TREES TO OFFSET STORMWATER

Case Study 09: City of Lynchburg, Virginia

December 2018

The Green Infrastructure Center Inc. is the technical services consultant for this project and the case study author. Illustrations in the report are by the Green Infrastructure Center Inc. (GIC).

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Lynchburg

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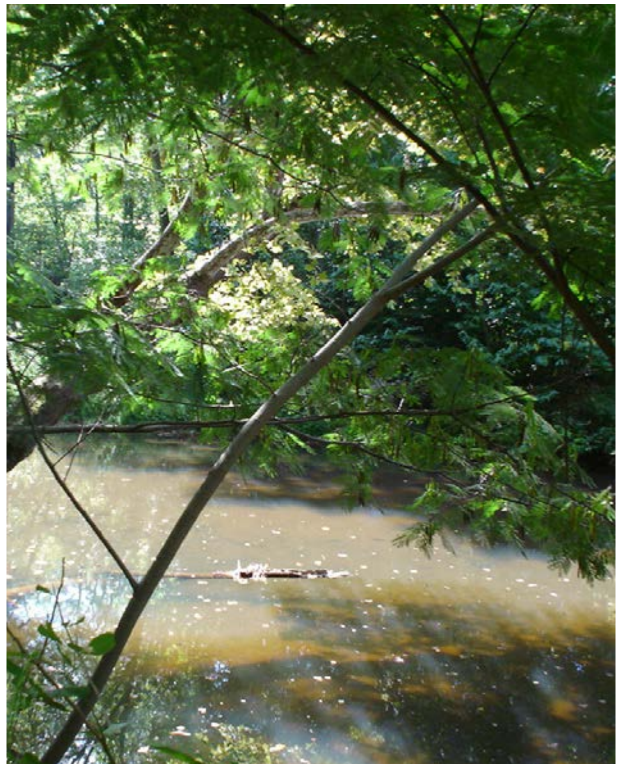
PROJECT OVERVIEW

This project Trees to Offset Stormwater is a study of Lynchburg's tree canopy and its role in taking up, storing and releasing water. This study was undertaken to assist Lynchburg 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 how the city can benefit from tree conservation and replanting. It also evaluates ways for the city to improve forest management as the city re-develops.

PROJECT FUNDERS AND PARTNERS

The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama. The GIC created the data and analysis for the project and published this report. This study is one of 12 pilot projects evaluating a new approach to estimate the role of trees in stormwater uptake. The USDA Forest Service provided the funding for Virginia to determine how trees can be utilized to meet municipal goals for stormwater management. The Virginia Department of Forestry (VaDOF) administered the pilot studies in Virginia and selected Lynchburg to be one of the three test cases. The cities of Harrisonburg and Norfolk are the other municipalities selected for study.

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, lack of tree replacement as older trees die, and for coastal cities such as Norfolk, inundation from Sea Level Rise. 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, Lynchburg now has baseline data against which to monitor canopy protection progress, measures for the stormwater and water quality benefits provided by its urban forest, and locations for prioritizing canopy replanting.



Blackwater Creek

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 Lynchburg's urban forest. 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 about the pilot studies as a case study at regional and national conferences, and
- A case book and presentation detailing the study methods, lessons learned and best practices.

The project began in September 2016 and Lynchburg 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): The Departments of Water Resources, Parks and Recreation, Community Development and Public Works and the Geographic Information System Division.

Two community meetings were held. The first meeting held in May 2018 provided an overview of the project. The second meeting held in November 2018 provided recommendations (listed below) for the city and elicited feedback. Comments from both meetings were provided to the city.

Participants discuss tree planting potential.

At the first meeting, residents learned about the project and offered suggestions to improve tree management and canopy coverage. At the second meeting they learned about the project's findings, provided their opinions and made additional suggestions to conserve the city's canopy. Participants included local educators who were keen to use the data and stormwater calculator tool in their college classes. In addition, participants suggested that schools lack canopy and should be prioritized as places for future planting projects.

At the second meeting, GIC presented specific code/ordinance or practice changes recommended for adoption by the city. Meeting attendees were asked to choose the top three changes they felt would most benefit the urban forest and reduce runoff.

Each participant voted for the top three strategies they believed to be most effective for growing/protecting the urban forest. The policy or code changes are listed below in priority order (most to least popular).

1. Publicize right of way plantings provided by the city to re-green neighborhoods.
2. Adopt a stream buffer ordinance.
3. Calculate funding needed to manage and grow the urban forest.
4. Require protection of critical root zones during construction.
5. Develop and enforce codes and ordinances that protect privately owned trees.
6. Redesign streets as complete green streets
7. Accommodate large trees in urban areas by providing adequate soil volume.

Water Quality Manager Erin Hawkins (left) listens to community ideas for the city's trees.

Lynchburg can use this report and its associated products to:

- *Set canopy goals by watershed and develop management plans for retaining or expanding its tree canopy.*
- *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 plant trees.*
- *Support grant applications for tree conservation projects.*

SUMMARY OF FINDINGS

Satellite imagery was used to classify the types of land cover in Lynchburg (for more on methods see page 18). This shows the city those areas where vegetative cover helps to uptake water and those areas where impervious land cover is more likely to result in stormwater runoff. High-resolution tree canopy mapping provides a baseline 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 from the study was provided to Lynchburg.

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 to intercept and soak up runoff. Tree canopy serves as 'green infrastructure' that can provide more capacity for the city's grey infrastructure (i.e. stormwater drainage systems) by absorbing or evaporating excess water before it runs off. The stormwater model created for this project shows how the city can reduce potential pollution of its surface waters, which can impact Total Maximum Daily Load (TMDL) outcomes and watershed plans.

The detailed land cover analysis created for the project was used to model 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 growing in a more natural setting (e.g. a cluster of trees in an urban forest), a lawn setting, or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water.

As city trees are evaluated, it's important to remember that trees within a cluster provide more value than individual trees alone because they also tend to have a more natural ground cover, more leaf litter (as they are not managed or mowed under) and less compacted soils. Thus, there is more stormwater retention for trees found in a natural setting than a tree over a lawn or over pavement. Trees also shelter one another from wind damages and are less likely to fall. As cities develop and lose forest, trees planted in isolation do not provide equivalent value as the same number of trees found clustered together. Therefore, when counting total trees in a city, managers should also consider the setting in which those trees are found and they should protect intact forested clusters of trees as often as possible. The Chesapeake Bay Program also provides a Best Management Practice (BMP) credit for planting trees. For more on the credit system, see Appendix C.

One mature tree can absorb thousands of gallons of water per year.

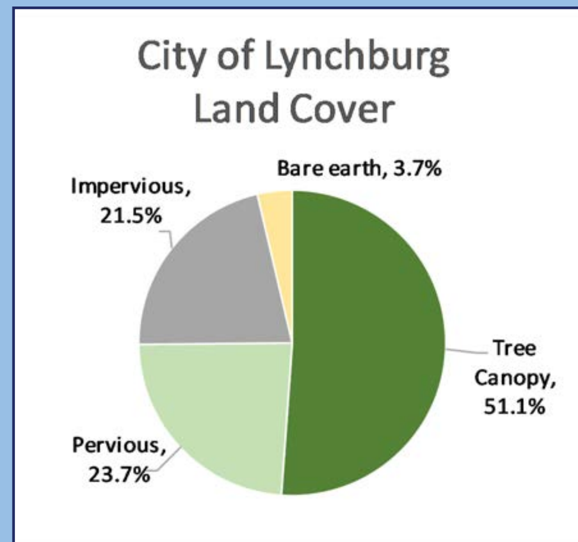
During an average high volume rainfall event in Lynchburg (a 10-year storm), over 24 hours the city's trees take up an average of 70 million gallons of water.

That's 105 Olympic swimming pools of water!

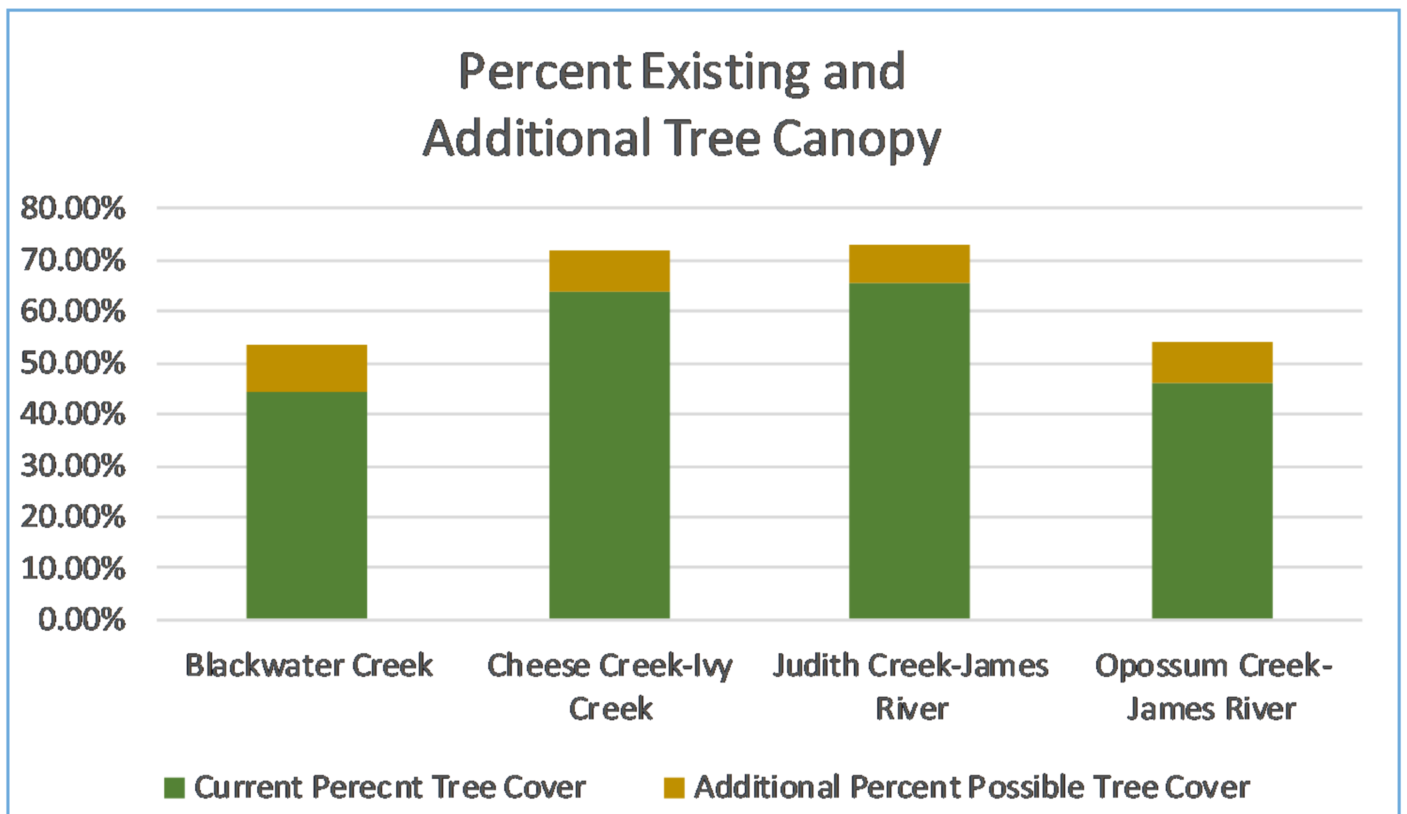
Lynchburg: Fast Facts & Key Stats

- Piedmont community in central Virginia.
- 2017 U.S. Census Population Estimate: ...... 80,995 people
- City Area From Land Cover
  - Total area: .... 49.48 sq. mi.
  - Land: .... 48.86 sq. mi.
  - Water: .... 0.62 sq. mi.
  - Streams: .... 101.5 miles*
  - Tree Canopy: .... 23,216 acres (51%)

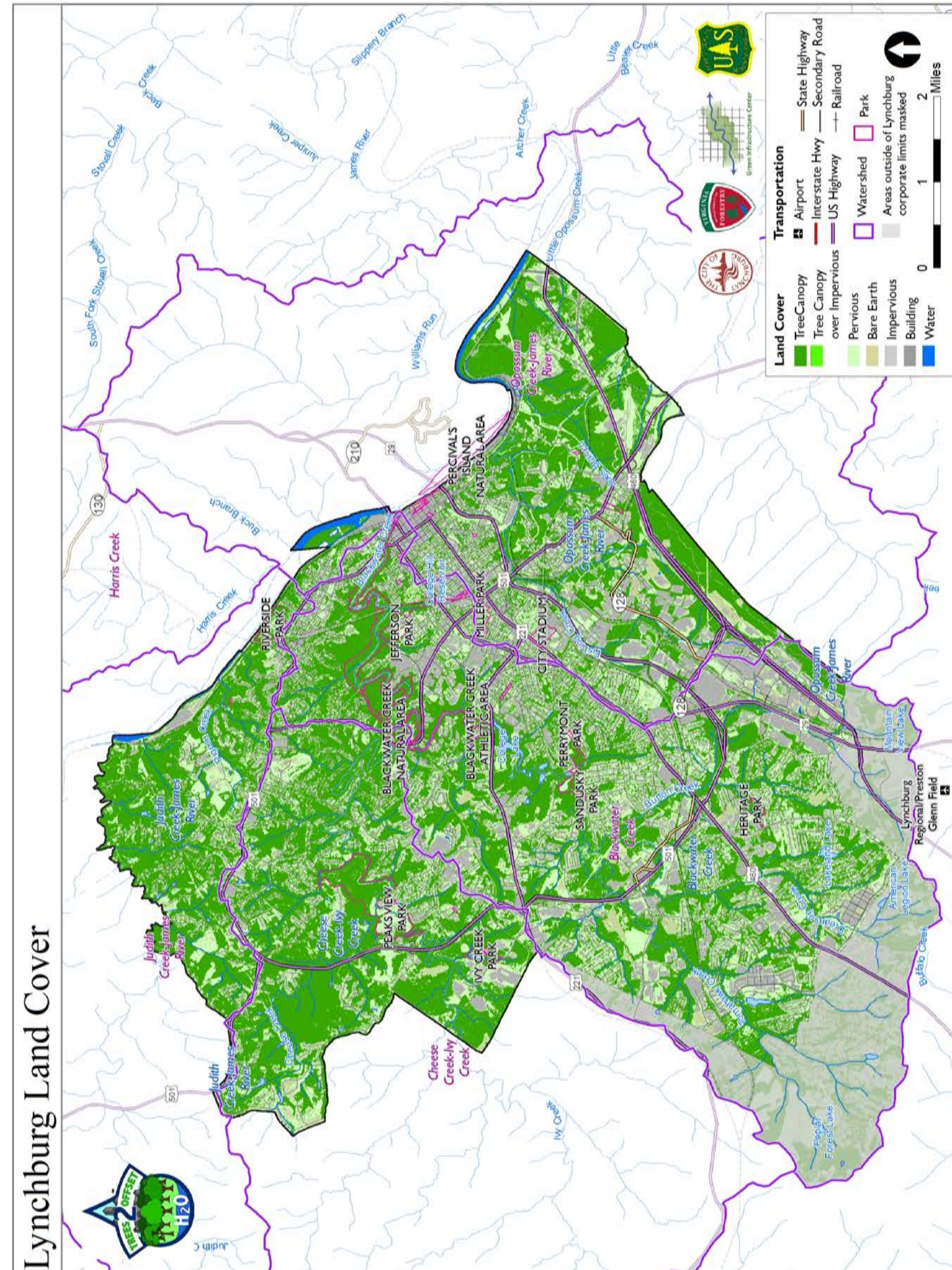
*Source: US Geological Survey



Citywide tree canopy is 51.1 percent.



Percent Tree Cover and Possible Planting Area by Watershed



This map shows the tree canopy of the city which covers 51.1 percent of the area.

WHY PROTECT OUR URBAN FORESTS?

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 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). In comparison to other Virginia cities, at 51 percent canopy (roughly half of the city), Lynchburg has very good urban forest coverage.

Despite its relatively high canopy, Lynchburg has lost natural forest cover as the city has grown. The city may see losses in the future if replanting rates decline. As older trees die (or before they die), younger trees need to be planted to restore the canopy. For recommendations on 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 development, but to help the city better utilize its tree canopy to manage stormwater. Additional benefits of improved canopy include:

- cleaner air
- aesthetic values
- reduced heating and cooling costs
- decreased urban heat island effects
- buffering structures from wind damage
- increased bird and pollinator habitat
- fostering walkability and multimodal transportation and
- increased revenue from tourism and retail sales

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

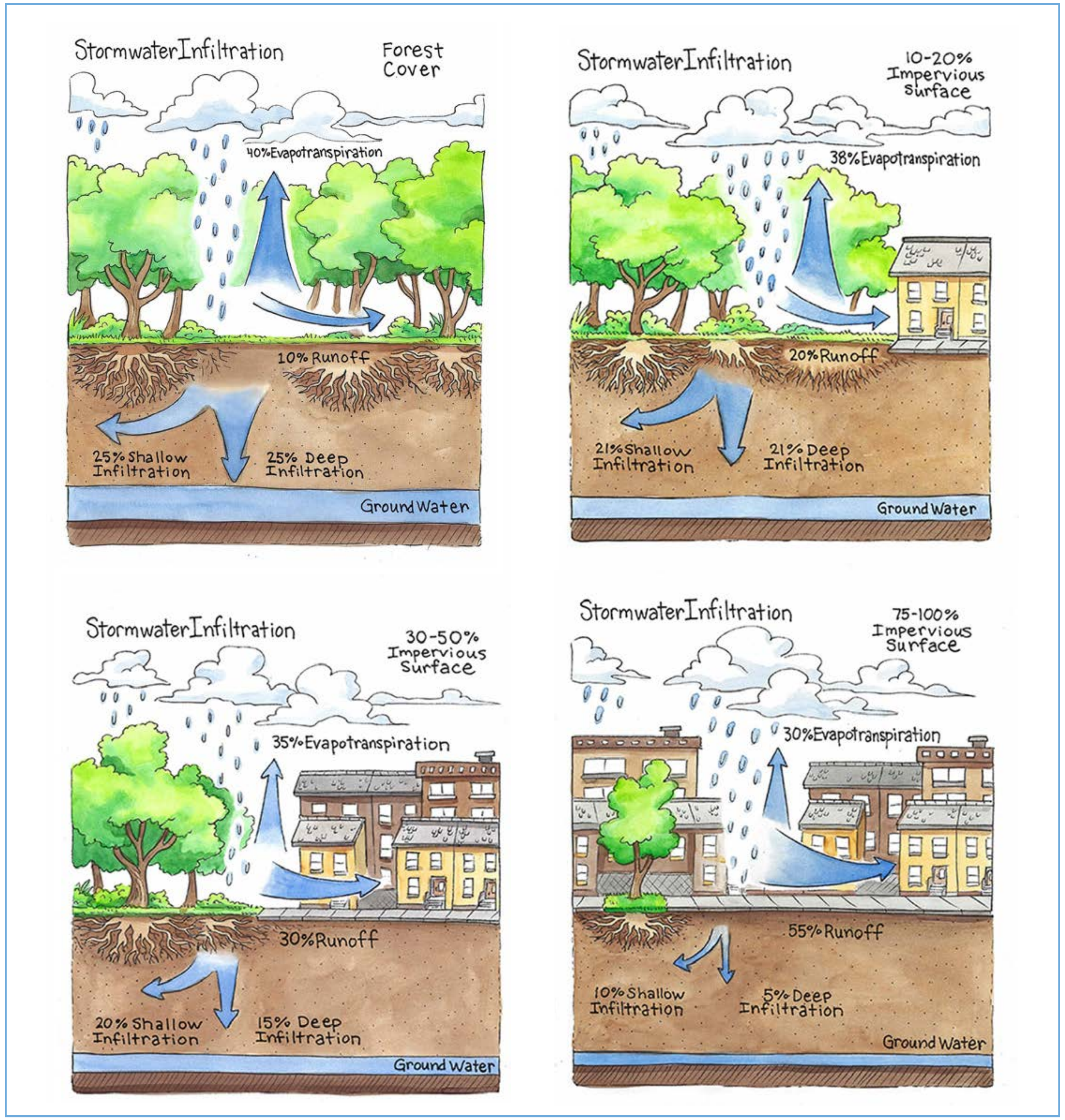
Older established neighborhoods still need new trees to be planted to replace older trees as they age and die.

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*.

As their urban forest canopies have declined across the south, municipalities have seen increased stormwater runoff. Unfortunately, many cities do not have a baseline analysis of their urban forests or strategies to replace lost trees. In evaluating runoff, the amount of imperviousness is one consideration; the other is the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff.

When forested land is converted to impervious surfaces, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving waters, increased potential for pollution of surface and ground waters and greater potential for flooding. When underground aquifers are not replenished, land subsides.

Another cause of canopy decline is the many recent powerful storms that have affected the Southeastern United States. This study was funded to address canopy decline 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.



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. On average, 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 trees 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, as an older city, parts of Lynchburg may lack stormwater management practices that are now required for new developments.

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 seven 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 also 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, annual stormwater runoff could be reduced by millions of gallons. This means less flooded neighborhoods and reduced stress on storm drainage pipes and decreased runoff into the city's creeks.

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

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. Not only do trees reduce the likelihood of extensive flooding, they also serve as a buffer against storm damages from wind.

In urban areas, 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 in the Methods Appendix).

Tree Planting

Trees in residential yards also help to soak up rainfall.

ADDITIONAL URBAN FOREST BENEFITS

Quality of Life Benefits

During Virginia'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. Trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Shaded pavement has a longer lifespan thereby reducing maintenance costs associated with repairing or replacing roadways and sidewalks (McPherson and Muchnick 2005).

Trees provide substantial shade and beauty.

Communities with greener landscapes benefit children by reducing both asthma and ADHD symptoms.

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).

Young tree planters in Lynchburg

Well treed areas encourage people to walk.

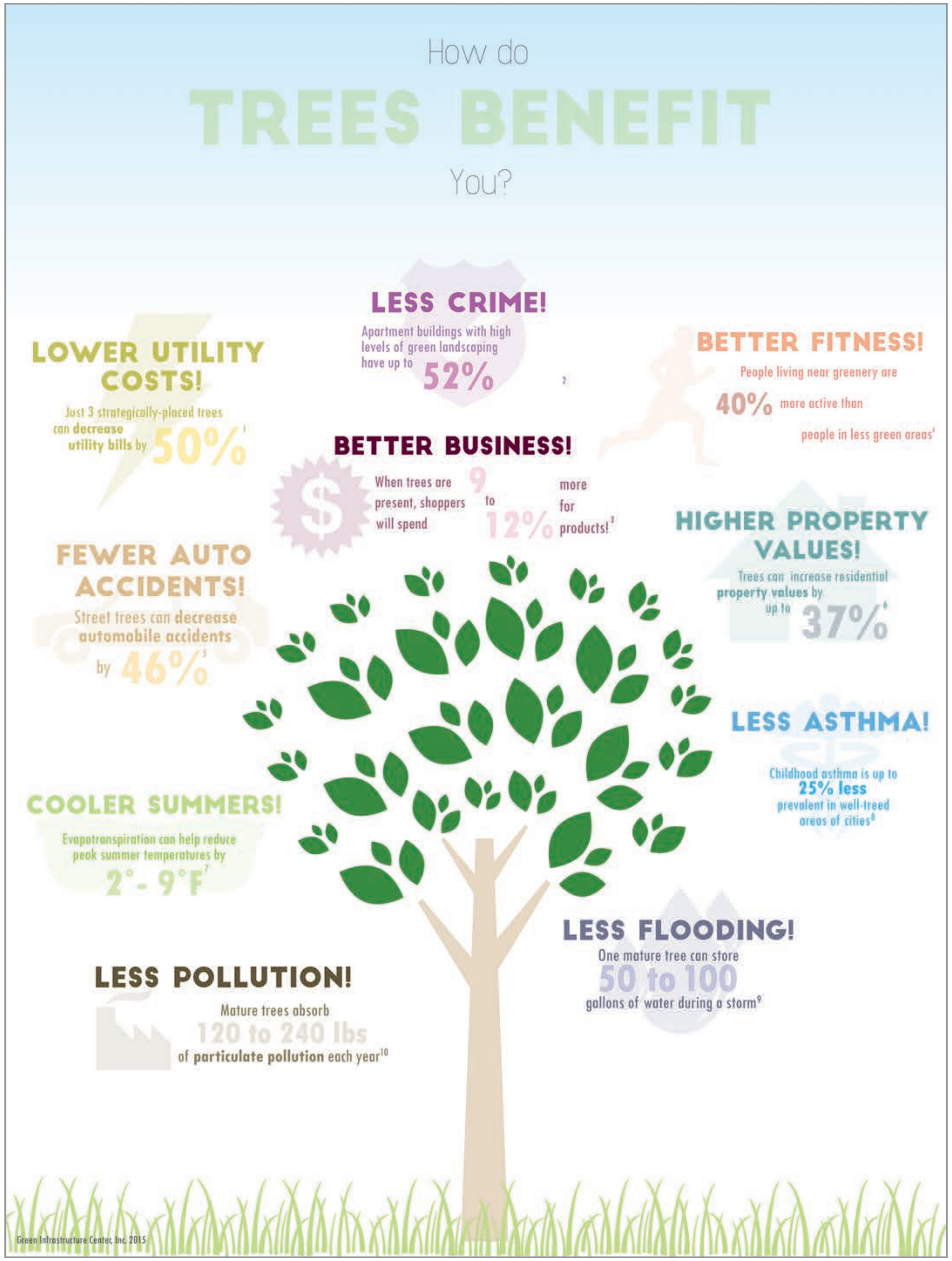
Economic Benefits

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). This desire for green space is supported by a National Association of Realtors study which 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 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 Virginia 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) 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. Two thirds of Virginia are under the Chesapeake Bay TMDL and must follow the bay's Watershed Implementation Plan (WIP) to reduce the impacts of nitrogen, phosphorus and sediment reaching the Bay. The Chesapeake Bay Program has adopted a standard for tree planting to provide credit for the WIP. See Appendix C for an explanation of how to use the credit.

There are many places where trees can be added for shade and beauty.



NATURAL ECOLOGY IN CHANGING LANDSCAPES

Natural history, even of an urbanized location, informs planting and other land-management decisions. Lynchburg is located in the Piedmont Region of Virginia, characterized by gently rolling, well-rounded hills and long, low ridges with a few hundred feet of elevation difference between the hills and valleys. It generally has high-grade metamorphic rocks and scattered igneous intrusions. Its vegetation consists of early succession and scrub-shrub habitat with low, woody vegetation and herbaceous plants with periodic disturbances that result in dense understory vegetation. The Köppen climate classification lists the city's climate as humid subtropical. Although the landscape of the City of Lynchburg is highly altered, the urban forest still supports birds, bees and other pollinators while providing shade and cooling for the city and water quality benefits.

Planting understory shrubs and other vegetation will help soak up rainwater and are better than lawns for reducing runoff.

HISTORIC LAND COVER

Alterations to the landscape began with its original inhabitants and accelerated most dramatically with urbanization in the latter half of the 20th century. The first settlers of the area were the Monacan Indians who inhabited the region well into the 17th century and Monacan descendants still live in the area today. The city was named for its founder, John Lynch, who started a ferry service across the James River in 1757. In 1786, a charter for a town of 45 acres was granted and funds were appropriated in order to improve the navigability of the James River, primarily to move tobacco products to Richmond in shallow draft boats known as batteaux. Lynchburg formally became a city in 1852. As a Piedmont landscape, the city is characterized by small hills known as the original seven hills of the city: College Hill, Garland Hill, Daniel's Hill, Federal Hill, Diamond Hill, White Rock Hill, and Franklin Hill.

Trees in the city's parks account for significant canopy in the city.

Trees along Lynchburg's extensive trail network create an inviting pathway to traverse the city.

GROWTH AND DEVELOPMENT CHALLENGES

Manufacturing has been the basis for the city's past development. For example, cast iron pipes and fittings became a major manufacturing base for the city in the 1930s. By the 1850's the city was one of the richest Tobacco communities in the nation, and other sectors also became prominent, such as cotton and shoes. The city also played a large role during the Civil War and World wars in manufacturing goods and supplies for the war efforts.

The city's population has increased 7.2 percent since the 2010 census (U.S. Census Bureau). Demands for space to meet the needs for housing, commercial, business, and transportation uses put strains on both the city's grey and green infrastructure. Although the city's economy was largely driven by manufacturing, today it is also a 'college town.' Lynchburg has annexed land to reach its current size and to meet the demand for growth driven by Liberty University with a student population of 45,000 spread over 7,000 acres, along with the smaller schools of University of Lynchburg with 2,800 students and Randolph College with 679 students.

The city's past contributes to its charming character today. Although manufacturing has declined in the city, many of the historic warehouses have been repurposed as shops, condos and restaurants, while many of the stately older homes from manufacturing's heyday are still found in the city's eight historic districts.

Lynchburg has embraced the scenic and tourism potential of the James River with parks, greenspaces and restaurants along the river, many of which also utilize historic industrial warehouses. The 49-acre Riverside Park is one of the city's oldest with large trees and trails that provide views of the rolling wooded hills and the river along the Alpine Trail, which was the first dedicated hiking trail in Lynchburg. Today, the city boasts 40 miles of trails that range from paved commuter pathways to more rustic Appalachian-style trails that provide a feeling of respite in the heart of an industrial city.

As Lynchburg grows, demands for green space increase. The city can use current park and school sites to help ensure tree cover is maintained and to plant more trees on public lands and right of way spaces to replace aging canopy in the future.

Trees planted (at left) will eventually become shade trees in the historic downtown.

Parks enhance the city's livability and soak up rainfall.

DEVELOPMENT AND STORMWATER

As an older city, established in 1786, there are areas that pre-date the 1987 Clean Water Act Amendments which require the treatment of stormwater runoff. Adding stormwater treatment for 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 Codes, Policies and Practices section of this report.

Stormwater should be captured to reduce the volume of water reaching storm drains.

Johnny Appleseed tells residents why and how to plant more trees in Lynchburg.

Reducing imperviousness and increasing vegetation are one way to ease the frequency of flooding because this limits the amount of water that needs to be drained by the storm drainage system. Vegetation reduces water entering the system by intercepting, capturing and transpiring that water.

The requirements set forth by the Clean Water Act of 1972 for the Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES) permitting program, and subsequent amendments in 1987 regulating nonpoint source pollution, form the foundation for the city's stormwater management program.

Planting the Arbor Day Tree

Residents can make a difference in runoff by planting trees and other vegetation to soak up runoff..

ANALYSIS PERFORMED

This project evaluated options for how to best model 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 17. However, new tools created for the project allow the stormwater benefits of tree conservation or additions as to be calculated at the large 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 below.

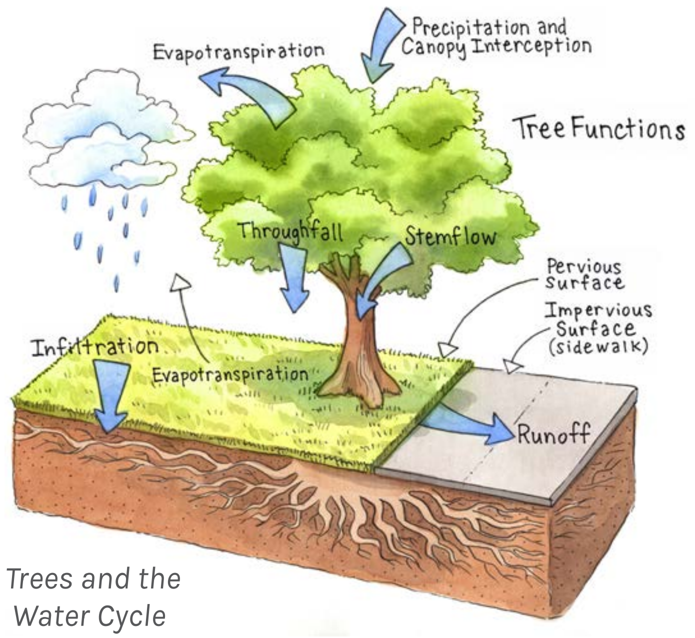
METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

This project provides 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. The chart shows the canopy breakdown by watersheds.

Watersheds in Lynchburg	Percent Tree Canopy Within City Limits
Blackwater Creek	44.5%
Cheese Creek - Ivy Creek	63.8%
Judith Creek - James River	65.5%
Opossum Creek - James River	46.1%
Citywide	51.1%

Currently, most cities use TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to model expected runoff amounts. This study used modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers and used for site plans to calculate stormwater. The equation used to calculate runoff includes a factor for canopy interception of stormwater.

Curve numbers produced by this study can be utilized in the city's modeling and design reviews. The project's spreadsheet calculator tool makes it very easy for the city to change the curve numbers if they so choose. The input to the calculator comes from the GIS land cover maps. When those maps are updated in the future (GIC recommends updates every 5 years) then new data can be input into the spreadsheet. 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

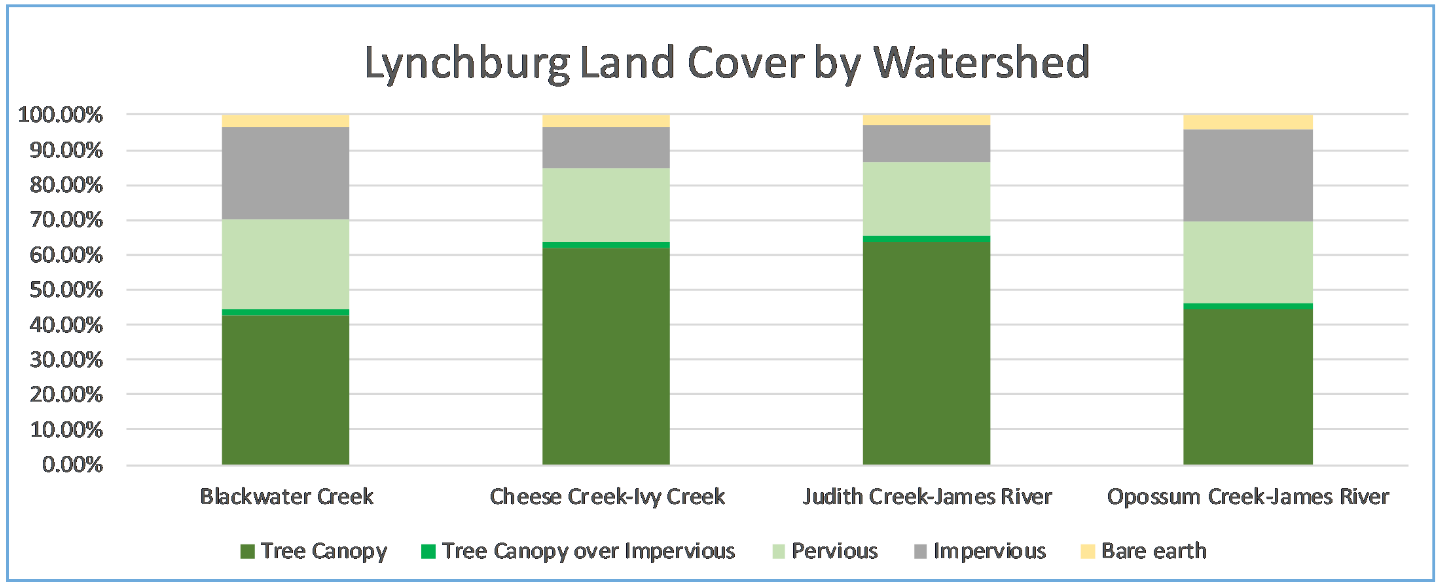
Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. In a study, Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing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

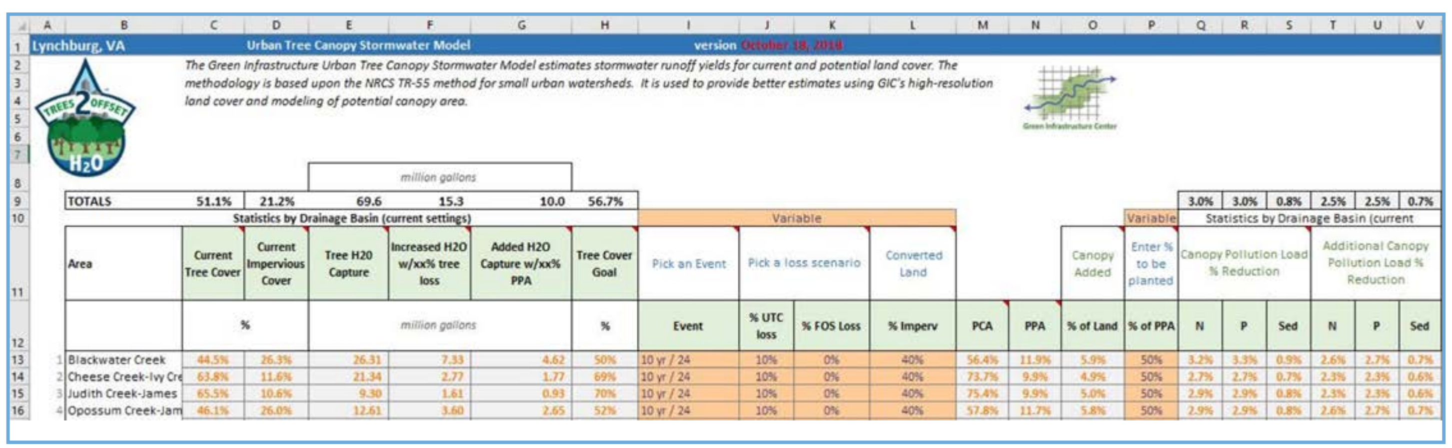
Major factors in determining Curve Numbers (CN) are:

- 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



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. In order to use the equation and model scenarios for future tree canopy and water uptake, the GIC 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 shown below. The actual model spreadsheet was provided to Lynchburg. It links to the land cover statistics for each type of planting area. It also allows the city to hypothetically add or reduce tree canopy to see what are the effects for stormwater capture or runoff. The key finding from this work is that removal of mature trees generates the greatest impacts for stormwater runoff. As more land is re-developed in Lynchburg, the city should maximize tree conservation to maintain 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. Several studies have shown that higher tree canopy percentage is associated with lower overall hospitalization numbers and also with lower hospital visits from asthma.


Lynchburg, VA — Urban Tree Canopy Stormwater Model — version October 18, 2018

The Green Infrastructure Urban Tree Canopy Stormwater Model estimates stormwater runoff yields for current and potential land cover. The methodology is based upon the NRCS TR-55 method for small urban watersheds. It is used to provide better estimates using GIC's high-resolution land cover and modeling of potential canopy area.

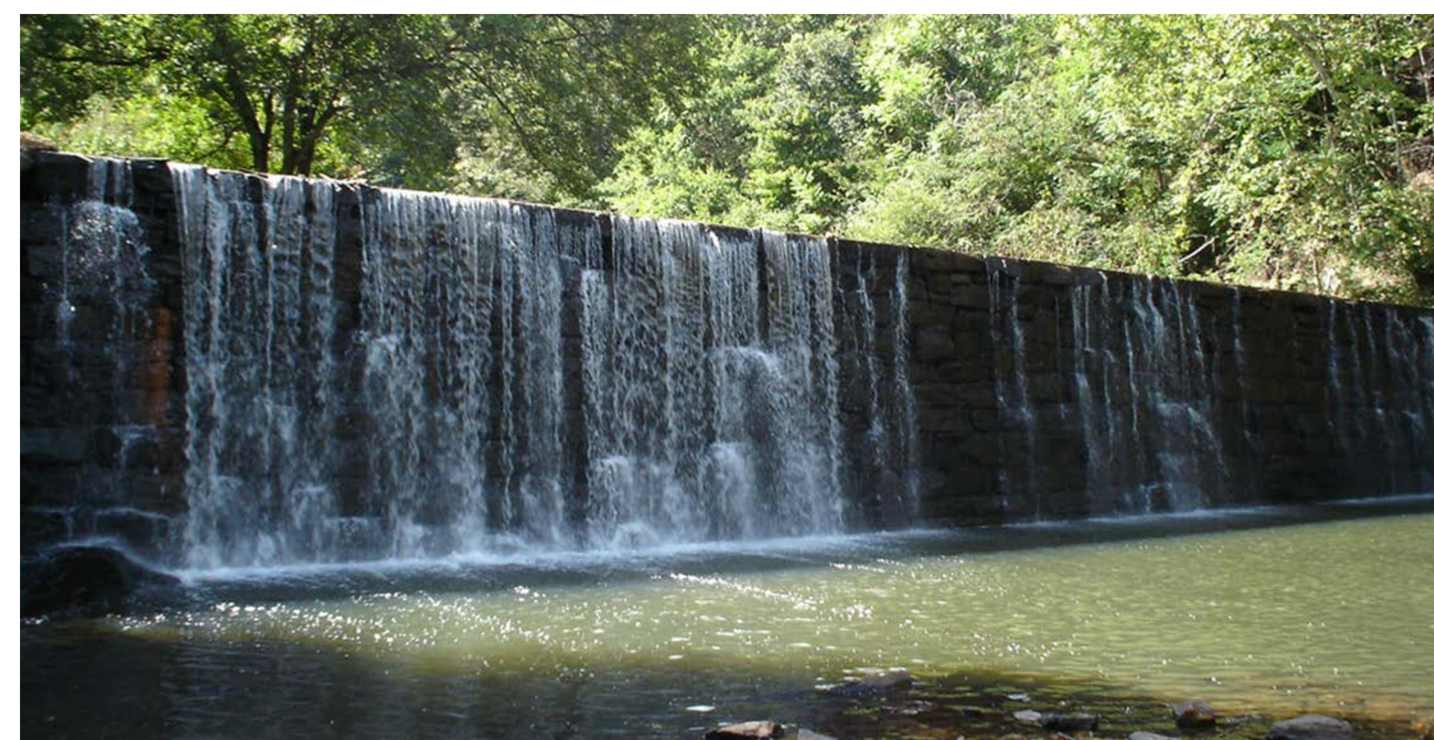
Area	Current Tree Cover (%)	Current Impervious Cover (%)	Tree H20 Capture (million gallons)	Increased H2O w/xx% tree loss (million gallons)	Added H2O Capture w/xx% PPA (million gallons)	Tree Cover Goal (%)	Pick an Event: Event	Pick a loss scenario: % UTC loss	Pick a loss scenario: % FOS Loss	Converted Land: % Imperv	PCA	PPA	Canopy Added: % of Land	Enter % to be planted: % of PPA	Canopy Pollution Load % Reduction: N	Canopy Pollution Load % Reduction: P	Canopy Pollution Load % Reduction: Sed	Additional Canopy Pollution Load % Reduction: N	Additional Canopy Pollution Load % Reduction: P	Additional Canopy Pollution Load % Reduction: Sed
TOTALS	51.1%	21.2%	69.6	15.3	10.0	56.7%									3.0%	3.0%	0.8%	2.5%	2.5%	0.7%
1 Blackwater Creek	44.5%	26.3%	26.31	7.33	4.62	50%	10 yr / 24	10%	0%	40%	56.4%	11.9%	5.9%	50%	3.2%	3.3%	0.9%	2.6%	2.7%	0.7%
2 Cheese Creek-Ivy Cre	63.8%	11.6%	21.34	2.77	1.77	69%	10 yr / 24	10%	0%	40%	73.7%	9.9%	4.9%	50%	2.7%	2.7%	0.7%	2.3%	2.3%	0.6%
3 Judith Creek-James	65.5%	10.6%	9.30	1.61	0.93	70%	10 yr / 24	10%	0%	40%	75.4%	9.9%	5.0%	50%	2.9%	2.9%	0.8%	2.3%	2.3%	0.6%
4 Opossum Creek-Jam	46.1%	26.0%	12.61	3.60	2.65	52%	10 yr / 24	10%	0%	40%	57.8%	11.7%	5.8%	50%	2.9%	2.9%	0.8%	2.6%	2.7%	0.7%

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).

The stormwater runoff model provides estimates of precipitation capture by tree canopy 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.

The trees and stormwater model can be used to estimate the impact of the current canopy, possible losses to that canopy, and potential for increasing that canopy. As shown on the previous page, for a 10-year,* 24-hour storm, a loss of 10% of the urban tree canopy would increase runoff by 15.3 million gallons, while increasing canopy coverage from the current 51 to 57 percent will decrease runoff by almost 10 million gallons for that storm event.

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 tree cluster, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. Tree setting is considered 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.



* A 10-year storm refers to the average recurrence interval, or a 10 percent chance of that level of rainfall occurring.

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. These data are from aerial images that are flown every two years by the USDA. Ancillary data for roads (from Lynchburg government), 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) Wetlands not distinguishable using spectral/feature-based image classification tools.

In cities studied for this project, 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 six classes listed below. The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. (i.e., areas where the growth of a tree will not affect or be affected by existing infrastructure.) Of the six land cover classes, only pervious (grass and scrub vegetation) is considered for PPA.

- Tree Canopy
- Tree Canopy over Impervious
- Pervious
- Impervious
- Bare earth
- Water

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 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) that are unlikely to be used for tree planting areas but that may not have been 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 PPA represents the maximum potential places trees can be planted and grow to full size. A good rule is to assume about half the available PPA space could actually be planted with trees.

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

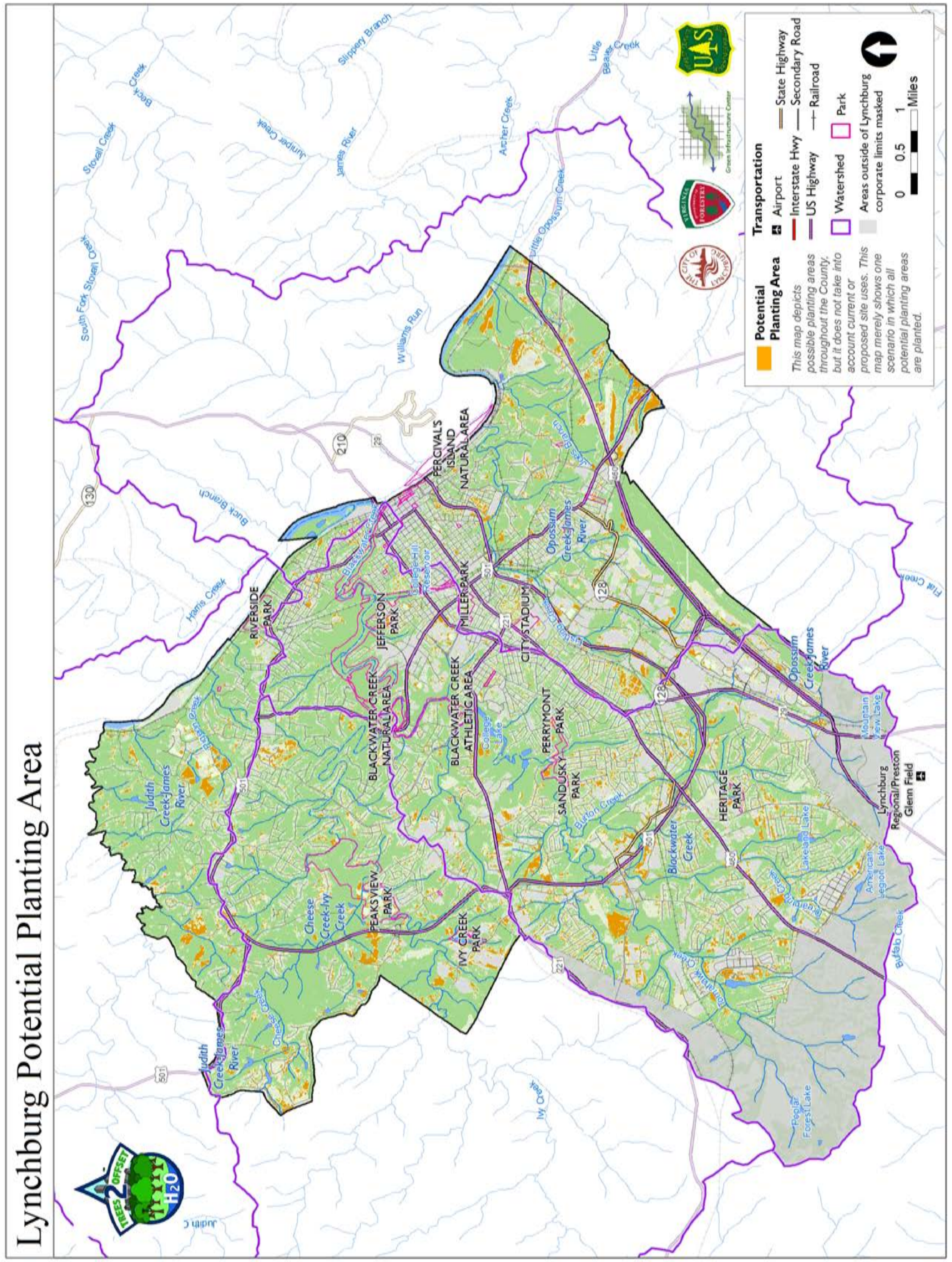

Adding more canopy can help alleviate flooding.


Tree over street

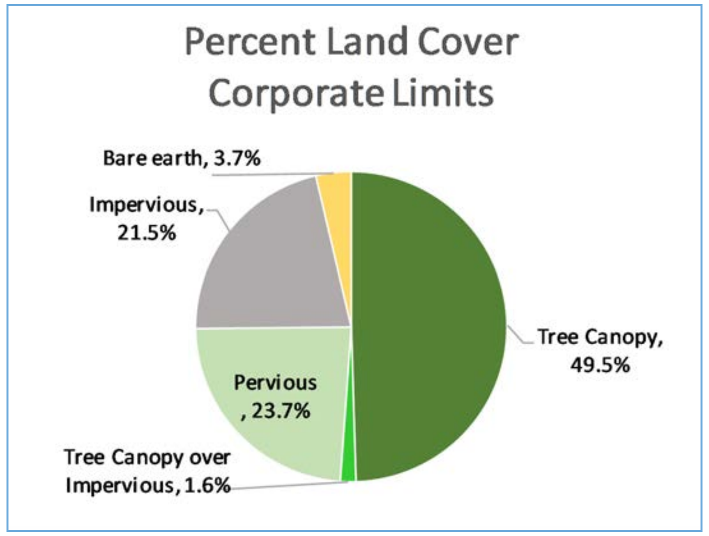

Trees over forest

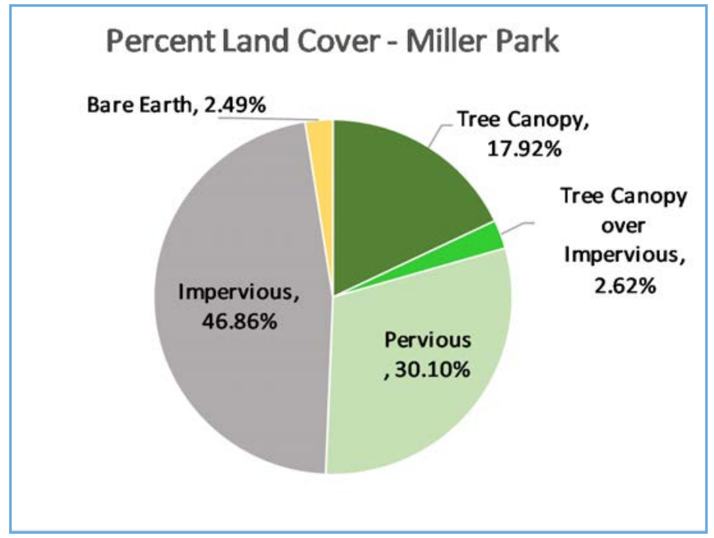

Tree over lawn


Tree over parking lot



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.





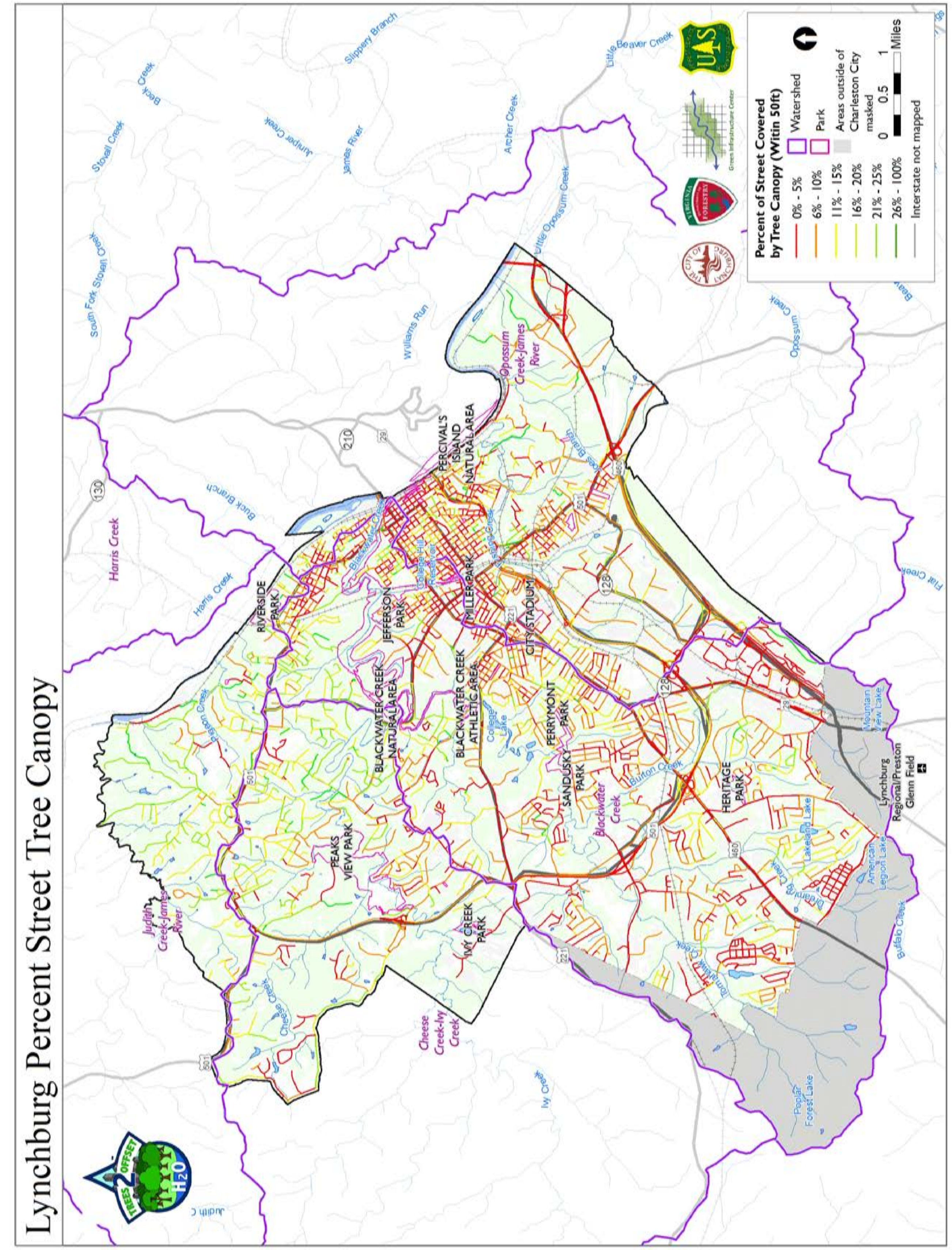
Potential Planting Spots (PPS)

Potential Canopy Area (PCA)

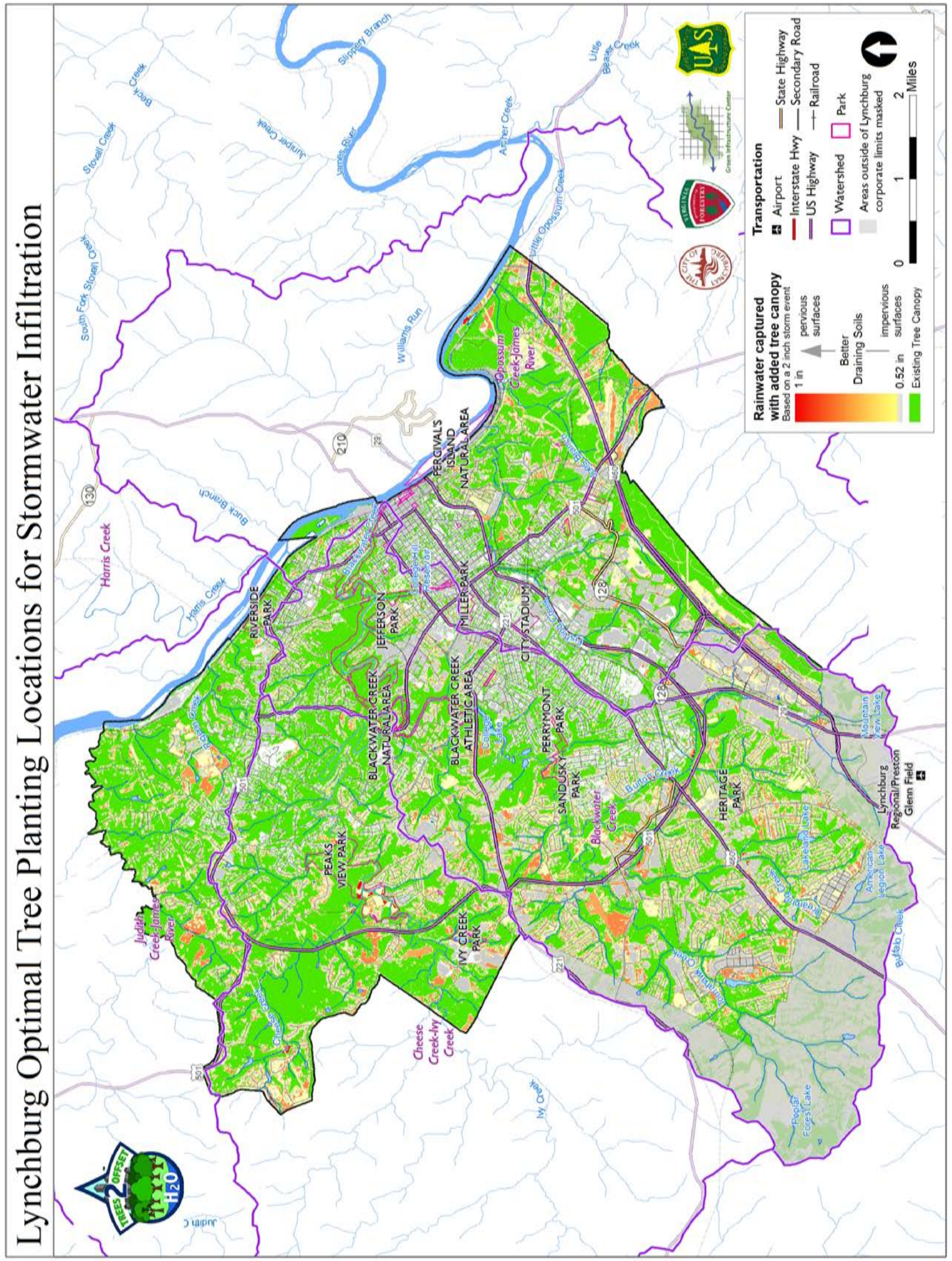
The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots where a tree can be planted depending on the size of trees desired. For this analysis, expected sizes of both 20 ft. and 40 ft. diameter of individual mature tree canopy were used 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. Similarly, the tree buffer radius is 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.



This map shows where tree planting will yield the greatest benefits for stormwater infiltration (darkest orange).

See Methods Appendix for more details on mapping methodology.

CODES, ORDINANCES AND PRACTICES REVIEW

This review is designed to determine which practices make the city 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 for 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 provides additional ideas for improvement.

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 can be used 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 studied localities will be issued by GIC in 2019.

Lynchburg is one of the Virginia's longest certified 'Tree City USA' cities, with 37 years of designation as a city that cares for its trees.

Lynchburg invests staff time and funds to manage its urban forest. The city was one of the first to be 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 fact, the City of Lynchburg celebrated 37 years as a tree city in 2018. The city has one arborist on staff with the City Department of Public Works.

The city has one of the higher canopies for communities evaluated under this project. To ensure that the canopy is maintained, the GIC recommends the following strategies to increase the protections for, and maintain the size of, the forest in Lynchburg. As noted earlier, the city's canopy is 51 percent, but it is not distributed equally citywide. Even just maintaining this level of coverage requires new plantings each year. Lynchburg is one of 12 localities in a six-state area of the Southeastern U.S. to be studied and the ninth to be completed. As other places are studied, they will be compared to the city, and vice versa.

Arbor Day, celebrated annually, includes tree planting and community education.

Preparing the next generation of tree stewards!

Top recommendations to improve forest care and coverage in Lynchburg listed in priority order include the following:

1. **Hold inter-departmental meetings about proposed projects to discuss and minimize site conflicts resulting in excess tree loss.** Often, requirements such as curb/gutter, sidewalks, driveways, parking pads etc. require tree removals on-site. Many of these requirements are managed by city departments such as Transportation, Planning, and Public Works. As requirements are managed by more than one department, inter-departmental communication is a critical component of achieving site designs which minimize tree canopy loss and maximize livability and connectivity.

2. **Work with developers to shrink the development footprint to minimize impervious surface.** Holding a pre-development conference allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning.

3. **Require a tree inventory of all single trees 10 or more inches of Diameter at Breast Height (DBH) on the concept and final site plan submittal.** Lynchburg code requires an inventory of all trees that are 10 or more inches DBH on final site plan submittals. However, this is not currently practiced. The city should implement this regulation and also require this for concept plan submittal as well. Knowledge of on-site trees allows planners and urban foresters to advocate for altering concept or site plans and preserving more urban tree canopy.

4. **During construction, allow staff to enforce best management practices for protection of public and privately owned trees.** Lynchburg codes only require protection for publicly-owned trees during construction. However, the majority of Lynchburg's urban forest is privately owned and trees are often lost during construction due to damage, soil compaction, root loss etc. The city should require tree protection fencing, root pruning and matting, air spading, and aeration where appropriate at the discretion of the city forester. Tree protection fence mechanisms should also be inspected before construction commences. More trees on a site 'post development' translate to higher home values.

5. **Define the critical root zone (CRZ) as 1.5' per 1" DBH.** A CRZ establishes the zone of protection for a tree during construction. Trees are often lost during construction due to damage, soil compaction, root loss etc. The city should require the use of root pruning, root matting, and tree protection fence where appropriate at the CRZ to protect soil porosity and better conserve trees during the development process.

6. **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed and to set urban forestry goals.** The calculator provided to Lynchburg allows the city to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading changes for nitrogen, phosphorus, and sediment. As the city makes new land cover maps, that data can be uploaded to the tool to obtain new results.

7. **Develop an Urban Forest Management Plan (UFMP) for the city.** Lynchburg code currently requires development of a Community Forest Plan but the plan has not been created. The city should develop a UFMP and include the condition of the urban forest, maintenance costs, and urban tree canopy coverage goals and steps to achieve or maintain canopy. An Urban Forest Management Plan (UFMP) details a vision for urban tree canopy. It meshes local government and community interests to proactively manage the urban canopy and provide long term benefits.

8. **Use the urban forestry budget calculator to determine funds needed for tree planting goals.** Planting and maintaining additional trees costs money, but it is well worth the outcome. Determine the goal tree canopy coverage level and allocate funds to make it happen.

9. **Prioritize essential forestry maintenance activities and develop a contingency budget.** During economic downturns, urban forestry is one of the first programs to be cut from a municipal budget. The city should set a contingency budget which funds maintenance for critical tree care activities, such as watering and risk management, to be carried out while less critical items, such as sucker pruning, are allowed to be completed at a later date.

10. **Conduct a land cover assessment every four to five 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 occur.

11. **Conduct a proactive tree risk assessments, especially for densely populated portions of the city.** Tree risk assessments help proactively manage the urban forest. Diseased or damaged trees can be pruned, treated or, if necessary, removed to ensure public safety even before a citizen tree risk report is filed. The City of Lynchburg currently performs tree risk assessments and mitigation by request. However, the city could also perform a visual (Level 1) tree risk assessments on all publicly owned trees annually in densely populated areas of the city.

12. **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 street design, green streets can also create and connect habitat, reduce urban heat island effect, reduce air pollutants, and promote walking and biking. The city should develop a policy that includes the following elements: green infrastructure (trees and other vegetation), pedestrian space, bicycle lanes, and stormwater management. A complete green streets study was conducted in 2012, but it has not been fully implemented. Now is the time to re-focus on green streets and move from study to implementation!

13. **Publicize the Right of Way (ROW) tree planting program offered by the city.** Community members are largely unaware of the ROW tree planting program offered by the city. The city has a program to plant trees upon request in ROW spaces in front of homes. The city should publicize the program and re-green city streets.

14. **Allow interdepartmental access to urban forestry data and train staff in use of the urban forestry data collection software.** Urban forestry data are currently collected about Lynchburg's urban forest. However, departments outside of Public Works do not have access to the data so it is difficult to utilize the information for decision making. The city should provide data access and train staff in utilizing the data to make informed urban forestry decisions across departments and incorporate the data into city GIS systems.

15. **Develop a Lynchburg Tree Commission.** Lynchburg currently has a Tree Stewards group which conducts tree plantings, tree pruning, and educational events about trees. However, the city does not yet have a Tree Commission, a group that would serve in an advisory role to assist City Council, the Planning Commission, and city staff on issues regarding tree planting, preservation, and removal. A Tree Commission could elevate the role of the community in policies and practices that support urban forestry.

16. **Develop a stream buffer ordinance for the City of Lynchburg.** Stream buffers are forested areas adjacent to perennial, intermittent, or ephemeral streams that shade and protect waterways from erosion. A 100' stream buffer takes up more than 90% of nitrogen, phosphorus and sediment that enters surface waters. Smaller buffers can be applied for areas where space for buffers is lacking. A GIS analysis can be used to show appropriate buffer widths based on existing land uses.

Lynchburg Tree Stewards Annual Winter Tree ID Walk.

17. **Assign or hire a staff member whose job responsibilities include management of urban forestry grants as part of their position.** Grants can fund urban tree projects such as planting and performing GIS analysis. Partial staff time devoted to grant management can allow completion of urban forestry projects that may otherwise not be funded by the municipality.

18. **Use the Urban Forestry BMP credits developed by the Chesapeake Bay Program (CBP) to credit tree plantings for achievement of watershed implementation program (WIP) goals for the city or for stormwater utility fees and for MS4 plan submittal.** The Bay Program developed urban forestry BMP credits for forest buffers, urban forests, and individual urban tree plantings. Use the credits and guidelines provided within the City of Lynchburg. See Appendix C for how to apply the credits.

19. **Permit the use of bioswales instead of curb and gutter in appropriate areas of the city.** Bioswales allow for infiltration of stormwater and can beautify a city. Use bioswales instead of curb and gutter when possible, or amend current curbs and recess planting beds within planting strips to divert runoff into street bioswales.

20. **Re-use urban waste wood.** Establishing an urban waste wood program is an excellent way to engage community members and re-use a valuable product. Lynchburg should have a plan for using storm damaged trees instead of sending them to a landfill. Lynchburg should launch a city-wide campaign encouraging the re-use of waste wood and let citizens and businesses know how to participate. Proceeds from sale of urban waste wood can fund tree plantings. For more ideas see: https://www.vibrantcitieslab.com/research/waste-management/

BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

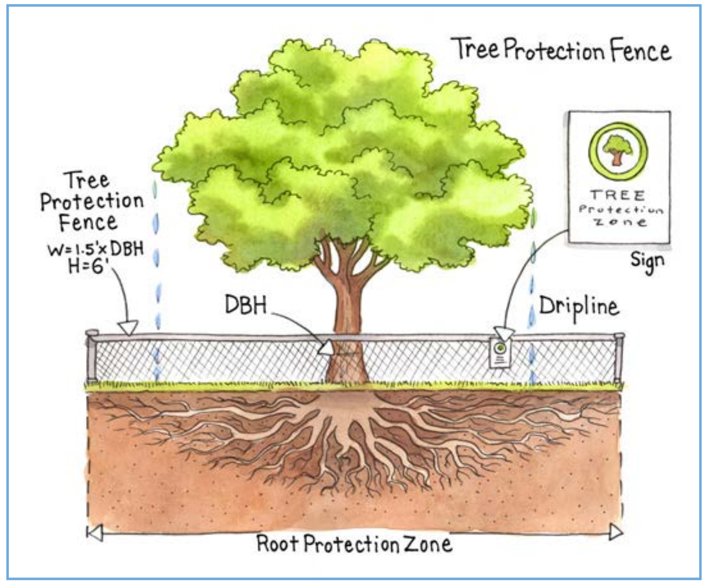
Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The City of Lynchburg can hold planning concept reviews at the pre-development stage and should identify large trees on conceptual and final site plans. These meetings, tree reporting and additional funding for the city's urban forestry program could expand the options for conservation of the city's trees.

Encouraging Tree Conservation

It is also necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. While the city 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 promote 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 higher premium in a well-treed development.

Tree Protection Fencing and Signage

Small roots at the radial extents of the tree root area, uptake water and absorb nutrients. Protection of these roots is critical for the optimal health of a tree. While protection at the dripline is an accepted practice, it does not adequately protect the roots.



Tree Protection Fence and Signage

Trees slated for protection may still suffer development impacts such as root compaction and trunk damage. The most common form of tree protection during construction is tree protection fencing. It is a physical barrier that keeps people and machines out of tree's critical root zones during land disturbance.

A value of 1.5 feet per DBH inch of trunk is a recommended practice. While Lynchburg calls for a tree protection area, the city has not defined the area that must be protected from disturbance.

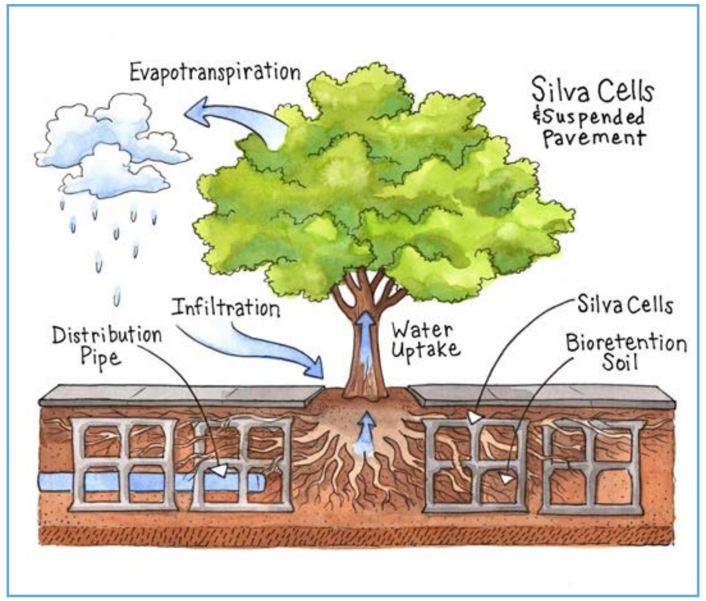
Tree protection signage communicates how work crews should understand and follow tree protection requirements. It also informs crews and citizens about the consequences of violating city code. The city does not have requirements for tree protection signage. It is important that building materials are not placed in tree protection zones and that protective fences not be moved.

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, stunt their growth and reduce 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 roots, 'Silva cells' or other trade technologies can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes). The city has discussed the possibility of choosing some demonstration sites to test the technology.

City staff have noted that tree losses will begin to increase with the death of Ash Trees due to the Emerald Ash Borer. At least 50 ash trees along the city's expressway will need to be removed. The city hopes to replant a new species of tree that is not susceptible to known pest outbreaks. The city is also planning a water line replacement and proposes to use this opportunity to require new tree plantings as part of the landscaping around the project.

The city is also considering whether some large impervious surfaces on vacant lots might be converted to open space and planted to provide more canopy in less well treed areas of the city and to uptake more stormwater along with other tree benefits.



Silva Cells and Suspended Pavement

Tree topping weakens the tree and leads to decay. Trees should never be topped as these poor trees have been.

Emerald Ash Borer is an invasive beetle from northeast Asia that kills Ash Trees by boring and feeding under their bark, thereby disrupting the movement of water and nutrients through the tree.

Newly planted cherry trees are not in the way of power lines, as they will not grow too tall.

Lastly, the city has a well-trained tree pruning force and an active Tree Stewards Group. The city has also partnered with nonprofit groups, such as the James River Association, to purchase and install trees in the city and plans to continue such partnerships. The key to maintaining city canopy is to engage even more residents as partners in city tree care and in planting on both public and private property.

Tree planting will be most successful when trees are planted in the right locations. Large trees should not be planted where they may interfere with overhead transmission lines or underground utilities. 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 city trees pay dividends for reducing stormwater runoff, as well as cleaner air and water, lower energy bills, higher property values and natural beauty long into the future.

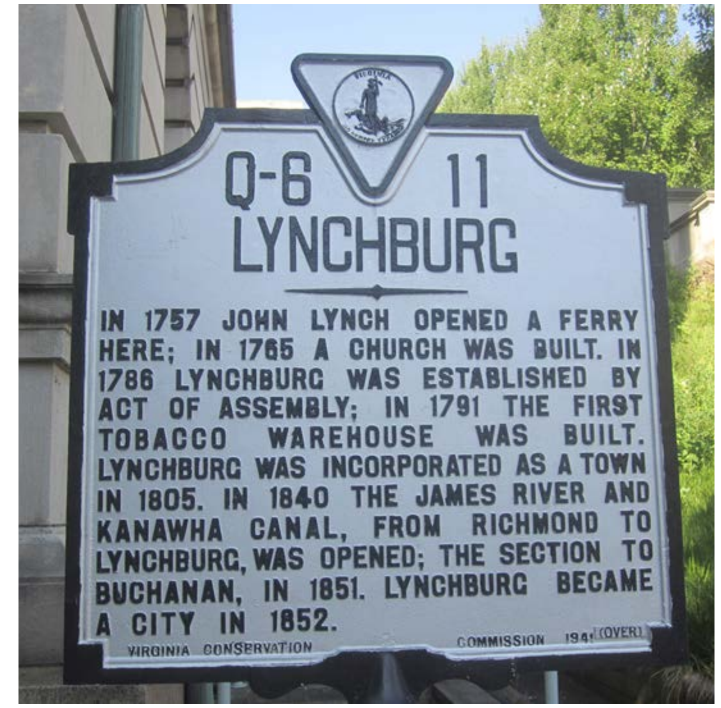
CONCLUSION AND NEXT STEPS

Adapting codes, ordinances and municipality practices to use trees and other native vegetation for greener stormwater management will allow Lynchburg 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.

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. Lynchburg can use the canopy map and updates to track change over time and to set goals for increasing or maintaining canopy by neighborhood. The city will use the canopy data to inform the future land use plan to strategize where to plant new trees. Additionally, the city plans to prioritize planting along streams and evaluating the options for a stream buffer ordinance with variable planting widths to reflect the realities of fitting a buffer within a highly urbanized landscape.

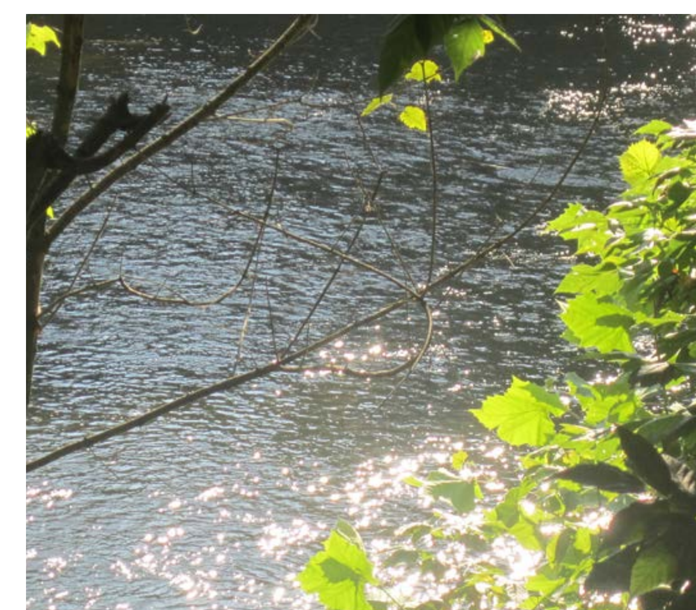
Lynchburg has created an urban tree canopy goal to maintain its canopy at 51%. This will require planting approximately 850 trees (canopy and understory) annually on public and private property. The city would need to plant 100 more trees per year (over current tree planting levels) and private citizens would need to plant 600 trees per year for the next 15 years to meet the canopy maintenance goal. This goal could be expanded to a longer time horizon (e.g. 25 years) to reduce the annual cost. In addition, the city aims to complete an urban canopy GIS assessment every four to five years to evaluate progress in maintaining 51 percent canopy and to ensure better planning for the urban forest and the health of the middle James River Watershed.











APPENDIXES

APPENDIX A: 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 Lynchburg.

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 images) 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 the city.

NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet
WKID: 2283 Authority: EPSG

Projection: Lambert_Conformal_Conic
False_Easting: 11482916.66666666
False_Northing: 6561666.666666666
Central_Meridian: -78.5
Standard_Parallel_1: 38.03333333333333
Standard_Parallel_2: 39.2
Latitude_Of_Origin: 37.66666666666666
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 'bull's eye' object recognition configuration was used to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables a 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,' – 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.

- **Initial Inclusion**
  (selected from GIC created land cover)
  - Pervious surfaces
  - Bare earth

- **Excluded Land Cover Features**
  - Existing tree cover
  - Water
  - Wetlands
  - Imperious surfaces
  - Ball fields (i.e.: baseball, soccer, football) where visually identifiable from NAIP imagery. Digitized by GIC.

- **Exclusion Features:** (buffer distance)
  - Roads areas (10 ft.)
  - Unpaved roads (10 ft.)
  - Sidewalks (5 ft.)
  - Railroads (10 ft.)
  - Structures (10 ft.)
  - Ponds (5 ft.)
  - Power lines and other identifiable utilities (10 ft.)

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 of trees desired. The 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.

NAIP Image 2016

Potential Planting Area (PPA)

Potential Planting Spots (PPS)

Potential Canopy Area (PCA)

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APPENDIX C: TREE PLANTING CREDIT UNDER THE CHESAPEAKE BAY WATERSHED IMPLEMENTATION PLAN

Introduction:

The Chesapeake Bay Program (CBP) is a regional organization that coordinates Chesapeake Bay restoration and protection for federal agencies and state partners along with local governments, non-profit organizations, and academic institutions. The CBP developed over 200 best management practices (BMPs) for accreditation in the Phase 6 Implementation of Chesapeake Bay Watershed Model. Many BMPs, including urban tree planting, are eligible for nitrogen, phosphorus, and sediment reductions toward their Phase III Watershed Improvement Plan (WIP) targets. This appendix explains how to calculate nitrogen, phosphorus, and sediment reductions through urban tree planning BMPs. This is derived from "Quick Reference Guide for Best Management Practices, Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters" (Pub. CBP/TRS-323-18)[1]

Types of Urban Tree Planting BMPs

CBP developed three classes of urban tree planting BMPs. Each one yields a different nitrogen, phosphorus, and sediment reduction per acre and loading reductions vary by state as well. See below for a description of each.

Urban Tree Canopy Expansion

The Urban Tree Canopy Expansion BMP credits planting of urban trees. Trees do not need to be planted in a contiguous manner but cannot be part of a riparian forest buffer or a structural BMP. For the BMP, 300 trees planted is equivalent to one acre of urban tree canopy expansion.

Urban Forest Planting

The Urban Forest Planting BMP offers credit for conversion of developed turf grass to urban forest. For credit to be granted, trees must be planted contiguously and urban forest plantings must be documented in a planting and maintenance plan that meets state planting density and associated standards for establishing forest conditions. These standards must include no fertilization and minimal mowing to aid tree understory establishment.

Urban Forest Buffer

The Urban Forest Buffer BMP credit is for contiguous forest planted in a recommended buffer of 100' or a minimum buffer of 35.'

Note: Trees may not be double credited. For example, if an acre of trees is planted along a stream in a developed area as an urban forest buffer, the same acre of trees may not be credited as urban forest planting or urban tree canopy expansion.

Calculating Nitrogen, Phosphorus, and Sediment Reductions

Trees are credited based on the standard that 300 trees comprise one acre of trees. This is based on the Chesapeake Bay panel's recommendation of 144 square foot average of canopy trees planted. To calculate the credit, first determine the type of urban tree planting BMP performed (Urban Tree Canopy Expansion, Urban Forest Planting, or Urban Forest Buffer). Calculate the number of trees planted (note that some BMPs require trees to be planted contiguous while others do not). Divide the number of trees planted by 300 and multiply by the corresponding nitrogen, phosphorus, and sediment reduction coefficient.

For example, if 600 trees were planted throughout an urban area in a noncontiguous fashion and not as part of a riparian forest buffer, these trees would be credited under the Urban Tree Canopy Expansion BMP. To determine the acres of trees planted, divide the number of trees planted (600) by 300. This yields two acres of Urban Tree Canopy Expansion. Multiply the nitrogen, phosphorus and sediment average reductions/acre for Urban Tree Canopy Expansion (see Table below) by two to find total nitrogen, phosphorus, and sediment reductions for the BMP. Thus,

- Total nitrogen reduction is 3.64 lb. (1.82 lb./ac x 2 ac).
- Total phosphorus reduction is 0.30 lb. (0.15 lb./ac x 2 ac).
- Total sediment reduction is 445 lb. (223 lb./ac x 2 ac).

[1] https://www.chesapeakebay.net/documents/BMP-Guide_Full.pdf

Jurisdiction	BMP	Nitrogen Average reduction per acre, Edge of tide (lbs/ac)	Phosphorus Average reduction per acre, Edge of tide (lbs/ac)	Sediment Average reduction per acre, Edge of tide (lbs/ac)
Virginia	Forest buffer	8.77	1.61	854
	Forest planting	7.33	1.16	451
	Tree planting - canopy	1.82	0.15	223

Above values are from Table D-7-1. Bay-wide average nitrogen, phosphorus and sediment reductions per acre of implementation. Pounds reduced edge-of-tide (EOT): TN and TP rounded to nearest hundredth of a pound; TSS rounded to nearest whole pound. Values derived in Phase 6 version of CAST and available by county or state. These values provided as useful estimates but the actual reductions for specific BMPs will be different from these average estimates. Source: BMP Pounds Reduced and Cost by State, July 13, 2018 version, available under "Cost Effectiveness" section at http://cast.chesapeakebay.net/Documentation/DevelopPlans