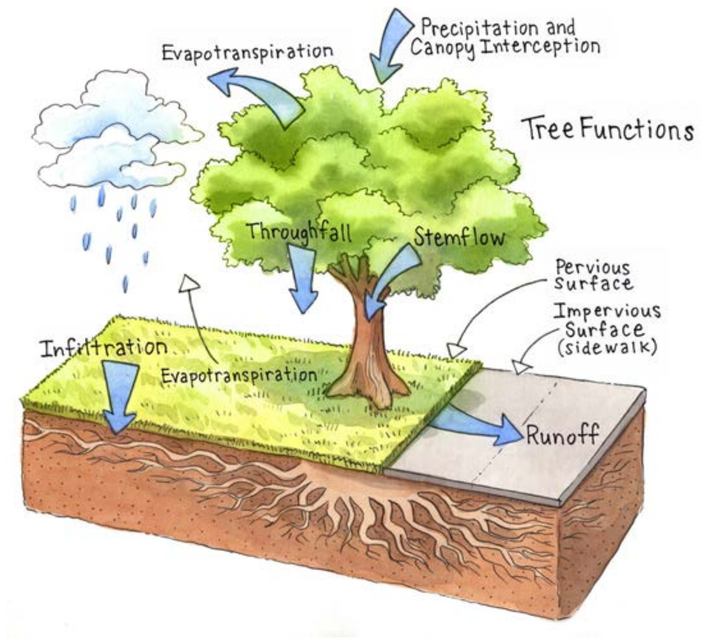
This project evaluated options for how to best evaluate stormwater runoff and uptake by the city's tree canopy. Its original intended use was for planning at the watershed scale for tree conservation. An example is provided on page 14. Howe ver, new tools created for the project allow the stormwater benefits of tree conservation or additions to be calculated at the site scale as well.

As noted, trees intercept, take up and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event to about three percent at the maximum rain intensity. Trees take up more water early on during storm events and less water as storm events proceed and the ground becomes saturated (Xiao et al. 2000). Many forestry scientists, as well as civil engineers, have recognized that trees have important stormwater benefits (Kuehler 2017, 2016). See diagram of tree water flow on the next page.

## METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

Currently, the city uses TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to generate expected runoff amounts. The city could choose to use the modified TR55 curve numbers (CN) for this study that include a factor for canopy interception. This project is also a tool for setting goals at the watershed scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff.

This study used the modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers. Curve numbers produced by this study can be utilized in the city's modeling and design reviews. The spreadsheet calculator tool provided makes it very easy for the city to change the curve numbers if they so choose. What is new about the calculator tool is that the curve numbers relate to the real land cover conditions in which the trees are found. A canopy interception factor is added to account for the role trees play in interception of rainfall based on location and planting condition (e.g. trees over pavement versus trees over a lawn or in a forest).




*Trees and the Water Cycle*

Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. A study by Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing stormwater, resulting in:

$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S}$$

Where R is runoff, P is precipitation, Ia is the initial abstraction, which is the fraction of the storm depth after which runoff begins, and S is the potential maximum retention after runoff begins for the subject land cover (S = 1000/CN – 10).

Major factors determining CN are:

- The hydrologic soil group (defined by surface infiltration rates and transmission rates of water through the soil profile, when thoroughly wetted)
- Land cover types
- Hydrologic condition – density of vegetative cover, surface texture, seasonal variations
- Treatment – design or management practices that affect runoff

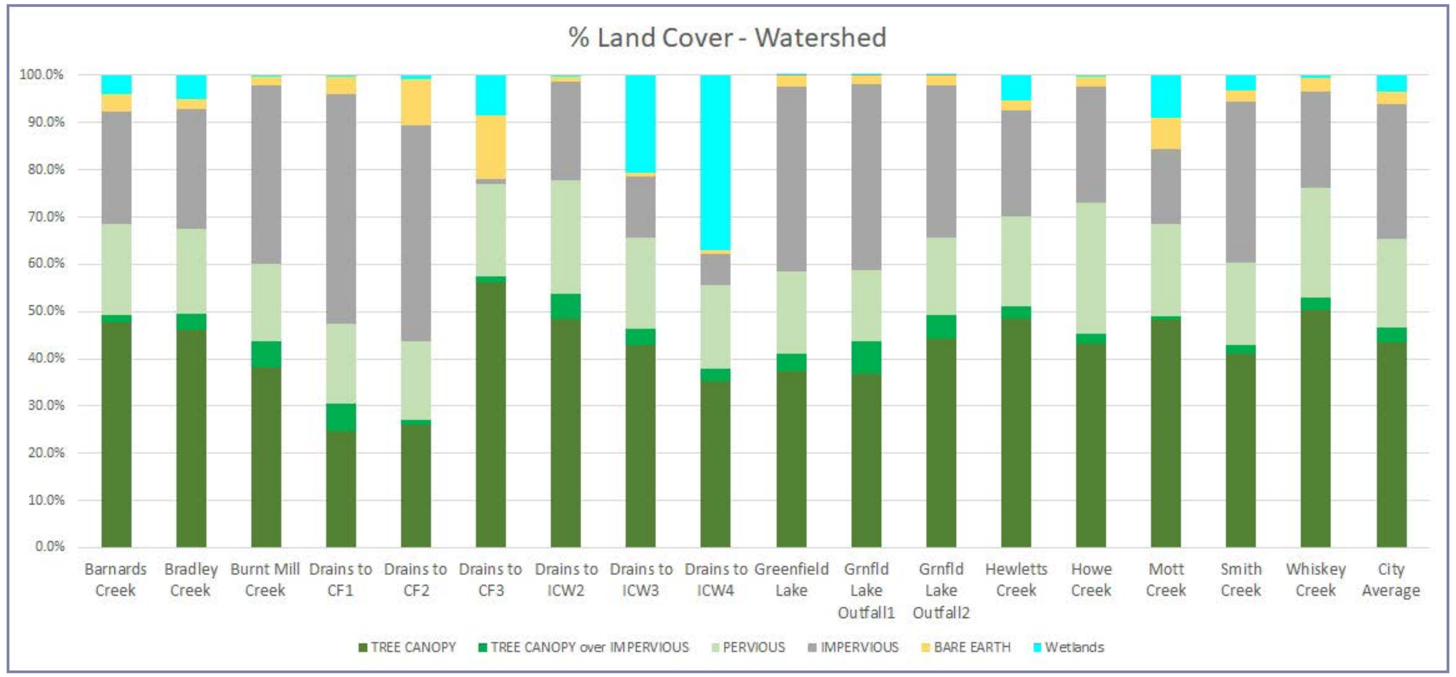
In order to use the equation and model scenarios for future tree canopy and water uptake, the project team first developed a highly detailed land cover analysis and an estimation of potential future planting areas, as described following. These new land cover analyses can be used for many other projects, such as looking at urban cooling, walkability (see map of street tree coverage on following pages), trail planning and for updating the comprehensive plan.

An example of how this modeling tool can be used for watershed-scale forest planning is indicated below. The actual model spreadsheet was provided to Wilmington for their use. It links to the land cover statistics for each type of planting area. It also allows the city to add trees or to reduce trees and to see what are the effects are for stormwater capture or runoff. The key finding from this work is that removal of mature trees and existing forests generate the greatest impacts for stormwater runoff. As more land is developed in Wilmington, the city should seek to maximize tree conservation for maintenance of surface water quality and groundwater recharge. This will also benefit the city's quality of life by fostering clean air, walkability, and attractive residential and commercial districts.

The stormwater runoff model provides estimates of the capture of precipitation by tree canopies and the resulting reductions in runoff yield. It takes into account the interaction of land cover and soil hydrologic conditions. It can also be used to run 'what-if' scenarios, specifically losses of tree canopy from development and increases in tree canopy from tree planting programs.

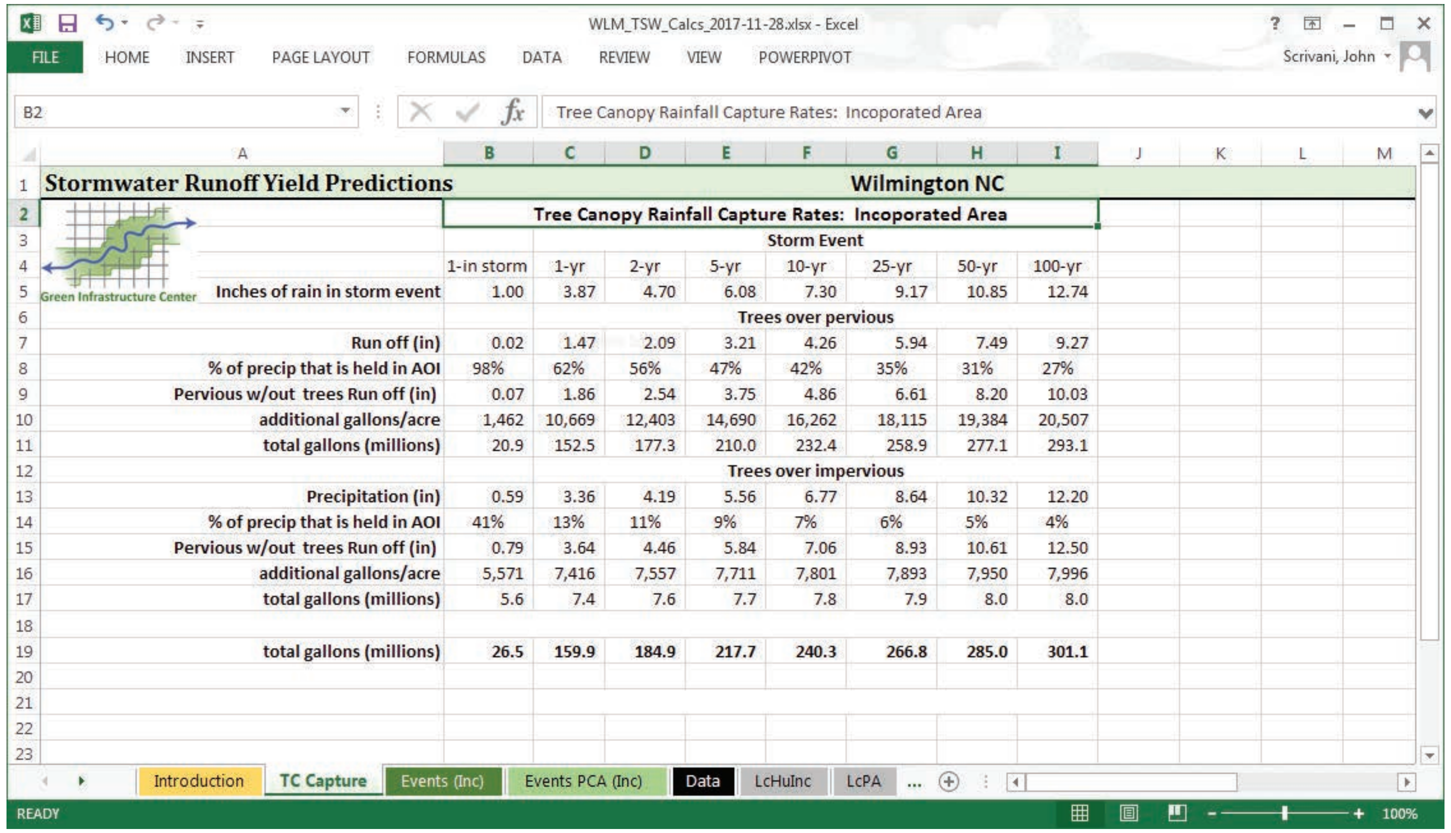
In the graphic of the calculator tool, the model is used to estimate a hypothetical 20 percent loss of tree canopy for Wilmington, which would result in an increase of 144 million gallons of stormwater runoff during a mean annual 24-hour storm. If planting efforts were to increase the canopy from 48 percent to 51.5 percent, the model shows a decrease in






stormwater runoff (or increase in capture) of 7.4 million gallons. The model is a tool for seeing the results or adding or losing tree canopy.

This new approach allows for more detailed assessments of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks because the conditions in which the tree is living affect the amount of water the tree can intercept. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following. The analysis can be used to create plans for where adding trees or better protecting them can reduce stormwater runoff impacts and improve water quality.




| Stormwater Runoff Yield Predictions | | | | | Wilmington NC | | | |
|---|---|---|---|---|---|---|---|---|
| | Tree Canopy Rainfall Capture Rates: Incoporated Area | | | | | | | |
| | Storm Event | | | | | | | |
| | 1-in storm | 1-yr | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| Inches of rain in storm event | 1.00 | 3.87 | 4.70 | 6.08 | 7.30 | 9.17 | 10.85 | 12.74 |
| | Trees over pervious | | | | | | | |
| Run off (in) | 0.02 | 1.47 | 2.09 | 3.21 | 4.26 | 5.94 | 7.49 | 9.27 |
| % of precip that is held in AOI | 98% | 62% | 56% | 47% | 42% | 35% | 31% | 27% |
| Pervious w/out trees Run off (in) | 0.07 | 1.86 | 2.54 | 3.75 | 4.86 | 6.61 | 8.20 | 10.03 |
| additional gallons/acre | 1,462 | 10,669 | 12,403 | 14,690 | 16,262 | 18,115 | 19,384 | 20,507 |
| total gallons (millions) | 20.9 | 152.5 | 177.3 | 210.0 | 232.4 | 258.9 | 277.1 | 293.1 |
| | Trees over impervious | | | | | | | |
| Precipitation (in) | 0.59 | 3.36 | 4.19 | 5.56 | 6.77 | 8.64 | 10.32 | 12.20 |
| % of precip that is held in AOI | 41% | 13% | 11% | 9% | 7% | 6% | 5% | 4% |
| Pervious w/out trees Run off (in) | 0.79 | 3.64 | 4.46 | 5.84 | 7.06 | 8.93 | 10.61 | 12.50 |
| additional gallons/acre | 5,571 | 7,416 | 7,557 | 7,711 | 7,801 | 7,893 | 7,950 | 7,996 |
| total gallons (millions) | 5.6 | 7.4 | 7.6 | 7.7 | 7.8 | 7.9 | 8.0 | 8.0 |
| total gallons (millions) | 26.5 | 159.9 | 184.9 | 217.7 | 240.3 | 266.8 | 285.0 | 301.1 |

*The calculator tool developed for this project allows the city to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees).*

## LAND COVER, POSSIBLE PLANTING AREA, POSSIBLE CANOPY AREA ANALYSIS

The land cover data were created using 2016 leaf-on imagery from the National Agriculture Imagery Program (NAIP) distributed by the USDA Farm Service Agency. Ancillary data for roads (from Wilmington government), the Cooperative Land Cover (CLC) Map (North Carolina Natural Areas Inventory), and hydrology (from National Wetlands Inventory and National Hydrography Dataset) were used to determine:

1) Tree cover over impervious surfaces, which otherwise could not be seen due to these features being covered by tree canopy; and

2) Wetland not distinguishable using spectral/feature-based image classification tools.

Forested open space was identified as areas of compact, continuous tree canopy greater than one acre, not intersected by buildings or paved surfaces.

The final classification of land cover consists of nine classes (types of land cover). The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. Of the nine land cover classes, only pervious, turf, and bare earth are considered for PPA.

Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect the feature itself such as power lines, sidewalks or roads. Playing fields, cemeteries and other known land uses that would not be appropriate for tree cover are also avoided. However, there may be some existing land uses (e.g., golf courses or ball fields that are expected to remain in recreational use, etc.) that are unlikely to be used for tree planting areas but that were not excluded from the PPA. In addition, the analysis did not take into account proposed future developments (e.g., planned developments) that would not likely be fully planted with trees. Therefore, the resulting PPAs represent the maximum potential places trees can be planted and grow to full size.

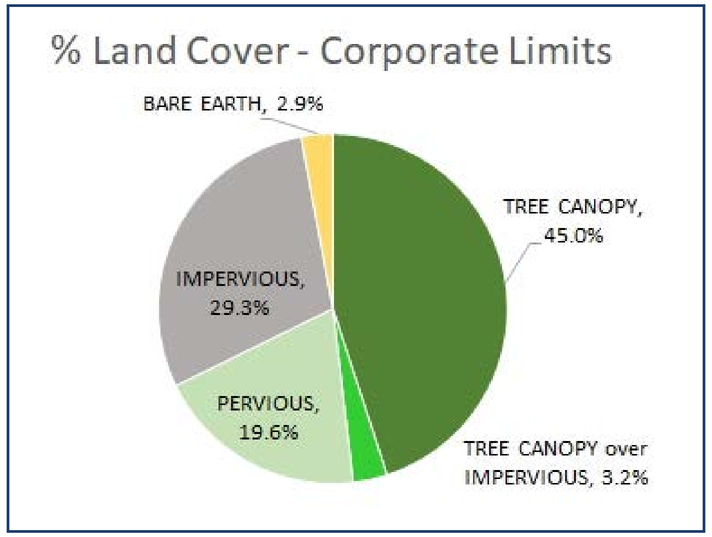

*Tree over street*


*Tree over parking lot*

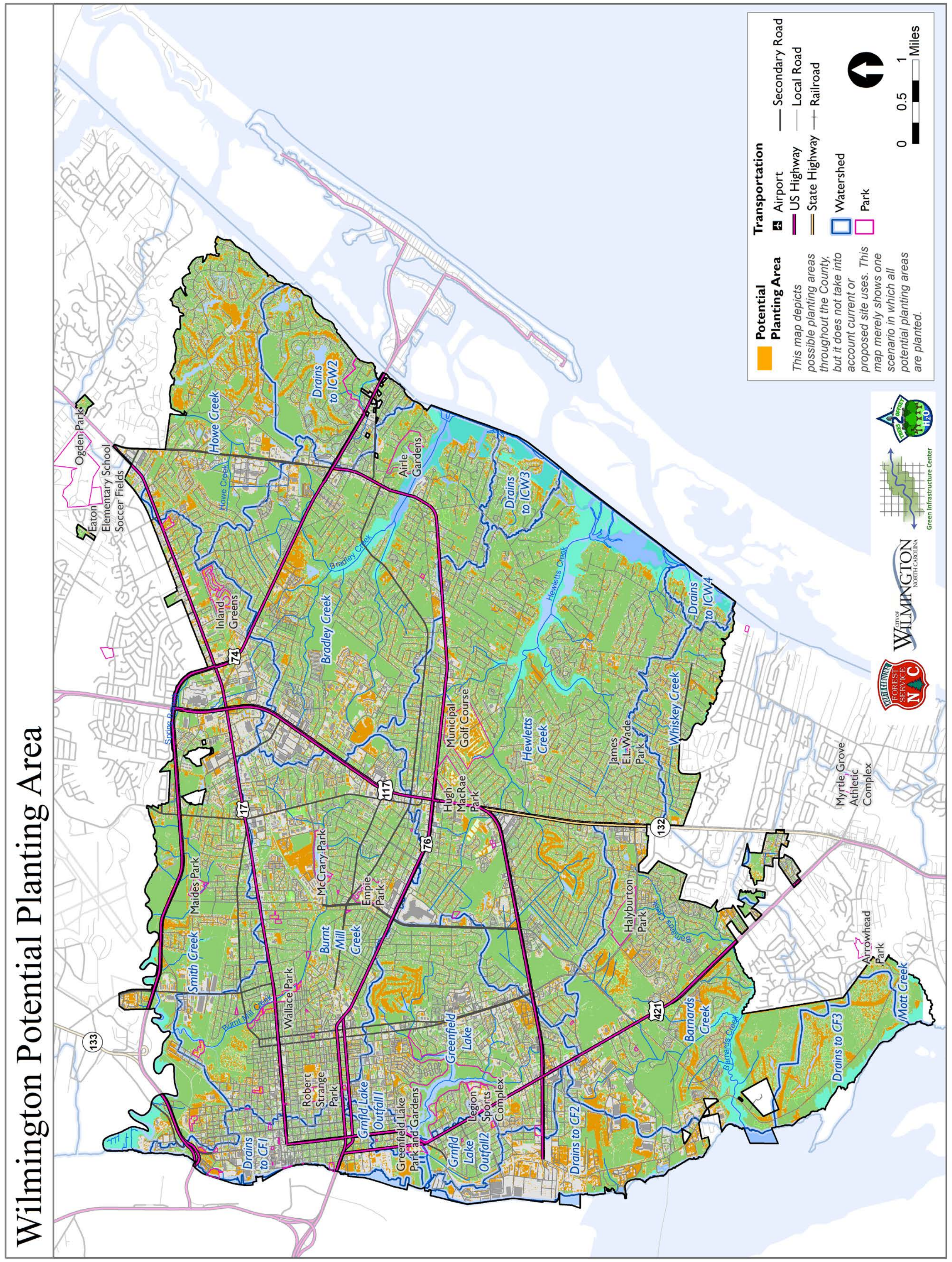

*Tree over lawn*


*Trees in forest*

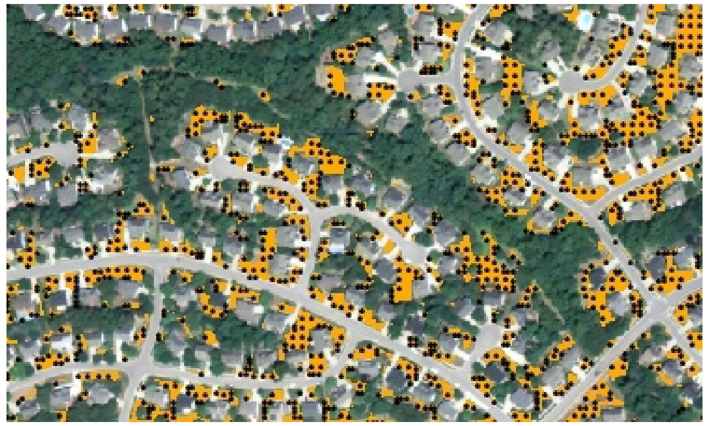

*This shows what is currently treed (green) and areas where trees could be added (orange).*



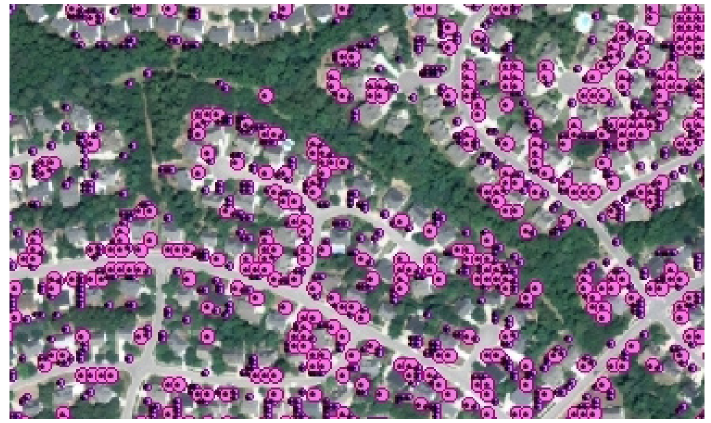
*This shows what is currently treed (green) and areas where trees could be added (orange).*




*Potential Planting Area (PPA) shown in orange depicts areas where it may be possible to plant trees. All sites would need to be confirmed in the field and may be on private or public lands.*



*Potential Planting Spots (PPS)*

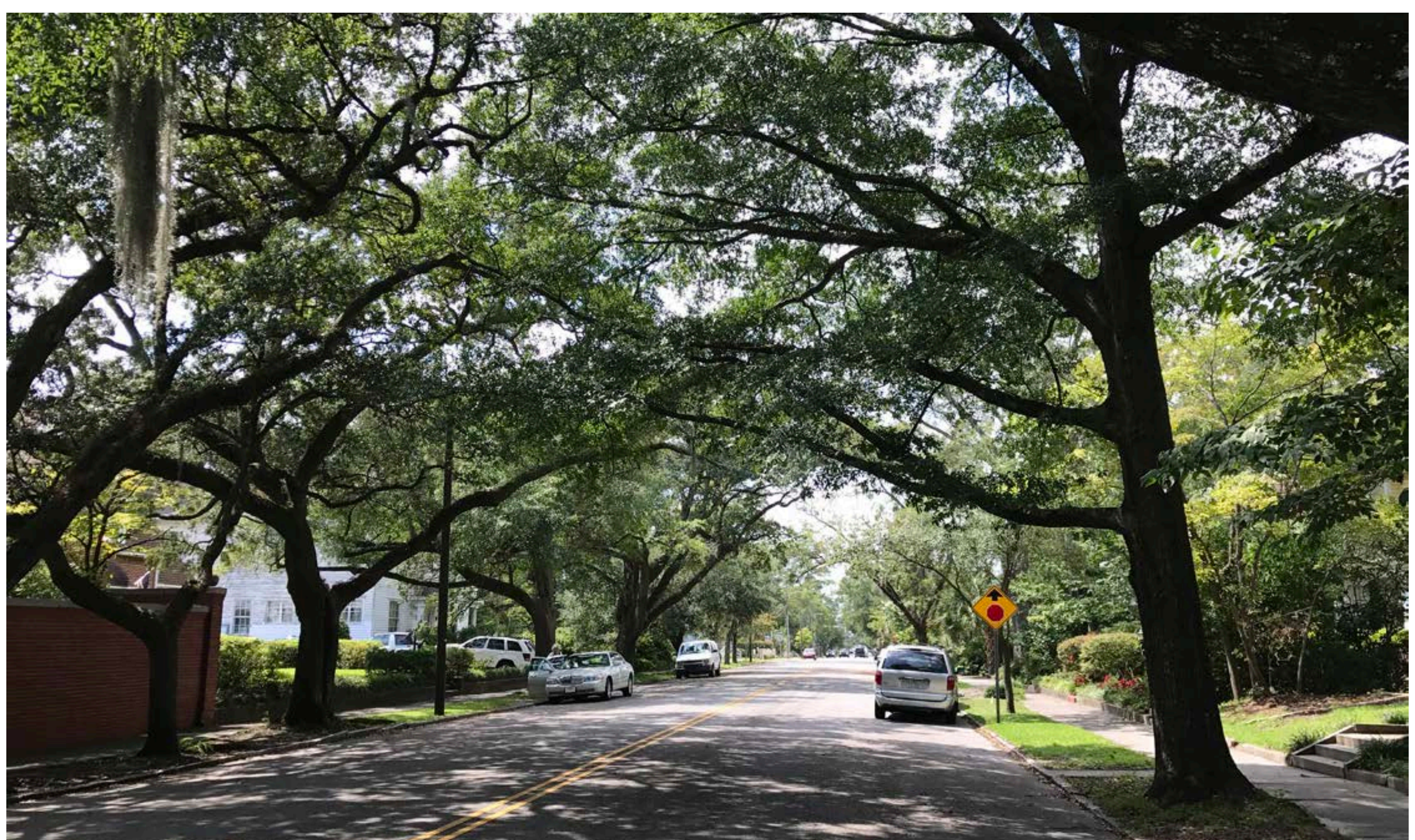


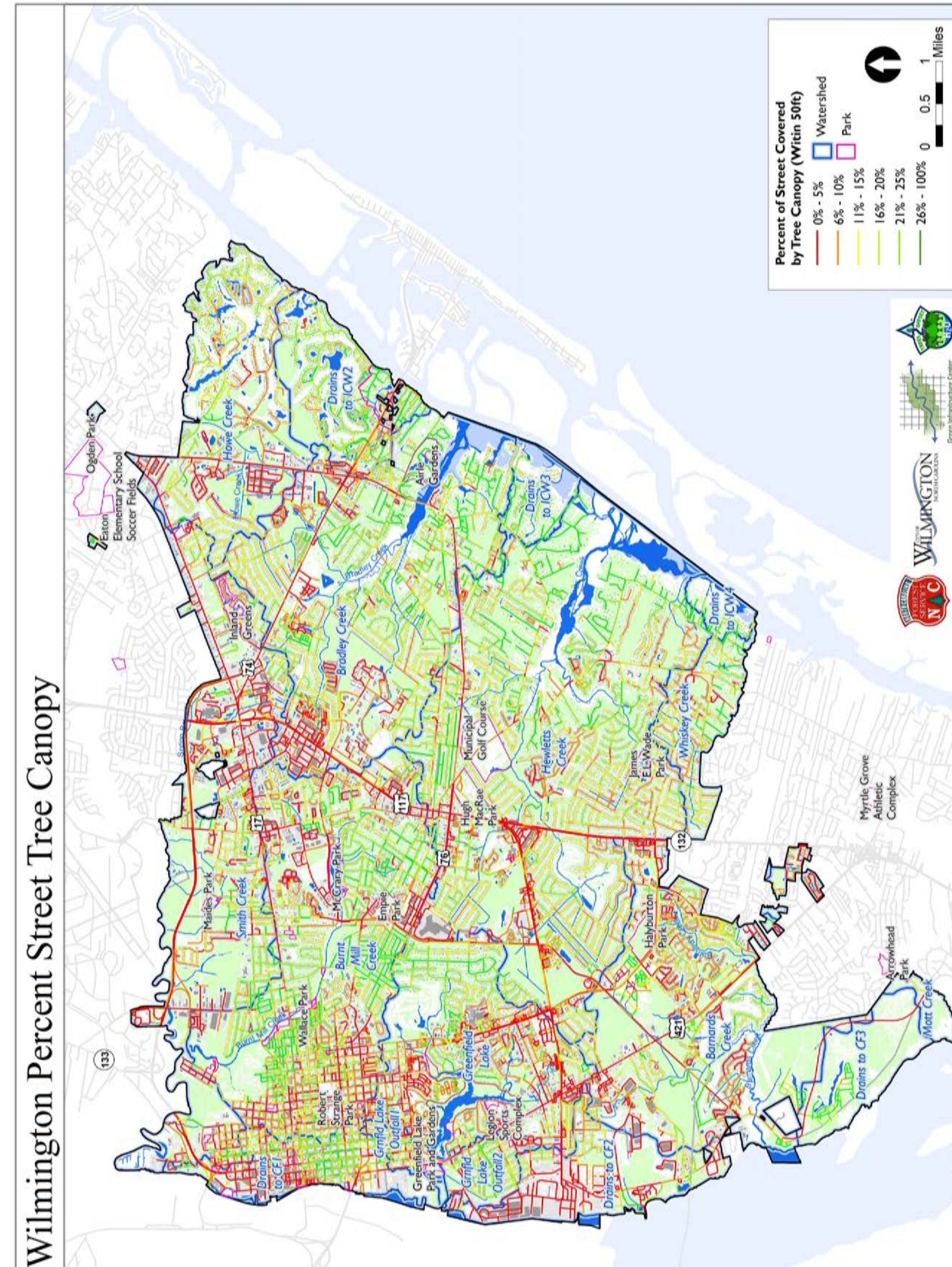
*Potential Canopy Area (PCA)*

The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots where a tree can be planted depending on the size of trees desired. For this analysis, expected sizes of both 20 ft. and 40 ft. diameter of individual mature tree canopy were used with priority given to 40 ft. diameter trees (larger trees have more benefits). It is expected that 30 percent overlap will occur as these trees reach maturity. The result demonstrates a scenario where, if planted today, once the trees are mature, their full canopy will cover the potential planting area and overlap adjacent features, such as roads and sidewalks.

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are selected, a buffer around each point that represents a tree's mature canopy is created. For this analysis, that buffer radius is either 10 ft. or 20 ft., which result in either a 20 ft. or 40 ft. diameter canopy for each tree. These individual tree canopies are then dissolved together to form the potential overall canopy area.

Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.






*The street trees map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be targeted for planting to facilitate uses, such as safe routes to school or beautifying a shopping district.*

*See Methods Appendix for more details on mapping methodology.*

# Codes, Ordinances and Practices Review

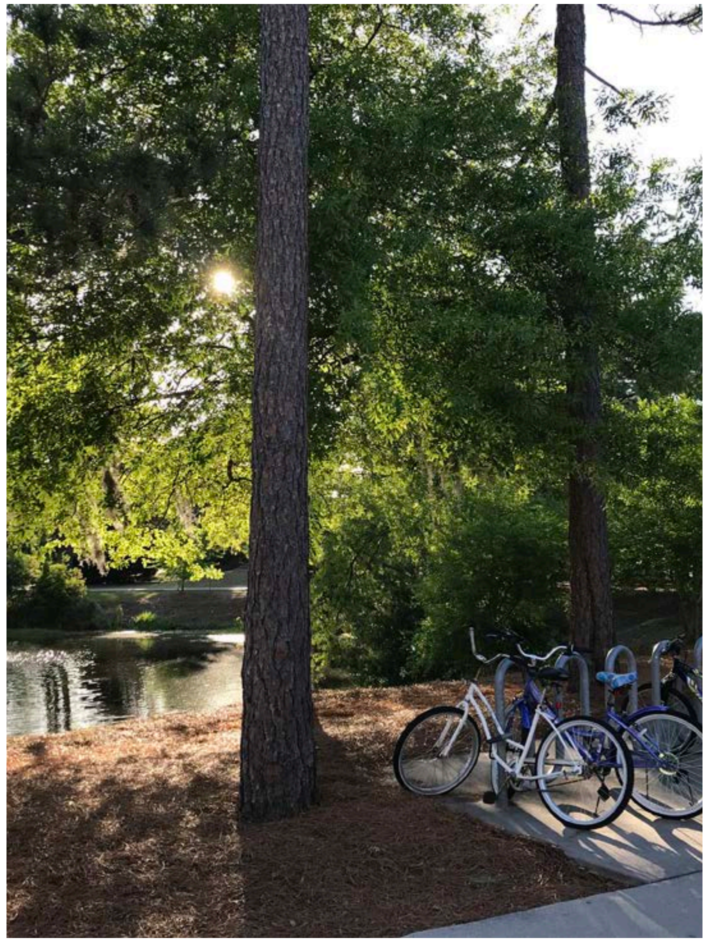
This review is designed to determine which practices make the town more impervious (e.g. too much parking required) and which make it more pervious (e.g. conserving trees or requiring open spaces). Documents reviewed during the codes, ordinances and practices analysis portion of the project include relevant sections of the city's current code that influence runoff or infiltration. Data were gathered through analysis of city codes and policies, as well as interviews with city staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the city lists all the codes reviewed, interviews held and relevant findings. A more detailed memo submitted to the city by GIC, also provides more ideas for improvements.

## EVALUATION AND RECOMMENDATIONS

Points were assigned to indicate what percentage of urban forestry and planning best practices have been adopted to date by the city. The spreadsheet tool created for city codes can also serve as a tracking tool and to determine other practices or policies the city may want to adopt in the future to strengthen the urban forestry program or to reduce impervious land cover. A final report comparing all localities' progress for those studies will be issued in 2019.

Wilmington invests staff time and funds to manage its urban forest. In fact, the city just celebrated its fifteenth year of being recognized as a 'Tree City USA' by the Arbor Day Foundation, which means that it spends adequate funds per capita on tree care, it has a tree ordinance, and it practices tree management. In addition, for the past 13 years, Wilmington has received the prestigious Tree City USA Growth Award.

The recommendations provided in this report are a way to increase the protections for, and size of, the forest in Wilmington. As noted earlier, although the city's canopy is impressive, it is not distributed equally citywide. Wilmington is one of 12 localities in a six-state area of the Southeastern U.S. to be studied and the third to be completed. As other places are studied, they will be compared to the city, and vice versa.





### Top recommendations to improve forest care in Wilmington listed in priority order include the following:

1. **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed.** The calculator provided to Wilmington allows the city to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading reductions for nitrogen and phosphorus, and sediment.
2. **Develop an Urban Forestry Management Plan (UFMP) which includes statistics on the community values of trees, measurable and achievable urban forestry goals, action steps required to achieve those goals, and a detailed list of maintenance items and frequencies.** Wilmington does not currently have an UFMP, but many of its codes and ordinances include typical UFMP components. These components can be divided into several sections including documentation of the community values of trees, outlining urban forestry goals and developing a maintenance item schedule.
3. **Work with developers to shrink the development footprint to minimize impervious surface.** Holding a pre-development conference, with all key staff in attendance, allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning.
4. **Conduct a land cover assessment every four years to determine and allow for comparison of tree canopy coverage change over time.** Keeping tree canopy coverages at levels that promote public health, walkability, and groundwater recharge for watershed health is vital for livability and meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place and to spot and address negative trends and take preventative actions.
5. **Remove the exception for tree inventory requirements on lots with single family homes that are two acres or smaller.** Requiring tree inventories affords more opportunities for city-led tree save decisions.
6. **Increase the number of tree protection mechanism inspections and enforcement staff.** Enforcement of tree-related codes and ordinances is more effective when there is adequate staff time available to enforce them. Hiring an additional urban forester to work with city staff on planning and zoning matters will help ensure that opportunities to save or add trees are realized.
7. **Perform tree risk assessments. Increase assessment intervals in densely populated portions of the city.** Tree risk assessments minimize tree-related risks by actively managing the urban forest and can lessen the costs of removing trees after storms.
8. **Require tree canopy coverage percentages by land use.** To assure quality of life for all in a community, add a requirement in Wilmington codes and ordinances for minimum tree canopy coverage by land use.
9. **Determine urban forestry data needs and which software will best collect the needed data. Implement the data collection process as part of the urban forestry program.** Site-scale landscape changes are easily seen with the imagery but information about the urban forest that could be used in planning is lacking. Urban forestry data collection should provide detailed, quan tifiable information.
10. **Use Silva Cells or other similar trade product, to provide adequate soil volume for trees in dense urban conditions.** Silva Cells can increase survival rates for newly planted trees. They are expensive and as such, should be used only strategically, in commercial districts for example or in public plazas.
11. **Publicize Wilmington's Right of Way (ROW) tree planting program and encourage more citizens to plant in ROWs near their homes.** Trees shade streets and sidewalks, making walking and biking more comfortable in Southern urban locations. The City of Wilmington will plant trees in ROWs if adjacent homeowners request them, but many homeowners or renters do not know about this program.
12. **Revise city planting lists to reduce the number of non-native invasive species listed. Develop a prohibited planting list.** The current recommended planting list includes many non-native invasive species. Revise the list to include more natives and enjoy the ecological benefits these species provide.
13. **Adopt a complete green streets policy.** Complete green streets allow for integration of stormwater management and aesthetic goals. By incorporating vegetation as an integral part of the design, they create and connect habitat, reduce urban heat island effect, help remove air pollutants, and promote walking and biking.
14. **Expand the application of the code that allows for variable space sizing to all city districts.** Excessive parking standards have exponential negative effects on stormwater volume generation, especially in urban environments. It is good practice to ensure that parking requirements are consistent with demand.
15. **Offer stormwater fee reduction credits for tree plantings.** Stormwater utility fees are a mechanism for funding stormwater management based on the amount of impervious surfaces generated for land cover by parcel and provide an incentive for reducing impervious areas to lessen the fee.
16. **Add a Geographic Information Systems (GIS) staff person to the Parks and Recreation Department.** Effective management of the urban forest is data driven and includes spatial analysis. Empower the Urban Forestry Program with data and allow for better management of the urban forest.
17. **Devote city resources to organization and training of a Wilmington tree stewards group.** Tree stewards can carry out tree planting projects, provide tree care trainings, and increase the public's awareness of the value and care of trees. In the past the city had a 'pruning corps' and this did not continue. Staff can investigate this past effort, as well as similar highly successful tree steward programs in other cities that are working well to determine the ingredients for what makes a successful program.
18. **Develop a forestry emergency response plan.** The city does not have a plan for replacing trees lost to natural disasters such as hurricanes or other storms. This means that canopy will decrease over time. Given the many benefits that trees provide (increased groundwater infiltration, soil stability, and reduced runoff and flooding, shade and better air quality), the city should plan for funding and replacement tree plantings following natural disasters.

## BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The City of Wilmington holds planning concept reviews, but they are not mandatory. Also, the city forester may not be available to attend all scheduled reviews. Greater encouragement for these meetings and funding for additional staffing within the city's urban forestry program could expand the frequency and benefits from these meetings.

However, it will also be necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. While the city actively encourages site layouts that conserve trees, developers may not always agree to implement staff suggestions. The GIC has found that economic arguments (real estate values for treed lots, access to open spaces, and rate of sales) are usually the most compelling way to motivate developers to take the extra effort and care to design sites and manage construction activities to manage tree conservation. This will facilitate site designs which save more trees and thereby require less constructed stormwater mitigation. Many developers are willing to cooperate in such ventures, as houses often sell for a premium in a well-treed development.

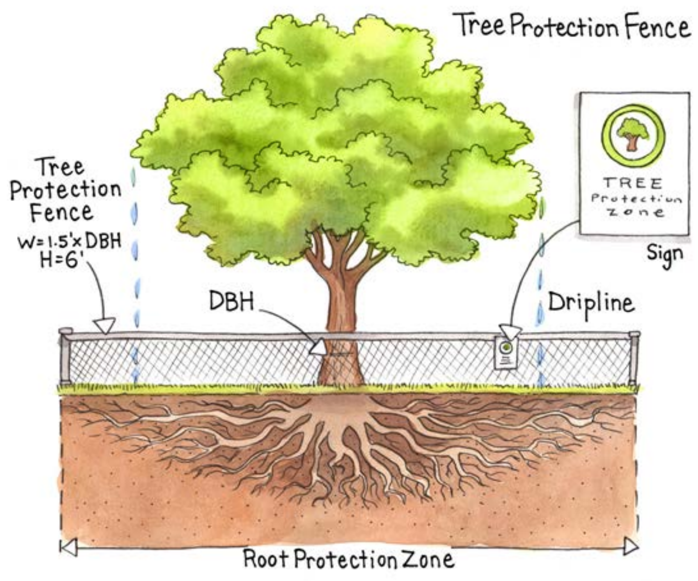
Photo credit: City of Wilmington

### *Tree Protection Fencing & Signage*

The most common form of tree protection is fencing. It is a physical barrier that keeps people and machines out of a tree's critical root zones during construction. However, some municipalities only require plastic orange fencing and wooden stakes. This type of fencing can be removed or trampled easily and makes tree protection efforts less effective. Trees slated for protection may suffer development impacts such as root compaction and trunk damage. Instead, sturdy metal chain link fencing can be required in high risk areas (such as near heavy construction equipment and active site grading) and use orange plastic fencing in lower risk areas (such as along woodland at the edge of a development property). The city currently uses orange silt fence material which is more sturdy than plastic mesh construction fence. Chain link fencing is more expensive but also more effective for high risk areas or to protect significant (e.g. historical or unusually large) trees.

Small roots at the radial extents of the tree root area uptake water and absorb nutrients. Protection of the small fibrous roots is critical for the optimal health of a tree. City code requires tree protection fence to extend only to one foot per tree diameter at breast height (DBH) inch, omitting protection for part of the tree most involved in stormwater uptake. In addition, up to 40 percent of the tree's critical root zone is permitted to be impacted by development on one side of the tree. This can leave trees damaged after construction and decreases tree survival rates depending on the species and other extenuating site conditions. Instead, tree protection fencing is recommended to be placed at a distance of 1.5' from the tree trunk per DBH inch of the tree and encroachment on the critical root zone should be highly discouraged in order to best protect trees and their functions.

Tree protection signage communicates how work crews should understand and follow tree protection requirements. It also informs construction crews and citizens about the consequences of violating city code. Construction crew members may not understand that building materials may not be placed in tree protection zones and that moving the protective fencing around the tree is never permitted. The city should design a standard tree protection sign which summarizes the do's and don'ts of working near and around tree protection zones. Additional training may be helpful to ensure that developers comply with the city's tree ordinances and understand how to protect trees during construction.

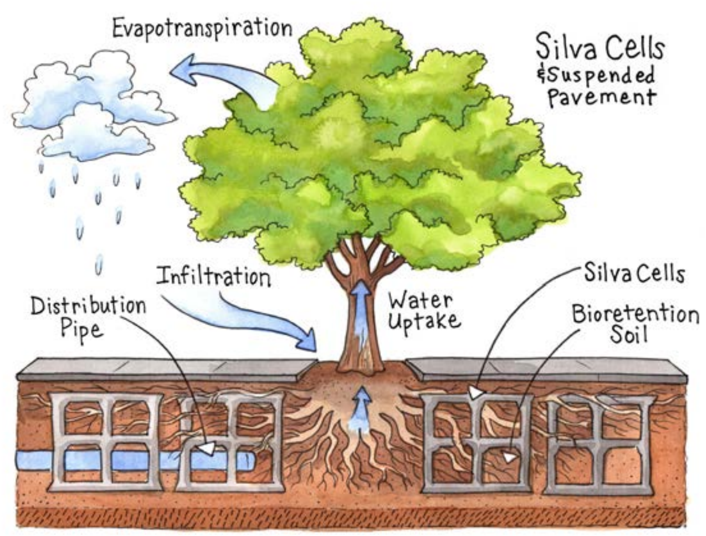



Tree Protection Fence and Signage

## TREE PLANTING

In urban environments, many trees do not survive to their full potential life span. Factors such as lack of watering or insufficient soil volume and limited planting space put stresses on trees, stunts their growth and reduces their lifespans. For every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). This means that adequate tree well sizing standards are a critical factor in realizing the advantages of a healthy urban forest. At a minimum, canopy trees require 1000 cubic feet of soil volume to thrive. In areas where space is tighter or where heavy uses occur above, 'Silva cells' can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes).

These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will help ensure that investments in town trees will pay dividends for reducing stormwater runoff as well as clean air and water, lower energy bills, higher property values and natural beauty long into the future.




Silva Cells and Suspended Pavement

## CONCLUSION

Adapting codes, ordinances and municipality practices to use trees and other native vegetation for greener stormwater management will allow Wilmington to treat stormwater more effectively. Implementing these recommendations will significantly reduce the impact of stormwater sources (impervious cover) and benefit the local ecology by using native vegetation (trees and other vegetation) to uptake and clean stormwater. It will also lower costs of tree cleanup from storm damages since proper pruning or removal of trees deemed to be 'at risk' can be done before storms occur.

Wilmington should use the canopy map and updates to track change over time. The city can use the canopy data, analysis and recommendations and stormwater calculator tool to continue to create a safer, cleaner, cost-effective and more attractive environment for all.

# Appendixes

## APPENDIX A: METHODS — TECHNICAL DOCUMENTATION

This section provides technical documentation for the methodology and results of the land cover classification used to produce both the Land Cover Map and Potential Planting Scenarios for Wilmington.

Land cover classifications are an affordable method for using aerial or satellite images to obtain information about large geographic areas. Algorithms are trained to recognize various types of land cover based on color and shape. In this process, the pixels in the raw image are converted to one of several types of pre-selected land cover types. In this way, the raw data (i.e. the imagery) are turned into information about land cover types of interest, e.g. what is pavement, what is vegetation. This land cover information can be used to gain knowledge about certain issues; for example: What is the tree canopy percentage in a specific neighborhood?

### Land cover classification

NAIP 2016 Leaf-on imagery (4 band, 1-meter resolution) was used for the land cover classification. The full set of NAIP data was acquired through the Earth Resources Observation and Science (EROS) Center of the U.S. Geological Survey.

### Pre-processing

The NAIP image tiles were first re-projected into the coordinate system used by:

NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet
WKID: 2264 Authority: EPSG

Projection: Lambert_Conformal_Conic
False_Easting: 2000000.002616666
False_Northing: 0.0
Central_Meridian: -79.0
Standard_Parallel_1: 34.33333333333334
Standard_Parallel_2: 36.16666666666666
Latitude_Of_Origin: 33.75
Linear Unit: Foot_US (0.3048006096012192)
Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

### Supervised classification

The imagery was classified using an object based supervised classification approach. The ArcGIS extension Feature Analyst was used to perform the primary classification with a 'bulls eye' object recognition configuration and was used to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables GIS analyst to rapidly and accurately collect vector feature data from high-resolution satellite and aerial imagery. Feature Analyst uses a model-based approach for extracting features based on their shape and spectral signature.

For better distinction between classes an NDVI image was created using Raster Calculator instead of ArcGIS' Imagery Analyst menu for consistency. The NDVI image along with the source NAIP bands (primarily 4,1 and 2) were used to identify various features where they visually matched the imagery most accurately.

### Post-processing

The raw classifications from Feature Analyst then went through a series of post-processing operations. Planimetric data were also used at this point to improve the classification. Roads, sidewalks, and trails were 'burned in' to the raw classification (converted vector data to raster data, which then replaced the values in the raw classification). The 'tree canopy' class was not affected by the burn-in process, however, because tree canopy can overhang streets. These data layers were also used to make logic-based assumptions to improve the accuracy of the classification. For example, if a pixel was classified as 'tree canopy,' but that pixel overlaps with the roads layer, then it was converted to 'Tree Cover over Impervious.' The final step was a manual check of the classification. Several ArcGIS tools were built to automate this process. For example, the ability to draw a circle on the map and have all pixels classified as 'tree canopy' to 'non-tree vegetation,' which is a process usually requiring several steps, is now only a single step.

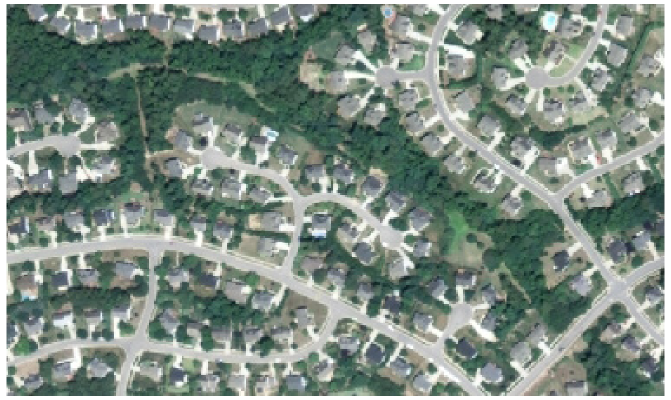


### Potential Planting Area Dataset

The Potential Planting Area dataset has three components. These three data layers are created using the land cover layer and relevant data in order to exclude unsuitable tree planting locations or where it would interfere with existing infrastructure.

1. Potential Planting Area (PPA)
2. Potential Planting Spots (PPS)
3. Potential Canopy Area (PCA)

The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees, then eliminating areas that would interfere with existing infrastructure.



NAIP Image 2016

### Inclusion Features

- Pervious surfaces
- Bare Earth

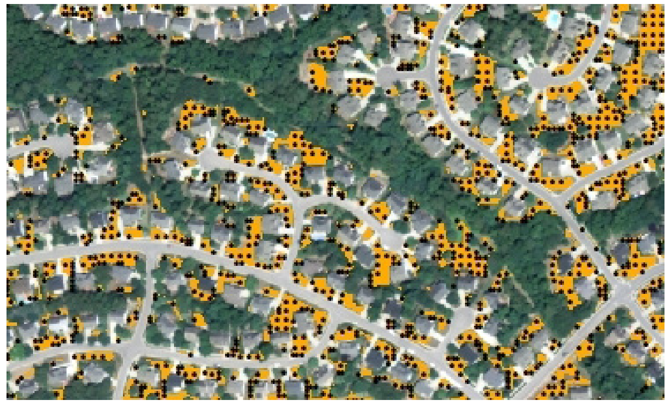
### Exclusion Features

- Existing tree cover
- Water
- Wetlands
- Imperious surfaces
- Ball Fields (i.e.: Baseball, Soccer, Football) where visually identifiable from NAIP imagery. (Digitized by GIC)

Potential Planting Area (PPA)

### Impervious surfaces setback

- Roads (based on road width estimate from centerlines) (5ft)
- Sidewalks (5ft)
- Railroads (10ft)
- Buildings (15ft) acquired from imagery
- Hydrological Features (10ft)
- Stormwater pipes (5ft)
- Sewer pipes (5ft)



Potential Planting Spots (PPS)

### Potential Planting Spots

The Potential Planting Spots (PPS) are created from the PPA. The potential planting area (PPA) is run through a GIS model that selects spots a tree can be planted depending on the size trees that are desired.

- Tree planting scenario was based on a 20 ft. and 40 ft. mature tree canopy with a 30 percent overlap.

### Potential Canopy Area

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are given a buffer around each point, this represents a tree's mature canopy. For this analysis they are given a buffer radius of 10 or 20 ft. that results in 20 and 40 ft. tree canopy spread.

Potential Canopy Area (PCA)

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