Bristol
RHODE ISLAND

Strategic Tree Canopy Plan

Prepared by the Green Infrastructure Center Inc.

MARCH 2024

Green Infrastructure Center

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Prepared by the Green Infrastructure Center Inc.
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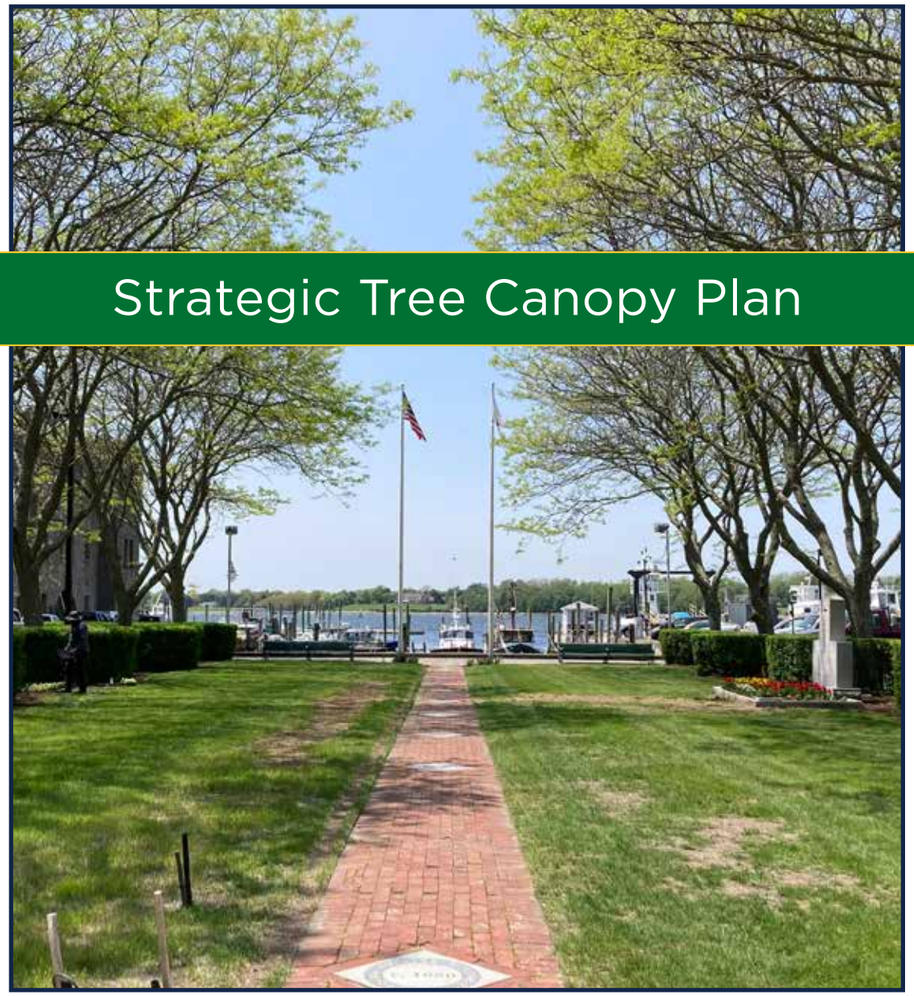
Town of Bristol
RHODE ISLAND



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Executive Summary

This Strategic Tree Canopy Plan for the Town of Bristol, RI and the accompanying assessments were completed by the Green Infrastructure Center, Inc. through a grant from the Rhode Island Department of Environmental Management's Division of Forest Environment (DFE). This plan describes the findings of the tree canopy assessment, ecosystem services analysis, and codes and ordinances assessment for Bristol, Rhode Island. Building upon these data the town, DFE, GIC and stakeholders participated in goal setting sessions and developed proposed strategies for meeting the goal to maintain tree canopy at 44% with the aim of increasing the canopy to 45% over the next 10 years. Data and strategies were presented to the public at an open house where they were given an opportunity to vote on proposed strategies and add additional comments. Finally, Force of Nature Solutions (FoNS), a consultant company, was brought in to connect trees as green infrastructure and provide guidance on how these data and proposed strategies could be used for disaster planning and hazard mitigation.

Bristol Canopy Goal: Maintain tree canopy at 44% with the aim of increasing the canopy to 45% over the next 10 years.

Top Five Strategies to Achieve This Goal:

- Plant more trees in right-of-ways where canopy is less than 10%.
- Adopt a town policy that states trees are a part of the community's infrastructure.
- Inventory Heritage trees in the historic district and Champion trees elsewhere in the community.
- Make a 5-year or 10-year street tree planting plan.
- Retrofit properties with new tree plantings and green infrastructure to reduce impervious surfaces.

(Above) The Rhode Island Division of Forest Environment provided support for Bristol to study its tree canopy, set a goal and identify strategies for managing its community forest.

(*Left*) Some of the best areas for planting trees are on residential private property. The town's Tree Setback Planting program is one way to increase canopy in right-of-ways and neighborhoods.

Bristol, RI Fast Facts

County: Bristol County
Population: 22,128 people*
Total Town Area: 9.85 sq. miles
Land Area: 9.45 sq. miles
Lakes/ponds: 20 acres
Swamp & Marsh: 568 acres
Tidal shoreline: 22.5 miles
Streams: 12.5 miles
Tree canopy: 2,718 acres
Impervious surfaces: 1,469 acres

(U.S. Census 2022 estimate)

Moving Forward, Bristol Can Use the Results of This Report to:

- Support the town's implementation of a state award from the Rhode Island Infrastructure Bank's Municipal Resilience Program to plant more trees and increase tree canopy in priority watersheds.
- Build capacity and planning for the Town's Street Tree and Tree Setback Planting programs.
- Identify areas to plant trees, slowdown and soak up stormwater and improve water quality and reduce nonpoint source nutrient loads in priority watersheds such as Silver Creek, Tanyard Brook and Mt. Hope Bay.
- Mitigate stormwater runoff in neighborhoods such as through tree planting and other green infrastructure.
- Document the many environmental and social benefits provided by town trees.
- Support greater resiliency of the urban forest in the face of storms, pests and other natural disasters.
- Determine the strategic locations for retaining or planting trees to realize environmental and social equity benefits.
- Inform management of the town's urban forest and support investments in tree care and planting.
- Prioritize policy and code updates to support more tree plantings and tree retention.

Trees play an important role in mitigating stormwater runoff and preventing nonpoint source pollution from entering into bays.

Summary Outcomes

Canopy

Bristol has a tree canopy of 44% and this tree canopy provides benefits to the town such as stormwater capture, cleaner air, urban cooling, wildlife habitat and natural beauty.
These benefits provided by trees are called ecosystem services. Bristol has room to add more tree cover and could achieve a maximum tree canopy of 60%. Any increase in tree canopy Bristol achieves expands the benefits provided.

Air quality

Trees play a critical role in not only providing oxygen, but also cleaning the air of particulate matter and ground level ozone (O3), which can harm human health. Trees also sequester greenhouse gases such as sulfur dioxide and carbon dioxide, and as these gasses are trapped by trees, the severity of climate change is reduced. Trees store carbon and prevent its release, also mitigating climate change impacts. Each year, the tree canopy of Bristol removes 10,708 metric tons of carbon, 51,721 lbs. of ground-level ozone (O3) and 9,626 lbs. of airborne particulate matter that can cause respiratory distress.

Heat Island

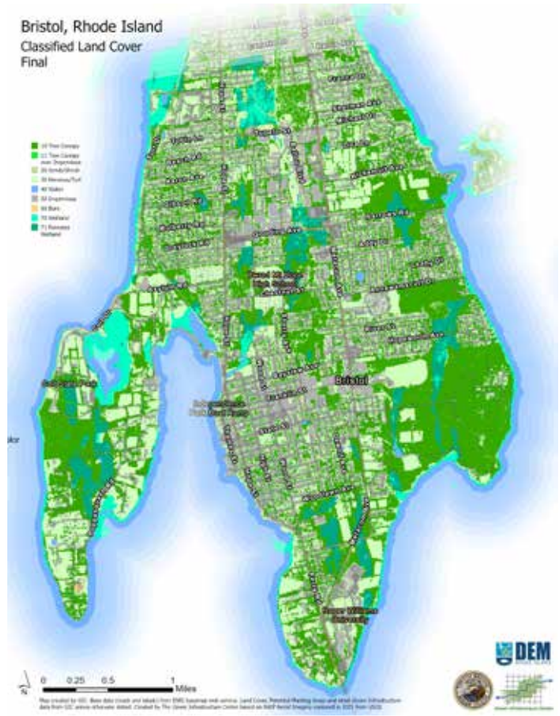
Bristol, like many developed areas, suffers from urban heating and stormwater runoff impacts resulting from high concentrations of impervious surfaces coupled with a lack of vegetative cover. Excessive pavement and lack of shade lead to increased temperatures known as urban heat islands. Bristol's existing tree canopy provides urban cooling. The higher the tree canopy, the lower the surface temperatures and the cooler the town.

Stormwater Uptake

The town's trees also help mitigate stormwater as they capture rainfall in their canopy, trunks, roots and surrounding soils and then release some of that water back to the atmosphere through evapotranspiration. One mature large tree can absorb thousands of gallons of water per year. During a one-year/24-hour rainfall event (2.83 inches), the town's trees soak up 13.8 million gallons of water! This means less flooding of streets. During that same rainfall, the town's trees reduce runoff pollution loads for nitrogen by 25%, phosphorus by 32%, and sediment by 22%, thereby reducing water pollution in local water ways and the Narragansett and Mt. Hope Bays.

Canopy Trends and Goals

Bristol's trees are continually lost as older trees age and die, storms destroy trees, pests kill trees, or trees are cleared for development. As the town recovers from past storms and continues to grow and develop, it will be important to maintain existing coverage and to plant replacement trees to overcome losses. To achieve its proposed goal, the community needs to increase the rate of planting on both public and private property.
Bristol has proposed a townwide goal of maintaining at least 44% canopy with the aim of increasing it to 45% over the next ten years. This requires planting more than 6,255 trees in total or 625 trees annually across the town to achieve a goal of 45%. The town can reassess progress and adapt its canopy goal over time to achieve a higher overall canopy coverage.



The Town of Bristol now has baseline data on its tree canopy and potential planting areas to identify opportunities to plant new trees. More trees equate to better air quality, more shade and energy savings, increased stormwater uptake and improved water quality too!

Introduction

Bristol, Rhode Island is a charming historic seaside community east of Providence RI and 2 hours south of Boston. The town has a lively downtown waterfront district as well as ample opportunities for recreation at its beaches, trails and parks. The town is a 9.85 square-mile community in Bristol County in Eastern Rhode Island and is the seventeenth largest municipality in Rhode Island, with an estimated 2022 population of 22,128 persons. The town was established in 1681 on land once cared for by the Pauquunaukit people, (anglicized to Pokanoket which means "land at the clearing") who lived and stewarded most of the East Bay. The demographic makeup of the town today is 90.6% non-Hispanic Whites, 1.3% Black/African Americans, 2.0% Asian, and 2.6% Hispanic or Latino residents.[1]

The Narragansett Bay (Algonquian: *Naiaganset*) is a brackish water body covering 120.5 square miles of Rhode Island and it is an important ecological, economic and cultural resource for Rhode Islanders. The bay's border adjoins 23 miles of Bristol's shoreline along with Mt. Hope Bay. These waters hold important marine ecosystems such as the Kickemuit River Shellfish Management Area and the Bristol Harbor Shellfish Transplant Area. The historic waterfront is interwoven with the town's culture and economy and is a key feature of the community today being located adjacent to the vibrant downtown. With 218 acres of municipal parks, beach and conservation lands, the town is rich in natural amenities that contribute to its high quality of life.

Why Map the Urban Canopy?

Trees are declining throughout the United States. The causes of this decline include land conversion for development, storm damage, pests and disease, and lack of tree replacement as older trees die. Many communities in Rhode Island are looking for ways to protect or expand their tree canopy and community forests. Data describing Bristol's tree canopy will allow the town to track trends, assess losses and set goals to retain or restore canopy. The town now has baseline data to set canopy goals, monitor canopy protection progress, measure environmental benefits of town trees and prioritize strategic tree planting locations.

Trees are an important part of the town's 'green infrastructure.' Just as we manage our grey infrastructure (roads, sidewalks, bridges and pipes), we also need to manage our 'green infrastructure' (trees and other vegetation). Bristol's green infrastructure provides many values that support a vibrant,

[1] https://www.census.gov/quickfacts/bristoltownbristolcountyrhodeisland

Gray vs Green. Image at left shows an example town's gray infrastructure including buildings and roads. Classified high-resolution satellite imagery (at right) adds town green infrastructure data layer (trees and other vegetation). The green infrastructure provides cleaner air, water, energy savings and natural beauty.

safe and healthful community. Trees add to the town's historic coastal character, and they enhance its livability by filtering storm water and reducing runoff, cleaning the air, providing oxygen, shade, and natural beauty, as well as enhanced property values. As the town continues to grow and adapt to climate change and more frequent and severe storm events, it should also manage and expand the urban forest. This will help the town meet its vision to "become a model seaside

One of the town's beautiful trees

community for the 21st century and 'the gem of the East Bay.' Bristol will be exceptional in the degree to which it will offer a small town, historic character blended with varied living and working environments, all closely connected with the water." (Bristol Comprehensive Plan 2016).

The Canopy Assessment

This report describes the state of the town's community forest based on current canopy coverage, an analysis of the canopy's environmental benefits and a review of the relevant codes and ordinances. With these data, the town and community devised strategies to sustain and expand the community forest. Products created include: :

- 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
- Calculation of the environmental benefits and pollution removal by town trees
- Analysis of town's codes, ordinances and practices for their effective conservation, protection, and management of the urban forest
- A public open house addressing priority tree planting efforts and the top strategies for increasing tree canopy
- Tree canopy community outreach and educational materials

The town can utilize the tree canopy to maximize environmental and social benefits including:

- Community health and vibrancy
- Aesthetic values and natural beauty,
- Decreased urban heat island and reduced heating and cooling costs,
- Abundant bird and wildlife habitat,
- Expanded walkability and multimodal transit support; and,
- Revenue from tourism and retail sales.

How the Urban Forest Benefits Bristol, RI

Reducing Stormwater Runoff and Filtering Pollutants

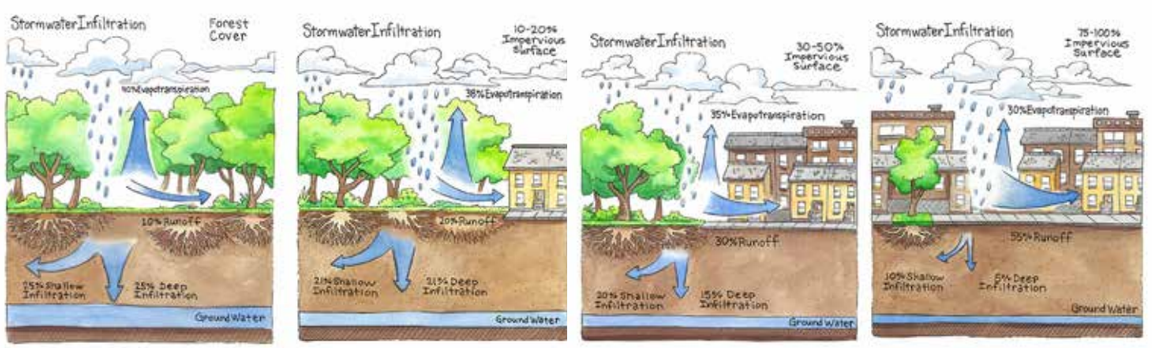
Trees provide natural flood protection and stormwater filtration at a fraction of the cost of engineered systems. As forested land is converted to impervious surfaces, runoff increases. Excess stormwater runoff can cause temperature spikes in receiving waters, increased pollution of surface and ground waters, and greater potential for flooding.

Trees also reduce nitrogen, phosphorus, and sediment runoff by cleaning rainfall and stormwater of these pollutants. Increased loads of nutrients can reduce oxygen in surface water causing harm to fish and other aquatic life. In areas with tree canopy less pollutants reach drainage ditches, the river, and the bay.

The average annual precipitation in Bristol is 44 inches (112 cm), some of which runs off carrying surface pollutants. Large, paved areas contribute significant volumes of this runoff. During a one-inch rainfall event, a one-acre paved area such as a mall parking lot, will release 27,000 gallons of runoff compared to an acre of forest, where only 750 gallons of water runoff. While stormwater ponds and other best management practices are designed to mimic rainfall release by detaining and filtering runoff, they do not fully replicate pre-development hydrology. In addition, older parts of the town may lack stormwater management practices that are required for new developments, so not all runoff is captured or treated before it flows to open waterways.

New tree plantings and new canopy can reduce nonpoint source pollution from entering into the local waterways such as the Narragansett Bay.

Water Infiltration Rates with Development



Stormwater runoff increases as land is developed. Data Source: U.S. EPA

Since trees filter stormwater and reduce overall flows, planting or conserving trees is a natural way to mitigate stormwater. Each tree plays an important role in stormwater management. 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 4000 gallons of water per tree per year, depending on the species and age. During a 1-year/24-hour rainfall event (2.83 inches) in Bristol, the trees take up 13.8 million gallons of runoff, or about 28 Olympic swimming pools of water. In a larger rainfall event similar to the Rhode Island floods in 2010 (up to 5 inches of rain in 24 hours) the trees take up 23.8 million gallons.

Excess impervious areas cause hot temperatures and runoff. This parking lot can be retrofitted to add more trees.

As tree cover is lost and impervious areas expand, excessive urban runoff results in pollutants such as oil, metals, lawn chemicals (e.g., fertilizer and herbicides), pet waste, trash, and other contaminants flowing into surface waters. Trees help capture and filter that urban runoff. According to GIC's stormwater model, during a 1-year/24hour rainfall event (2.83 inches) in Bristol the trees capture:

- 20,584 lbs. nitrogen,
- 1,676 lbs. of phosphorus and
- 1,111 tons of sediment.

Nitrogen and phosphorus are plant nutrients that can cause harmful algal blooms while sediment can clog fish gills, smother aquatic life, and necessitate additional dredging of canals and waterways. Algal blooms can reduce oxygen levels further harming fish and other aquatic life.

These recessed tree islands in the Bristol Town Beach parking lot are a good example of integrating trees into Low Impact Design (LID) which slows, filters, and reduces stormwater entering the bay.

Trees help mitigate stormwater runoff from residential properties too.

Buffering Storms and Flooding

Another benefit of conserving trees and forests is buffering against storms and losses from 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. The EPA recommends a number of ways to use trees to manage stormwater in the book *Stormwater to Street Trees*.

Retaining trees and forests along coasts also provides a wind break and helps to evaporate and reduce standing water. In addition, utilizing trees as 'green infrastructure' can provide a basis for reimbursement from FEMA if trees are damaged during storms. To qualify, trees must be inventoried and specifically utilized for stormwater management, erosion and sediment control, buffers or other green infrastructure functions.

Bristol participates in the National Flood Insurance Program's Community Rating System (CRS). The CRS is a voluntary incentive system that allows local governments to earn flood insurance premium discounts for policyholders in the community.

Local governments receive points for actions or policies that reduce flooding and flood damage; these points earn premium discounts as high as 45%. Bristol is currently rated as Class 7 in the CRS program, saving residents and businesses within its special flood hazard areas a 15% discount on standard-rate policies.

Additionally, communities can earn credit for adopted management plans that protect the critical natural functions of floodplains and native species, while implementing habitat restoration projects. CRS requirements include an inventory of all species in the plan's geographic purview, action items for protecting one or more of the identified species of interest, restoring natural floodplain functions, and the review and update of the plan every 10 years. If a green infrastructure plan is created using the canopy data, this can also be tied to the town's effort to earn additional points in the CRS to further reduce flood insurance premiums. Multiple objectives can be achieved by combining canopy data with the planning efforts to identify green infrastructure networks.

Air Quality and Surface Temperature

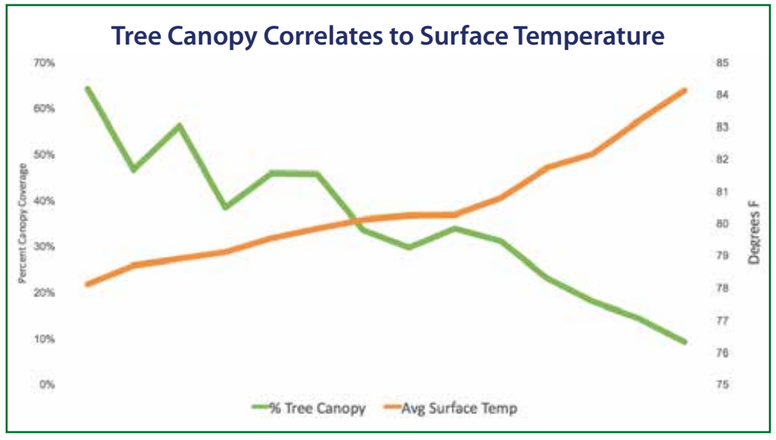
Trees Cool the City

As summer temperatures in Rhode Island climb, the importance of shade cast by trees increases. Excessive heat can lead to heat stress which especially affects infants and children up to four years of age, those 65+ years of age and older, those with underlying medical issues, and those on some medications (Centers for Disease Control 2020).

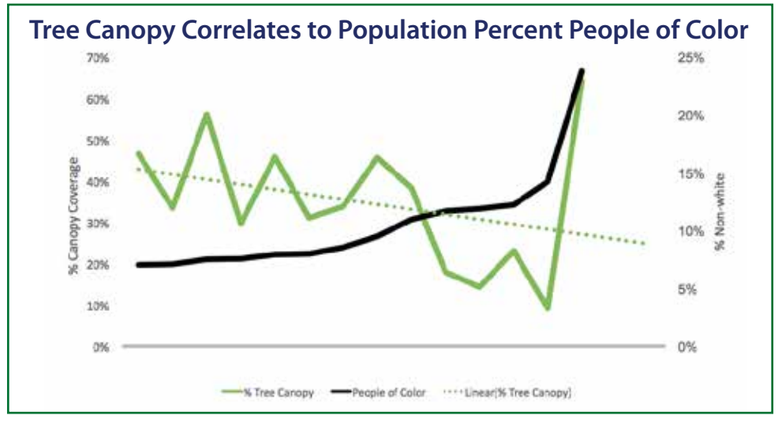
Tree cover shades streets, sidewalks, parking lots, and homes, making urban locations cooler, and more pleasant for walking or biking. Multiple studies have found significant cooling (2-7 degrees Fahrenheit) and energy savings from having shade trees in cities (McPherson et al 1997, Hashed et al 2001). Shaded pavement also has a longer lifespan, so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick, 2005).

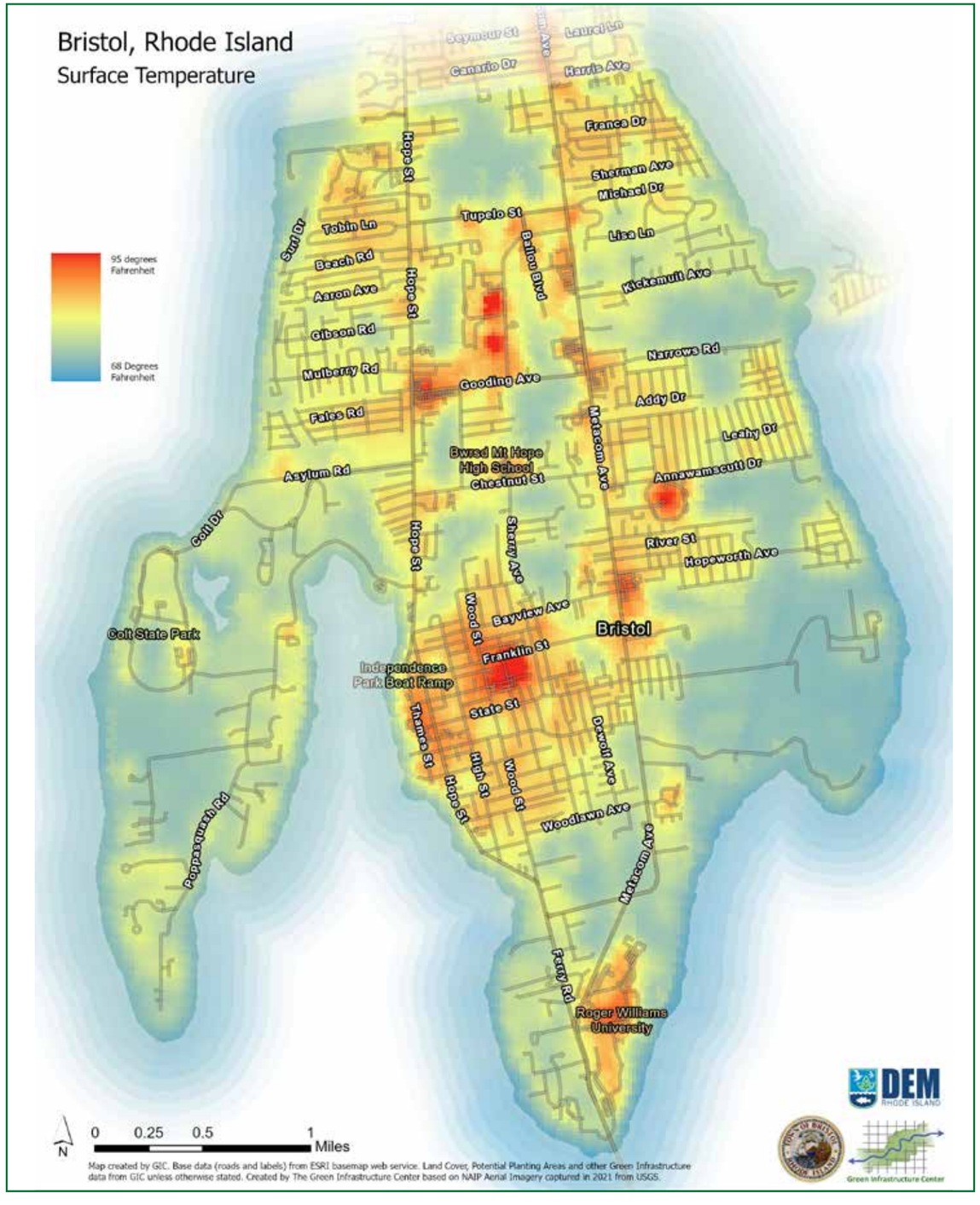
Using the tree canopy data, surface temperature data and U.S. Census data at the Block Group level, analyses can be done to identify inequities in the distribution of tree canopy and discover opportunities to correct those inequities through strategic tree planting efforts. The following map illustrates one way to prioritize tree planting efforts in the city through an urban heat island and tree equity lens. Using the Potential Planting Areas (PPA) data, surface temperature and the U.S. Census's Median Household Incomes (MHHI) data at the Block Group level, GIC prioritized areas of the city for tree planting that lack canopy, are the hottest and have low-income populations that are vulnerable to heat (see map on page 16). The city can use this data to do further analysis and inform how they implement tree planting efforts in the town that are equitable and help to restore canopy in neighborhoods where trees are lacking.

Higher surface temperatures are positively correlated with reductions in tree canopy coverage.

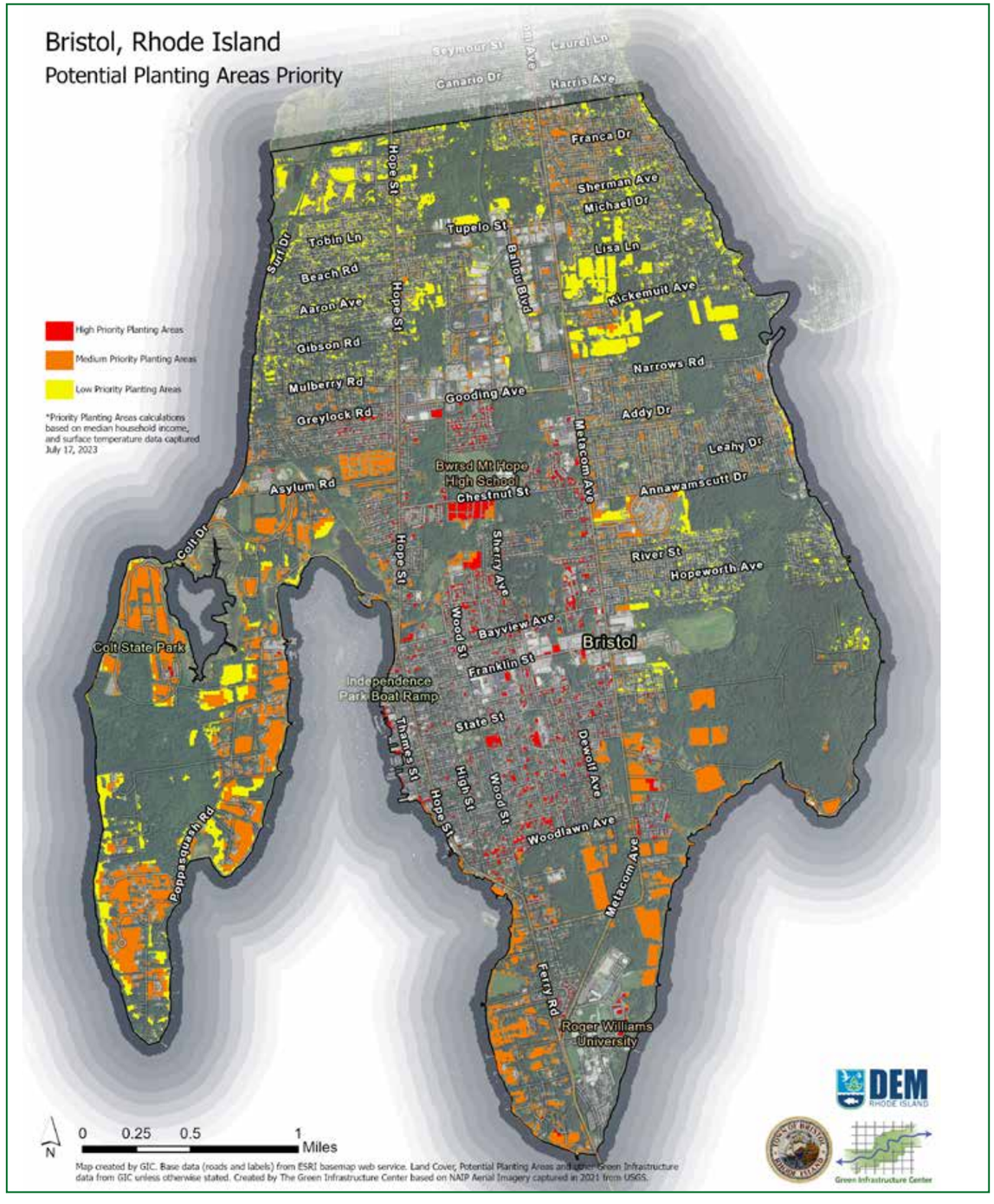


Combining U.S. Census data with tree canopy coverage we can see that Census Block Groups with higher percentages of People of Color (POC) tend to have lower canopy cover.





This map shows the hottest surface temperature areas (in degrees Fahrenheit) of Bristol on July 17, 2023



This map shows one way to prioritize tree planting efforts in the town through a tree equity lens by focusing tree planting in the hottest and lowest income neighborhoods of the town.

Trees Clean the Air

In addition to cooling surfaces, trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Trees play a critical role in not only providing oxygen but also cleaning the air of particulate matter and ground level ozone (O3), which can harm human health. Trees also sequester greenhouse gases such as sulfur dioxide and carbon dioxide. As these gasses are trapped by trees, the severity of climate change is reduced. Trees also store carbon and prevent its release, further helping to alleviate climate change impacts. Even at the neighborhood level, trees reduce pollutants. Trees clean the air and well treed neighborhoods suffer less respiratory illnesses, such as asthma. (Rao et al, 2014).

Social Values

Trees Improve Cognitive Function

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. Exposure to green spaces for 20 minutes a day can also improve cognitive function. Providing more natural areas on or near school grounds as well as greening routes to school can better prepare children to learn.

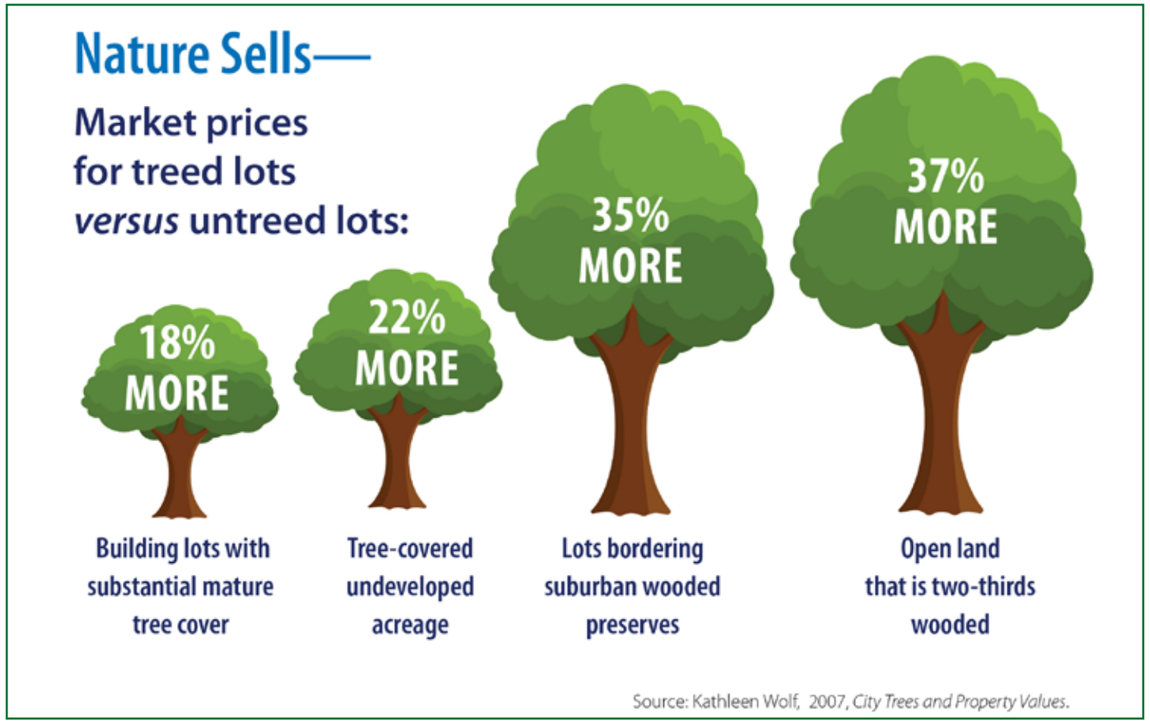
The trees on this athletic field provide cooling shade to children playing during hot summer months.

Exposure to green spaces for 20 minutes a day can improve cognitive function.

Well treed areas encourage people to walk and bike.

Trees Improve Walkability

The presence of trees encourages people to walk more and walk farther. According to research, when trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk than if streets are well treed (Tilt, Unfried and Roca 2007).



Home buyers are willing to pay more for homes located near a park or other natural area.

Trees Increase Property Values and Sales

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% of voters surveyed were more likely to purchase a home near green space and 50% were more willing to pay 10% more for a home located near a park or other protected area.

Urban Tree Loss – Reversing the Trend

Bristol now has baseline data to monitor canopy increases from plantings, measure the stormwater and water quality benefits of its community forest, and prioritize restoration of canopy where it is most needed. Currently the town's canopy coverage is 44%, but it could be expanded.

To maintain the canopy, the town needs to actively plant trees to replace those lost to natural mortality (old age), storms, development, pests, and neglect or poor care. As older trees die (or before they die), younger trees need to be planted to restore the older canopy. While the town has been planting trees, more trees need to be planted by both the public and private sectors at greater numbers to achieve the goal of a sustaining canopy at 44%. The data from this report can inform the town's tree canopy planting plan and can be shared with the public to encourage them to plant trees. Data and plans can also be used to secure grants and donations to help fund the effort.

Newly Planted Tree

Why Are Urban Trees Declining?

Tree loss is not a problem that is unique to Bristol. Trees are declining throughout the United States. 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).

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. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can all lead to tree canopy loss. For every 100 street trees planted, only 50 will survive 13-20 years largely due to poor planting conditions and care (Roman et al 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. It is 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.

Current and Potential Canopy and Ecosystem Services Modeling

In order to determine the current tree canopy, model scenarios for future tree coverage, and quantify their ecosystem services, a highly detailed land cover analysis and an estimation of potential future planting areas were developed (see Appendix A for details). In addition to community forest planning, the new land cover data can be used for other purposes such as analyzing urban cooling, walkability or street tree plantings and informing area plans such as the town's comprehensive plan.

Method

Satellite imagery from the National Agricultural Imagery Program (NAIP) distributed by the USDA Farm Service Agency was classified based on 4 infrared bands to determine the types and extent of different land covers in Bristol. Canopy maps were created using NAIP imagery data from 2021. Additional data from the Town of Bristol, the National Wetlands Inventory, and National Hydrography Dataset were also used to determine:

1) Tree canopy (including trees and wooded wetlands).
2) Wetlands not distinguishable using spectral/feature-based image classification tools.
3) Forested open space (compact, continuous tree canopy greater than one acre) not intersected by buildings or paved surfaces.

The final classification for land cover consists of eight classes (types of land cover). See Appendix A for more information on the land cover classification.

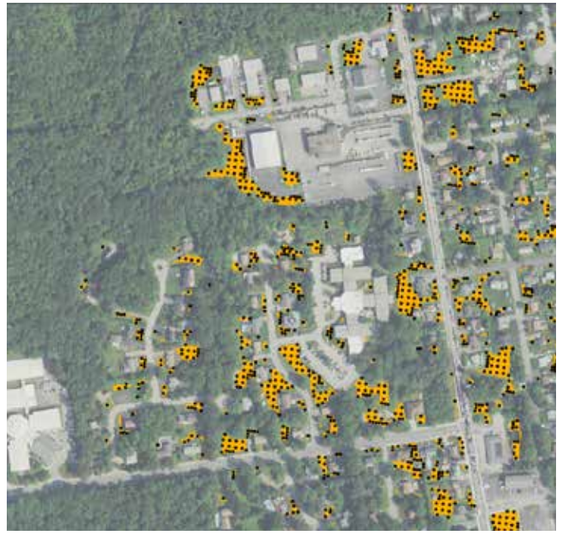
NAIP Image 2021

Potential Planting Area (PPA) with exclusions in red hatching

Potential Planting Areas (PPA)

In urban areas, realistic goals for expanding tree canopy depend on an accurate assessment of plantable open acreage. A Potential Planting Area (PPA) map estimates areas that may be feasible to plant trees. The PPA is created by selecting the land cover features that have space available for planting trees and accounts for the overlap of canopy (e.g., canopy that is intermingled or a large canopy tree that partially covers an understory tree). Of the land cover classes, only pervious/turf were considered for PPA. However, some paved areas could be removed or reduced, soils conditioned, and then used to plant new canopy.

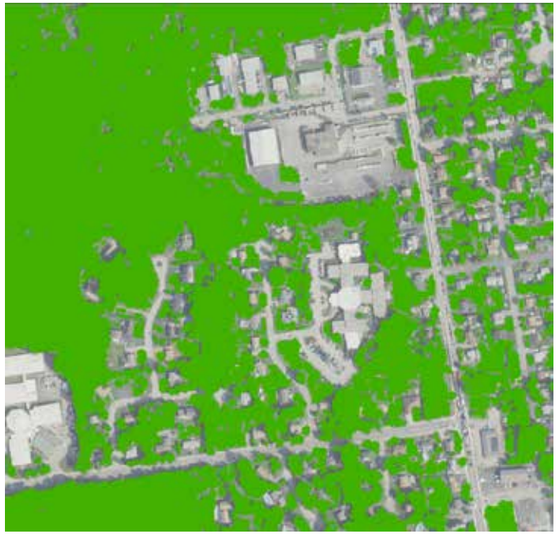
Eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect the feature itself, such as power lines, sidewalks or roads. Playing fields, cemeteries and other known land uses that would not be appropriate for tree cover, such as golf courses and airports were also avoided in calculating plantable areas. The resulting PPA represent the maximum potential places trees can be planted and grow to full size.



Potential Planting Spots (PPS)

Potential Planting Spots (PPS)

Potential Planting Spots (PPS) are created from the PPA. A GIS modeling process is applied to select spots where a tree can be planted depending on the desired size. For this analysis, expected sizes of 20 ft. and 40 ft. diameter for individual mature tree canopy were used with priority given to 40 ft. diameter trees (larger trees have more benefits).



Potential Canopy Area (PCA)

Potential Canopy Area (PCA)

The Potential Canopy Area (PCA) is created from the PPS. Once 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 represents a 20 ft. or 40 ft. diameter canopy. These individual tree canopies are then dissolved together to form the potential overall canopy area. For Bristol 16% more canopy could be added to the town.

Maps and Findings

The tree canopy map should be used to plan for tree conservation and as a benchmark to gauge future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS shape files produced during the study was provided to the town.

Tree Canopy Goal for the City of Bristol

Using tree canopy and land cover data, the GIC mapped the maximum potential tree canopy for planting 100% of the available planting areas which equates to a potential canopy cover of 60%. However, planting 100% of the PPA is not a realistic goal because property owners have other uses for their land such as vegetable and ornamental gardens, or lawns. A more realistic goal for the maximum potential tree canopy is to plant only 50% of the PPA, resulting in a maximum desired goal of 52% tree canopy.

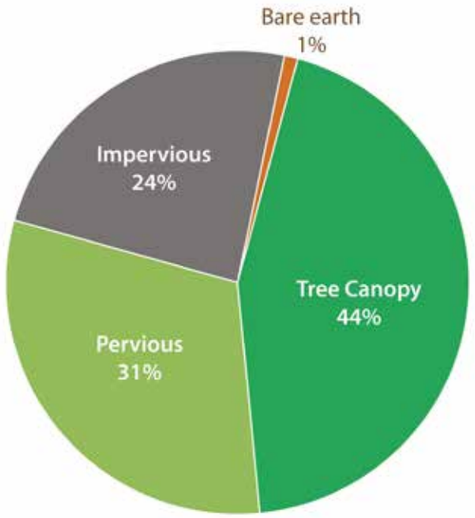
Using this information and other tools, such as GIC's Canopy Budget Calculator Tool which estimates the financial cost of increasing canopy to a certain percentage, the town decided to set a goal of at least maintaining its current canopy at 44% with the aim of increasing the canopy by an additional 1% over the next 10 years. If the Bristol community wants to increase the canopy from the current 44% to 45% over the next 10 years assuming around 200 trees are lost per year, it will require planting an additional 6,255 trees; approximately 3,748 large shade trees and 2,507 small trees at a rate of 625 trees planted annually.

The town also requested statistics for canopy by the following geographies:

- Streets
- Floodplains
- Census Block Groups
- Parcels

The canopy data and the possible planting area map can inform tree planting decisions to meet many goals such as walkability, stormwater mitigation, energy savings or economic revitalization. Knowing the distribution of canopy for different types of properties allows the town to craft more specific strategies for achieving their canopy goal of increasing tree cover by 1% and ensuring that canopy is distributed equitably across the landscape. The following maps can be used to prioritize where to start planting and for public awareness of such planting needs.

Bristol Percent Land Cover 2021

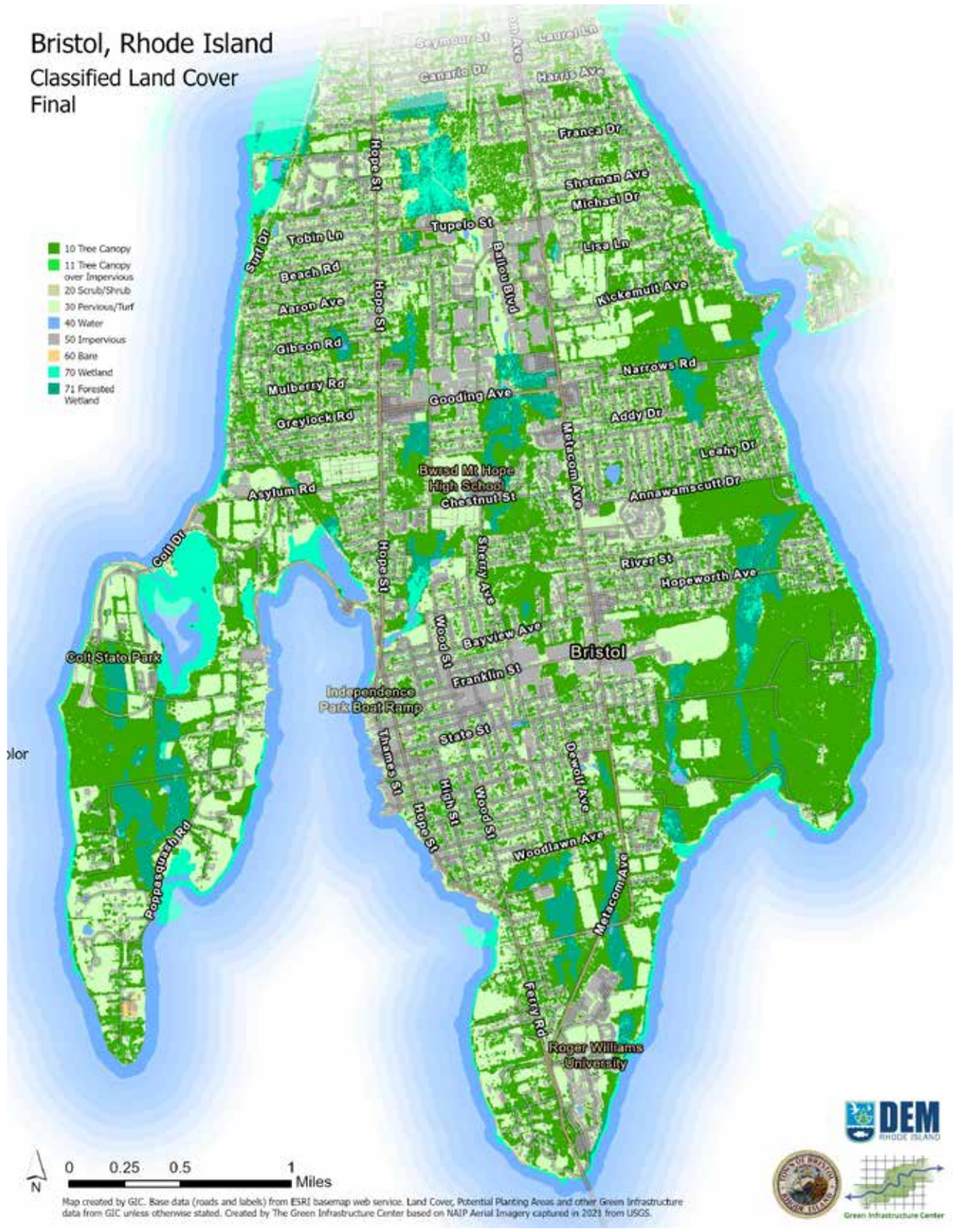


Townwide forest cover is 44%.

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

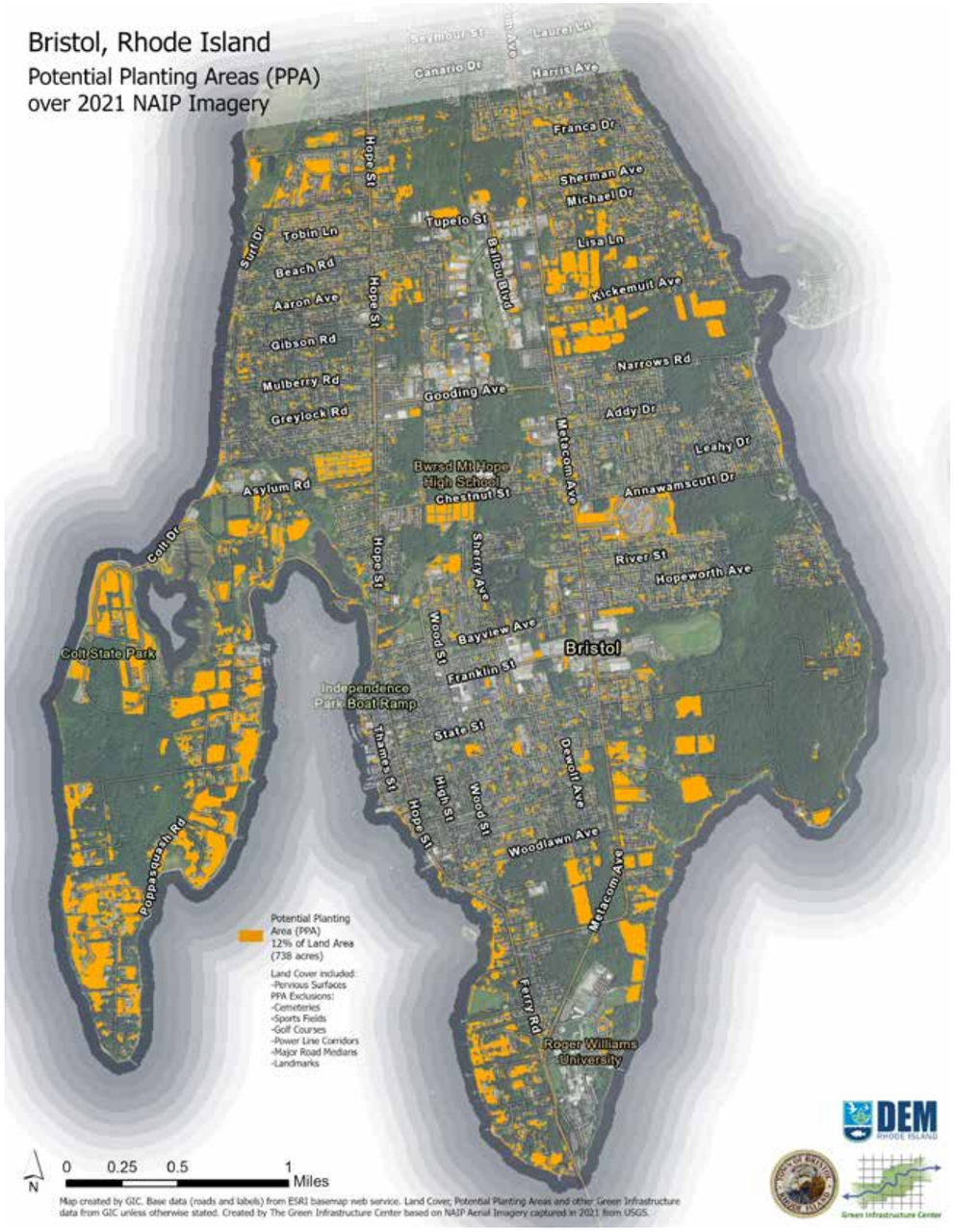
Map of Town Land Cover and Tree Canopy

This map shows the tree canopy of the town which covers 44% of the area.



Map of Possible Planting Areas

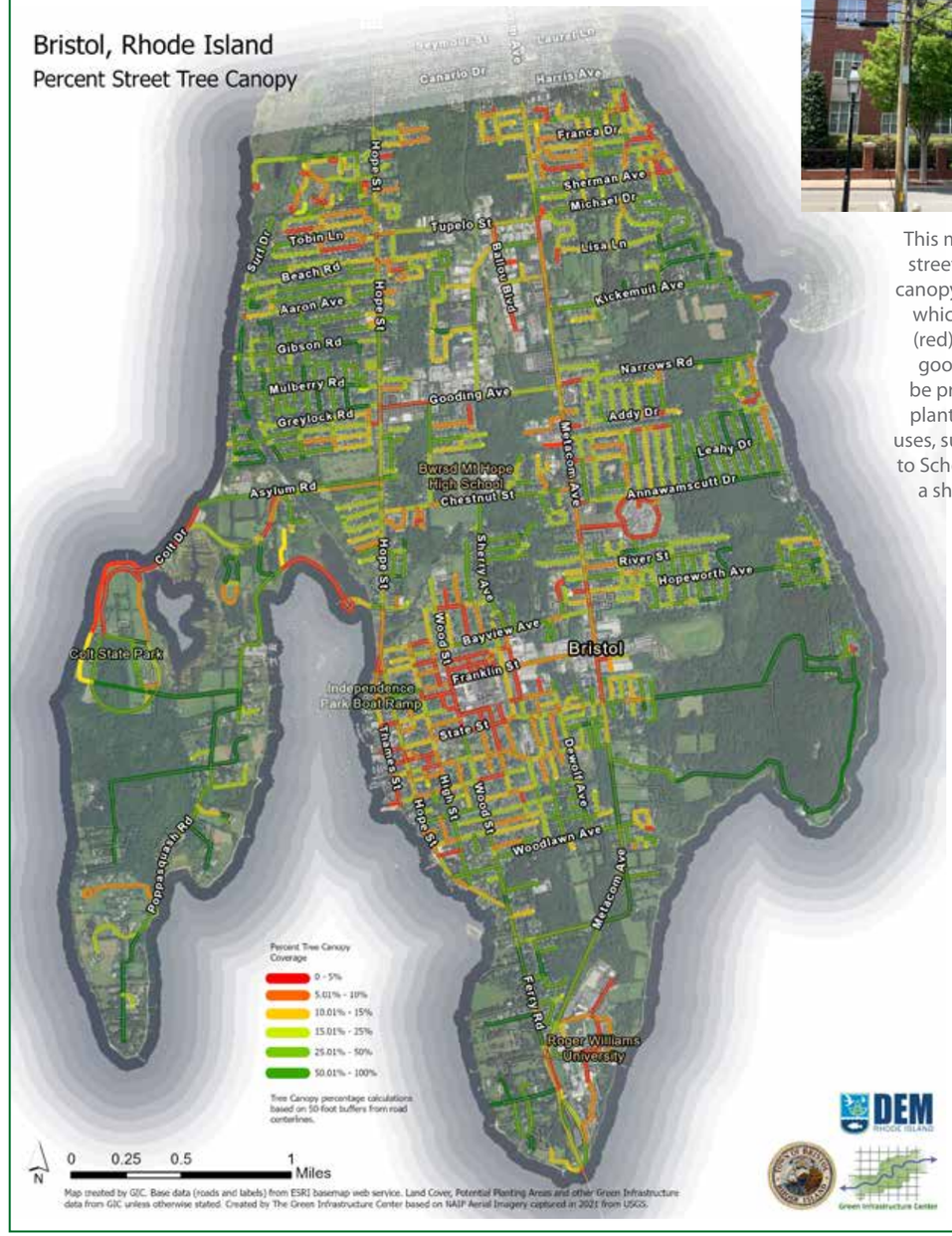
Potential Planting Areas (PPA) shown in orange depicts areas where it may be possible to plant trees. All sites need to be confirmed in the field and may be on private or public lands.



Map of Street Tree Coverage

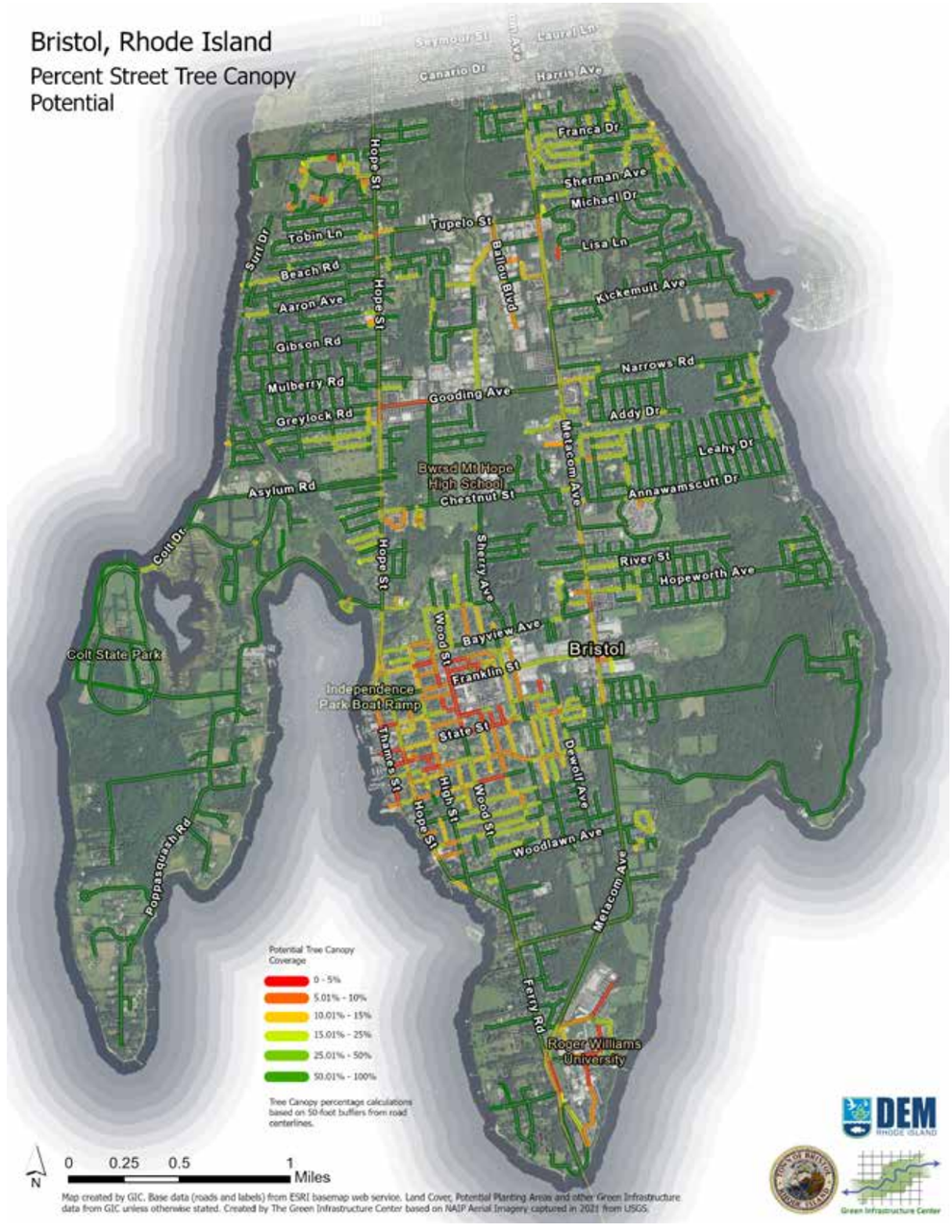
Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. outward from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.

This map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be prioritized for tree plantings to facilitate uses, such as Safe Routes to School or beautifying a shopping district.



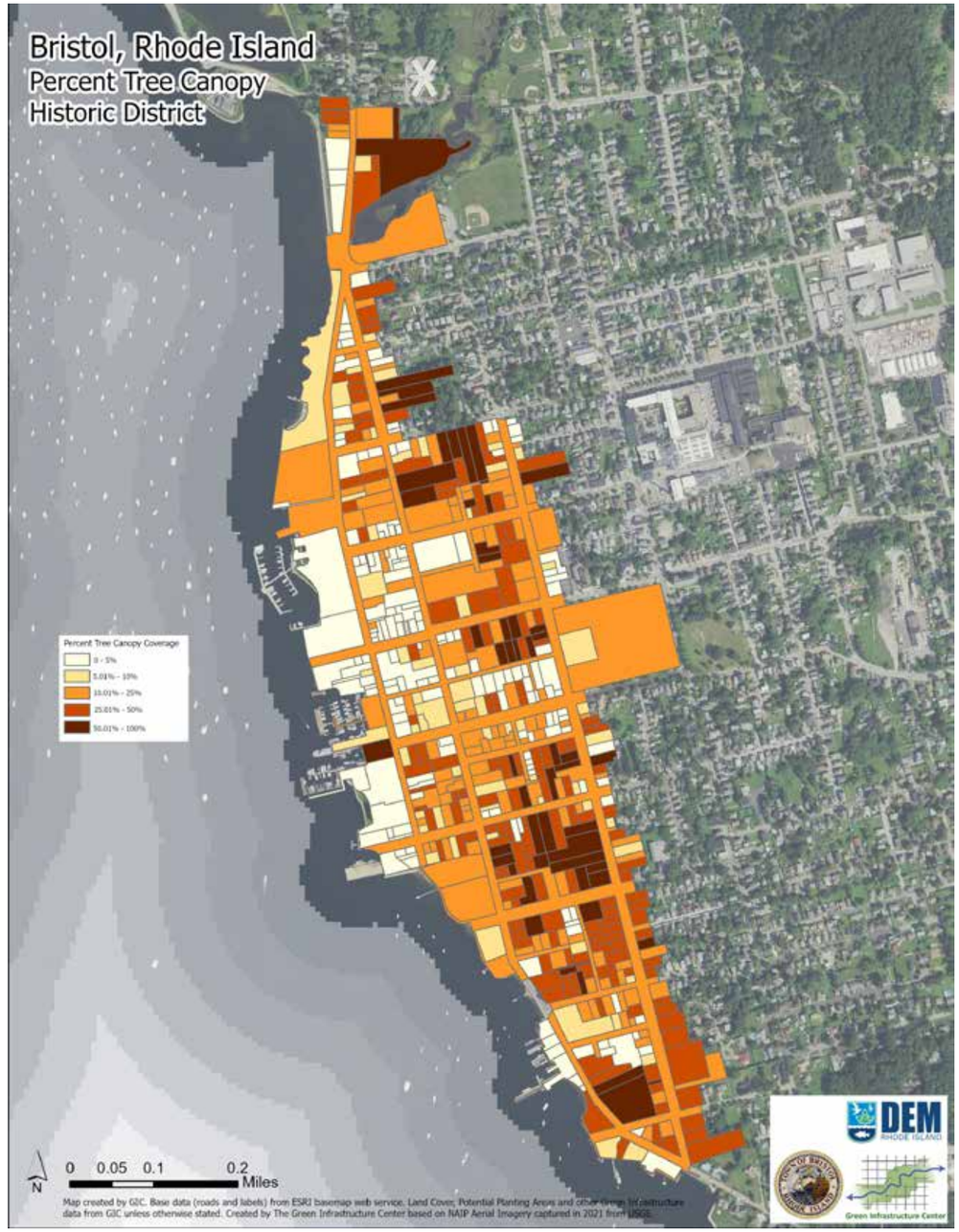
Map of Potential Street Trees

The potential street trees map shows which streets could support additional tree canopy if planted with more trees. Greater canopy coverage along streets and sidewalks can keep neighborhoods cooler and more walkable.



Map of Historic District Coverage

Historic downtown Bristol has an average tree canopy of 20% but has room for planting more than 800 additional trees.

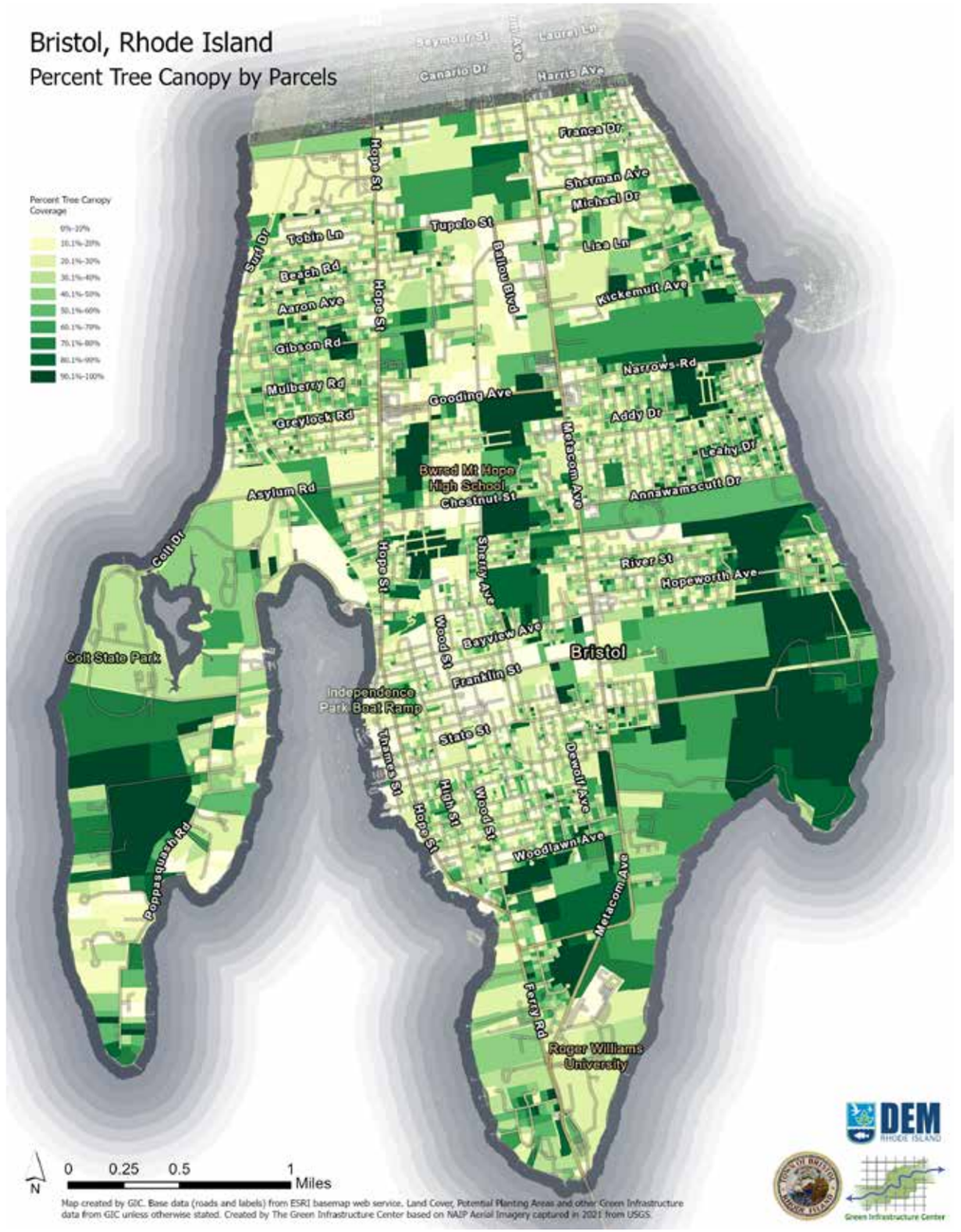


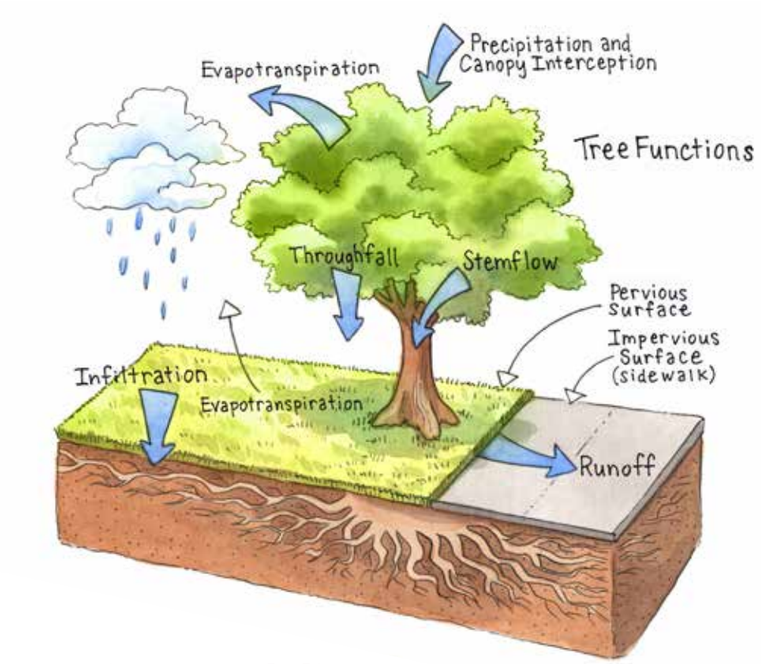
Map of Watershed Coverage

This map shows tree canopy by watersheds using the Hydrological Unit Code 12 (HUC12). Trees help manage stormwater runoff and reduce harmful pollution from entering into local waterways and bays.

Map of Parcel Coverage

Every town parcel was analyzed for tree canopy cover. The data show that some residential properties lack sufficient canopy and have potential for more trees.





Ecosystem Services Modeling

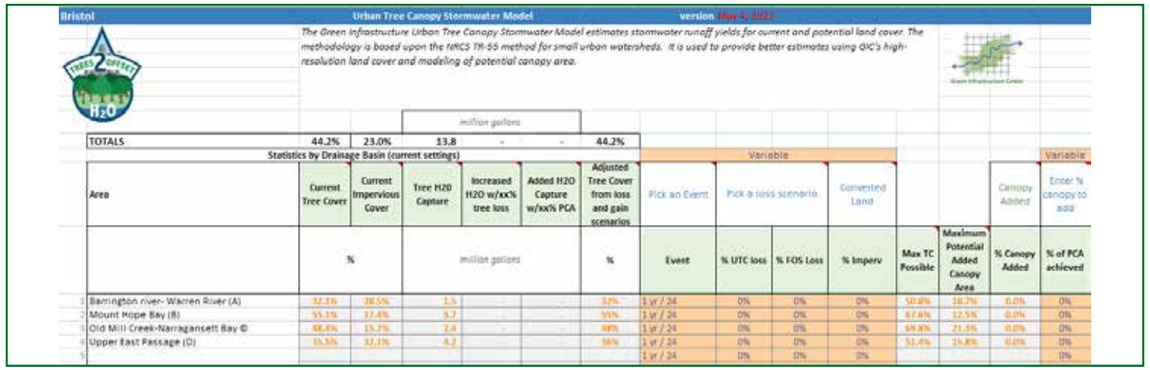
Methods to Calculate Tree Benefits

Stormwater Uptake Modeling

The best land cover for taking up stormwater is the community forest. The GIC evaluated stormwater runoff and uptake by the town's tree canopy using the GIC's Trees Stormwater Calculator (TSW) Tool. The TSW tool estimates the capture of precipitation by tree canopies and the resulting reductions in runoff yield. It considers 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 or storms and increases in tree canopy from tree planting programs.

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 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 recognize that trees have important stormwater benefits (Kuehler 2017, 2016).

See diagram of tree water flow above.



Bristol — Urban Tree Canopy Stormwater Model — version May 5, 2022

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.

	million gallons					
TOTALS	44.2%	23.0%	13.8	-	-	44.2%

Statistics by Drainage Basin (current settings)

	Area	Current Tree Cover	Current Impervious Cover	Tree H2O Capture	Increased H2O w/xx% tree loss	Added H2O Capture w/xx% PCA	Adjusted Tree Cover from loss and gain scenarios	Pick an Event	Pick a loss scenario		Converted Land			Canopy Added	Enter % canopy to add
		%		million gallons			%	Event	% UTC loss	% FOS Loss	% Imperv	Max TC Possible	Maximum Potential Added Canopy Area	% Canopy Added	% of PCA achieved
1	Barrington river- Warren River (A)	32.1%	28.5%	1.5	-	-	32%	1 yr / 24	0%	0%	0%	50.8%	18.7%	0.0%	0%
2	Mount Hope Bay (B)	55.1%	17.4%	5.7	-	-	55%	1 yr / 24	0%	0%	0%	67.6%	12.5%	0.0%	0%
3	Old Mill Creek-Narragansett Bay ©	48.4%	15.7%	2.8	-	-	48%	1 yr / 24	0%	0%	0%	64.8%	21.5%	0.0%	0%
4	Upper East Passage (D)	35.5%	32.1%	4.2	-	-	36%	1 yr / 24	0%	0%	0%	51.4%	15.8%	0.0%	0%
5								1 yr / 24	0%	0%	0%				0%

The Trees to Offset Stormwater Tool (TSW) allows the town to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees and adding impervious surfaces).

The amount and type of open space under and around the tree and the condition of surface soils affect the infiltration of water. The TSW tool developed for Bristol has a data field to hypothetically add trees to determine stormwater uptake from new tree planting. The TSW tool applies the PPA data to determine how many more trees could be planted. The tool also calculates the amount of nitrogen, phosphorus and sediment the trees and their surrounding soils take up. For more about the stormwater calculator tool, see Appendix B.

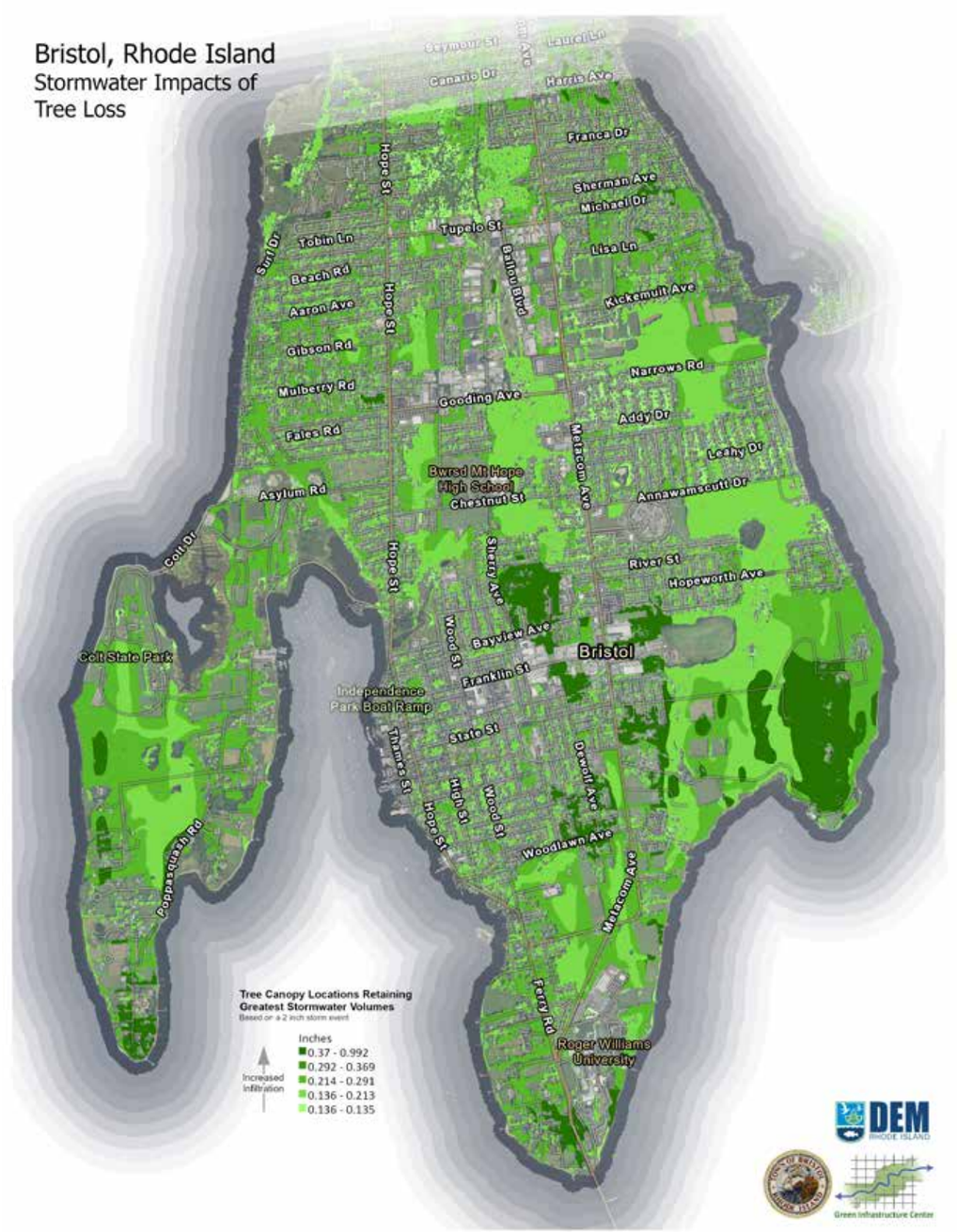
The TSW model is a tool for seeing the stormwater impacts of adding or losing tree canopy and the resulting pollution increases or decreases.

The TSW model is a tool for seeing the stormwater impacts of adding or losing tree canopy and the resulting pollution increases or decreases (nitrogen, phosphorus, sediment). For example, the model shows that for a hypothetical 5% loss of tree canopy for the town, during a 10-year storm event, an additional 1.1 million gallons of rainfall runoff would occur: that's more than three Olympic swimming pool's water volume. Conversely, if half of each plantable area were covered with new trees – increasing tree canopy – the TSW model shows that trees could capture an additional 2 million gallons of water during the same storm; or about four Olympic pools' volume of water.

Removal of mature trees and existing forests generates the greatest impacts for increasing stormwater runoff. As more land is developed, the town should seek to maximize tree conservation for maintenance of surface water quality and groundwater recharge. The following maps show areas that are the most important to retain trees for stormwater uptake and those areas where tree planting will have the most benefits for stormwater uptake. This is based on the types of soils present.

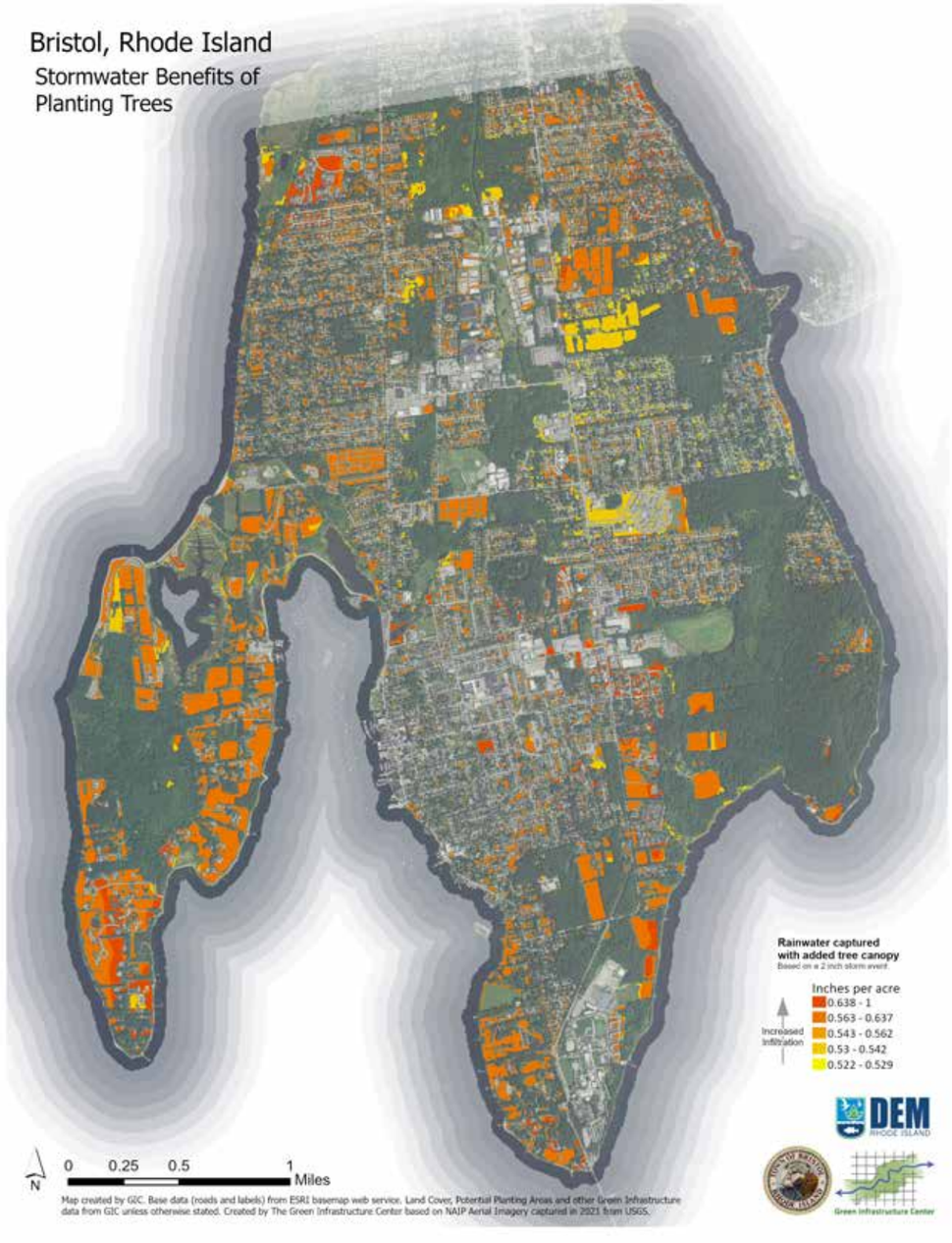
Map of Stormwater Impacts of Tree Loss

This map identifies existing mature tree canopy that is in the best location (in dark green) for retaining stormwater on site.

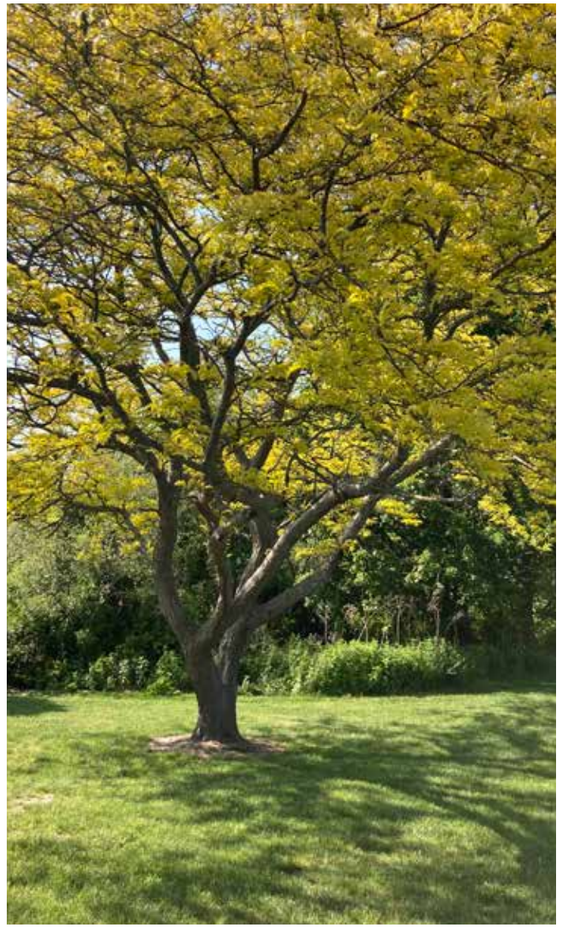


Map of Stormwater Benefits of Planting Trees

This map identifies the best planting areas to plant trees to infiltrate stormwater into the soil.



Investments in canopy at the neighborhood level can improve the respiratory health of residents.



Air Quality Pollution Removal Values

Air quality pollution removal values were calculated by applying the multipliers used by the i-Tree models. I-Tree is a peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefit assessment tools. It provides standard pollution removal values per acre for various air pollutants. The following i-Tree model values for urban areas were used to derive the pollution removal values per acre of tree canopy.

Carbon monoxide (CO) affects how quickly greenhouse gases such as methane breakdown, which are linked to climate change and global warming. Carbon is another element that contributes to climate change mainly in the form of carbon dioxide. Trees sequester carbon from carbon dioxide in their leaves, trunk, and roots, and prevent it from being released into the atmosphere where it can contribute to climate change.

Ground level ozone O3 can cause the muscles in people's airways to constrict, trapping air in the alveoli, leading to wheezing and shortness of breath, which is particularly harmful to those with respiratory diseases or chronic conditions, such as asthma. Nitrogen dioxide (NO2) and Sulphur dioxide (SO2) also irritate airways in the respiratory system and aggravate respiratory conditions such as asthma.

PM10 is particulate matter measuring 10 micrometers or less in diameter and PM2.5 is particulate matter 2.5 micrometers or less in diameter (a human hair is about 100 micrometers = about 40 fine particles). PM2.5 is generally described as fine particles. Finer particles have the potential for greater harm since they may lodge deeper in the lungs. Trees are able to filter and clean particles from the air.

Well-treed neighborhoods suffer less respiratory illnesses, such as asthma (Rao et al, 2014). This means that investments in canopy at the neighborhood scale can increase the health of residents.

Pounds of air pollution and greenhouse gases removed annually by all trees in Bristol

CO (carbon monoxide)	NO_2 (nitrogen dioxide)	O_3 (ozone)	PM_{10}* (particulate matter 10 microns)	$PM_{2.5}$ (particulate matter 2.5 microns)	SO_2 (sulphur dioxide)	CO_2seq (carbon dioxide sequestered) in lbs	CO_2stored ** (carbon dioxide stored in lbs)
620	3,098	51,721	7,672	1,954	5,772	23,606,526	333,606,890

*PM = Particulate matter
**CO_2 stored is not an annual rate but a total amount of carbon stored.

Codes, Ordinances and Practice Review

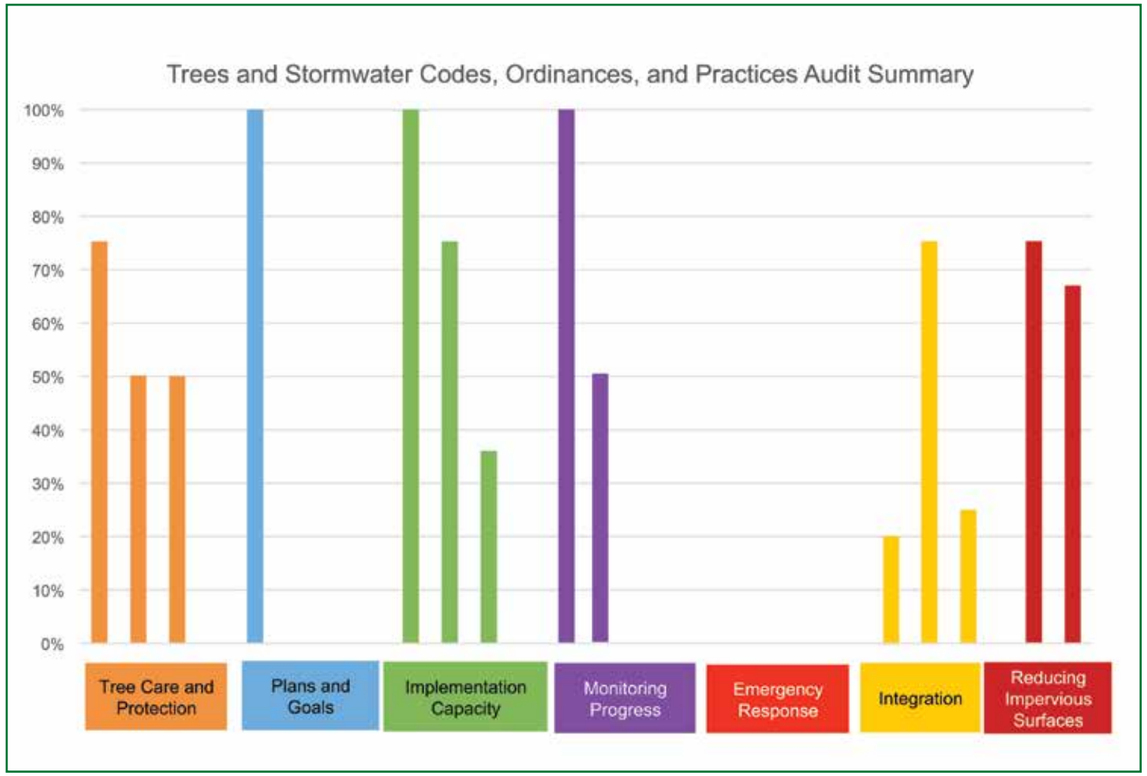
This review determined which practices create more impervious surfaces (e.g., too much parking required), protect or restore pervious surfaces (e.g., conserving trees or requiring open spaces), and create a healthy urban forest (e.g., tree planting and care standards). Documents reviewed during the codes, ordinances and practices analysis for the project include relevant sections of the town's current code that influence urban forest practices, runoff or infiltration. Data were gathered through analysis of town codes and policies, as well as interviews with town staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the town lists all the codes reviewed, interviews held and relevant findings.

Points were assigned to indicate what percentage of urban forestry and planning best practices have been adopted to date by the town. The spreadsheet tool created for town codes can also serve as a tracking tool and for determining other practices or policies the town may want to adopt in the future to strengthen the community forestry program or to reduce impervious land cover. The less town land that is paved, the more room there is to add trees.

Categories the town scored best in were "Implementation Capacity," "Monitoring Progress," and "Reducing Impervious Surfaces" while "Tree Care and Protection", "Plans and Goals", "Emergency Response", and "Integration" all had room for improvement. Best practices the town follows under "Implementation Capacity" include having a certified arborist on staff who manages the day-to-day operations of the community forest and is also trained in Tree Risk Assessment Qualification (TRAQ). The town also has a Tree Commission that is actively engaged in the community forest program and has a dedicated line item in the annual budget for community forest management. The town is building the planning phase of its community forestry program by collecting data, both in the form of a tree inventory and canopy mapping, to support strategic decision-making.

Tree Care							
Is a gov't agency responsible for public tree care?	Yes		The Department of Public Works is responsible for public tree care along with the Tree Warden.	https://www.bristolri.gov/departments/dpw/tree-service-requests/	Task a municipal agency with tree care. Municipalities where an internal agency is tasked with tree care score one point.	1	1
Is there a program to plant trees in the ROW?	Yes		Residents can request a tree planted in the ROW by filing out a form via the city's website.	https://www.bristolri.gov/departments/dpw/tree-service-requests/	Where practicable and feasible, plant trees in ROW areas. Trees shade streets, sidewalks, and minimize urban heat island effect. Use a street by street analysis to target planting areas. Municipalities planting ROW trees using a visual or spatial street by street analysis to determine where more trees are needed, score two points.	2	2
Is there a program to maintain trees in the ROW?	Yes		Resident can request a tree inspection which includes possible trimming and pruning of trees in the ROW.	https://www.bristolri.gov/departments/dpw/tree-service-requests/	Task a government agency with street tree plantings. Municipalities planting and maintaining street trees score two points.	2	2
Are ANSI tree care standards used?	No	None that the planning department is aware of.		Email communication from Ed Tanner.	Municipalities using ANSI or other comprehensive tree care standards (e.g. Municipal Urban Forestry Standards and Specifications) score two points.	0	2
Is there a Tree Care Ordinance which requires pruning and preventative maintenance including an annual schedule for city owned trees?	Yes		There is a tree ordinance and within the ordinance it directs the tree warden and Tree Commission to develop annual recommendations for management of the urban forest.	Sec. 25-28. - Authority of the Bristol Conservation Commission function as tree commission.	Adopt a Tree Care Ordinance and an annual schedule for city owned trees. Municipalities with both documents score three points.	3	3
Is an urban forest canopy calculation performed once every four years?	No		The town is in process of having its tree canopy mapped. This will give it baseline data for future canopy change. However, nothing in the code specifies a frequency in monitoring the canopy over time.		Perform an urban forest canopy calculation and change comparison every four years. Determine funding (or devote staff time) to the study. Codify performance of the canopy calculation in the Tree Care Ordinance. Municipalities with as a funding mechanism and a requirement of an urban forest canopy study on a four year cycle score three points.	0	3
Is the city a Tree City USA?	Yes		The Town has been a Tree City USA for 21 years.	https://www.arborday.org/programs/treecityusa/	Municipalities designated as Tree City USAs score one point.	1	1

A snapshot of the types of questions or sections of code evaluated.



Summary scores for town codes and policies within each category. The town scored best in "Implementation", "Monitoring" and "Reducing Impervious Surfaces" but had room for improvement in "Tree Care and Protection"', "Plans and Goals", "Emergency Response", and "Integration".

Recommendations

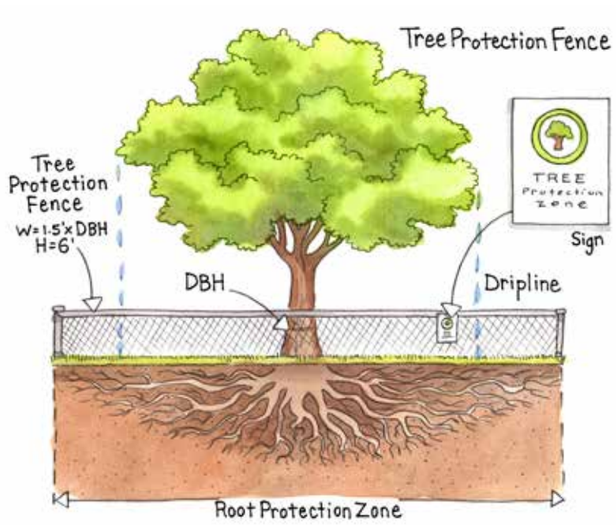
Tree Care and Protection

The town tree canopy would benefit from strengthened tree protection requirements. Currently tree protection only applies to public trees. The town should expand tree protections to include trees on private property as well. The urban forest is part of the greater community fabric and as such the impacts of tree loss on private property impact the entire town. The town could limit tree protection on private property to only include significant trees (16 inches DBH or greater) or another standard for tree size found on the site. Updating the tree ordinance to protect private trees will minimize the loss of trees during development. In situations where trees must be removed to accommodate the development, requiring the replacement of those trees elsewhere on site or the developer to pay a fee into a tree mitigation fund in-lieu of planting will limit tree loss. Establishing a tree mitigation fund that allows funds to be used to plant trees on public and private property will give greater flexibility to plant trees where they are most needed. The tree replacement fee should be strong enough to discourage wholesale tree removal on a site.

Additionally, the town should create a more comprehensive tree protection zone standard. The current standard is to protect 30 feet from the base of the tree which in practice gives much greater protection to smaller trees while giving less protection to the largest trees in the community. The tree protection zone only applies to public trees; this should be expanded to any tree impacted by development. The Critical Root Zone (CRZ) is the zone where 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. Many municipalities require that tree protection fences be placed at the dripline. While protection at the dripline is an accepted practice, it does not adequately protect the roots. Instead, the town should require placement of tree protection fencing at a distance 1.5' times the tree's diameter at breast height (DBH) from the tree. For example, a 20-inch DBH tree would need its CRZ protected out to a distance of 30-feet while a 10-inch DBH tree would need its CRZ protected out to a distance of 15-feet. This formula adequately sizes tree protection of the CRZ based on the size of the tree and not a standard distance.

The ordinance should also include detailed standards for what constitutes tree protection mechanisms. The most common form of tree protection is tree fencing. It is a physical barrier that keeps people and machines out of a tree's critical root zone during construction. However, some municipalities only require plastic orange fencing and wooden stakes. This type of fencing can be removed or trampled easily and reduces protection effectiveness. Without effective barriers, even trees designated to be saved may suffer development impacts such as root compaction and trunk damage. The town should require sturdy metal chain link fencing in high-risk areas (e.g., near heavy construction equipment and active site grading) and use orange plastic fencing in lower risk areas (e.g. along the tree line at the edge of a development property).

The town currently does not require tree protection signage. Tree protection signage communicates how work crews should follow tree protection requirements. It also informs construction crews and citizens about the consequences of violating town 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 town should design a standard tree protection sign which summarizes the does and don'ts of working near and around tree protection zones. Additional training may be helpful to ensure that developers comply with the town's tree ordinances and understand how to protect trees during construction. If the work crews are of different nationalities, consider signage that has multi-lingual instructions.



Tree Protection Fence and Signage

Other examples of best management practices for tree protection include require the severing of roots of nearby trees prior to being removed, require thick mulching (no more than 4-5") if heavy equipment is to be driven in the critical root zone, encourage (or require) boring versus trenching for utilities and irrigate protected trees during construction during periods of drought.

Soil volume and soil surface area standards for various sizes of trees.

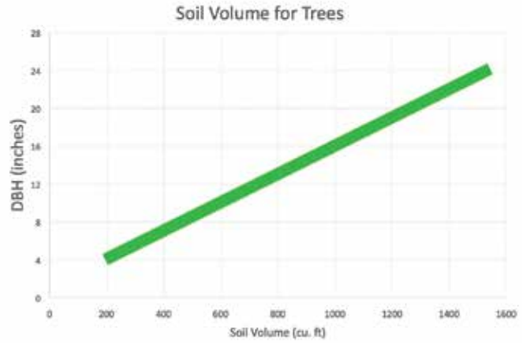


Table 1. Soil requirements for trees based on their size at maturity.

Tree Size at Maturity	Total Soil Area*	Distance From Paved Surface
SMALL Height: less than 30 ft	10 ft x 10 ft	2 ft
MEDIUM Height or less than 50 ft	20 ft x 20 ft	6 ft
LARGE Height or spread greater than 50 ft	30 ft x 30 ft	10 ft

*Measurements for when rootable soil depth is 3 feet or greater. For soil less than 3 feet deep, smaller maturing trees are recommended

In urban environments, many trees do not survive to their full possible 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 allowed to reach its full potential.

To encourage proper planning, planting and design for trees on sites, the town should designate root soil volume and soil surface area standards. Tree roots need adequate soil volume and surface area to absorb water and promote gas exchange for healthy root growth. At a minimum, large canopy trees require 1000 cubic feet of soil volume to thrive. Additionally, the most critical factor for a tree to withstand hurricane force winds without falling over is adequate soil volumes to allow for proper tree anchorage into the ground. (Duryea 2007). The following table provides recommended soil volume and soil surface area standards for healthy tree growth and resistance to wind. In areas where space is tight or where heavy uses occur above, underground tree support cells can be used to stabilize and direct tree roots towards areas with less conflicts (e.g., away from pipes).

In addition, large trees should not be planted where they may interfere with overhead lines. The town can promote better tree planting by specifying non-interference with utilities in the tree ordinance and on intake forms for street tree and tree setback plantings on private property. These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will ensure that investments in town trees will 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.

Planting trees in the right place can avoid harmful over pruning.

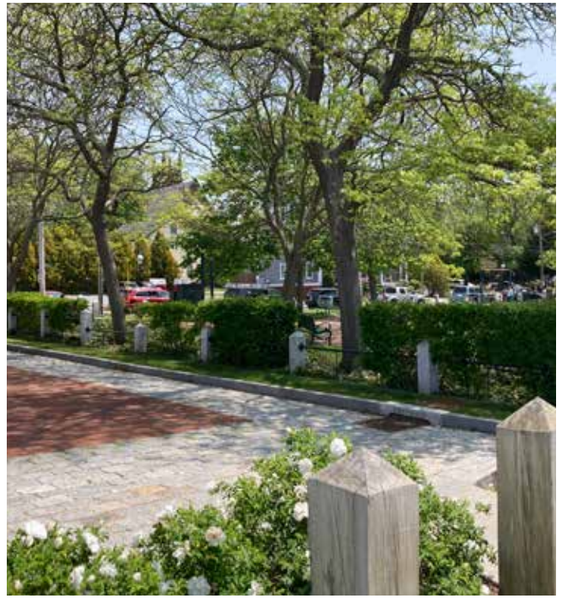
Plans and Goals

The town's comprehensive plan references tree canopy and the community forest, including a goal of maintaining existing tree canopy, collecting tree inventory data to support proper planning and decision-making and planting a minimum number of trees annually. The data provided by this assessment can be incorporated into future planning efforts by the town and give more detailed data on the actual number of trees to plant townwide in order to achieve its canopy goal. The data from this project can inform other planning efforts in the town and should be included in updates for its comprehensive plan, open space plan, stormwater management plan, and hazard mitigation plan. Other recommended plans and goals include identifying local and regional community partners that can help support the long-term planting and maintenance of the community forest. The assessment data produced for this project can also be used to create an urban forest management plan for the town. This will allow for the town to prioritize and schedule maintenance of public trees and help estimate the necessary annual budgets to do the work.

Emergency Response

Recommended areas of improvement for "Emergency Response" were the inclusion of trees and built green infrastructure practices such as bioswales, rain gardens, etc. into future Hazard Mitigation Plan updates. Trees are a low cost, low impact solution to managing stormwater runoff. Specifically calling out green infrastructure practices and trees in the plan opens opportunities for federal funding through FEMA's grant programs. Identifying trees as green infrastructure and documenting the role they play at managing stormwater on public property and in rights-of-way makes them eligible for funding assistance through FEMA's Public Assistance grant program if the town experienced a federally declared disaster.

Another area of improvement is establishing an annual program to assess tree risk for public trees. The town could apply for funding from the Division of the Forest Environment to contract a tree risk assessment on its tree inventory data after it is updated. An annual Level-1 tree risk assessment of public trees, also known as a windshield survey, is a simple and relatively quick way to assess trees in the town for potential risk. This type of survey can help the town track trees with potential hazards and follow-up for a more detailed assessment and mitigation. Using the tree inventory the town can develop a risk management program for public trees and mitigate potential impacts from natural disasters such as winter storms.



Integration

Recommendations under "Integration" include incorporating urban forestry data (canopy data, tree inventory) throughout town departments and systems. Integrating this data also allows for various town staff to use and incorporate the data into their work such as planning staff who can use the data in daily and long-range planning. In addition, by making the canopy data available online, the town can provide information to the public about this important natural asset. Integrating this data also allows for staff to understand the resources on site during the development review process.

The town's stormwater management plan does not mention trees at all. The town's website on stormwater mentions land cover change, but nothing about the role trees play in soaking up stormwater. Using the data and tools provided in this assessment, the town can integrate the role trees play in managing and mitigating stormwater in the town. This can lead to a more holistic approach to managing stormwater and can incentivize developers and the community at-large to preserve and better care for trees on private property. The town is already using the tree canopy data at the watershed scale to plant trees in priority watersheds to reduce stormwater and nonpoint source pollution through action grants funded by the Rhode Island Infrastructure Bank.

Planning Process and Community Engagement

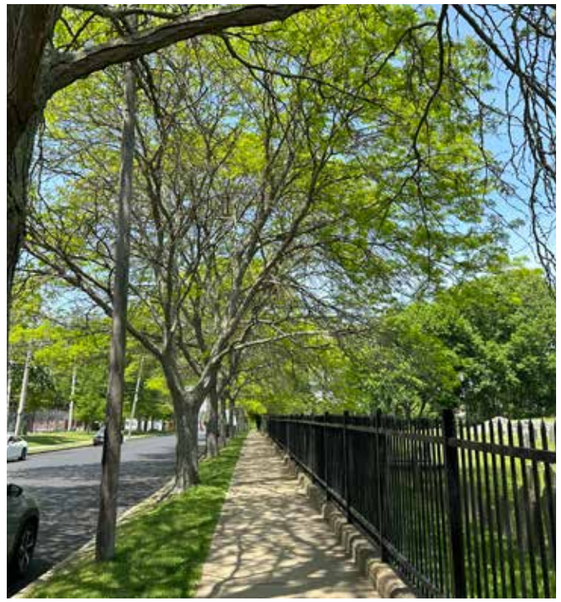
Steering Committee

The first step in the GIC's planning process was to develop a steering committee of town staff and tree commission members to provide their knowledge and expertise when reviewing data, maps and tools. The steering committee participated in a series of six workshops each focused on a different area of analysis presented in this report. Using final land cover, Potential Planting Areas (PPA) data and each of the analyses, the steering committee created a list of proposed strategies and a proposed canopy goal. The proposed goal and strategies along with a summary of the results from the canopy study and codes audit were presented to the general public at an open house in October of 2023. The open house was an opportunity for the public to learn the results of the study and vote on the proposed goal and strategies developed by the steering committee. The voting results were reported to the steering committee which influenced the final strategies chosen. This process is only a first step in thinking strategically and engaging the public on a broader scale around the tree canopy. This information and community feedback will support future tree canopy planning for the Town of Bristol.

The Bristol community attended open houses in the fall of 2023 to review maps and learn more about the town's tree canopy.

Public Open House and Input

The Green Infrastructure Center held an open house on October 3, 2023 in the Herreshoff Community Room at the Rogers Free Library to share maps and findings from the canopy study with the public. GIC also presented the town's proposed canopy and strategies for increasing canopy or reducing its loss. Twenty-six members of the community showed up to learn more about the tree canopy and vote on the town's proposed strategies.



The Top Five Strategies

Voted Highest by the Public

- **Plant more trees in Right-of-Ways where canopy is less than 10%.** (20 votes)
- **Adopt a town policy that states trees are a part of the community's infrastructure.** (17 votes)
- **Inventory Heritage trees in the historic district and Champion trees elsewhere in the community.** (14 votes)
- **Make a 5-year or 10-year street tree planting plan.** (10 votes)
- **Retrofit properties with new tree plantings and green infrastructure to reduce impervious surfaces.** (9 votes)

Informing Other Existing Planning Efforts With Bristol

Community forest planning has roots in other existing planning efforts in the town. The following plans highlight previous community input for managing the community forest resource or are policies, programs or goals that align with many of the strategies and recommendations found within this document. The data from this study and many of the strategy ideas developed during the course of this project can inform other planning efforts in the town and identify ways to accomplish many of these stated goals. The integration of canopy data and planning of the town's green infrastructure will make other types of planning more successful by achieving many different goals.

Bristol's Comprehensive Plan, 2016

Chapter 3: Land Use

Goal 1. Promote land use patterns that are sensitive to the Town's character and assets, recognize the Town's resource constraints, are economically sound, and facilitate smart growth to build capacity in sustainability and climate resiliency in Bristol.

A. Protect Bristol's natural landscape and resources for present and future generations.

B. Respect the historic resources that link Bristol's present with Bristol's past and use these resources as guidelines for managing future growth.

F. Embrace Smart Growth principles, conservation development zoning and encourage sustainability of our resources in all land use decisions made by the Town of Bristol.

Chapter 6: Natural, Historical and Cultural Resources

Goal 1. Protect Bristol's natural landscape and resources for present and future generations.

A. Protect Bristol's water, air, soil, plant, and wildlife resources, especially all resources that are identified as being threatened or endangered. Protect and encourage biological diversity. Conserve and manage natural resources in a manner that consistent with the contemporary vision of the town.

E. Increase and maintain the forest cover by 25% by the year 2020.

Goal 2. Continue to protect the historic and cultural resources that link Bristol's PAST with the vision for Bristol's FUTURE.

C. Incorporate historic resource protection and planning within the overall community planning and development review process. Identify and protect historic, cultural and natural landscapes, plantings and features within Bristol.

E. Continue to work with Newport Chamber of Commerce and Explore Bristol to publicize and promote tourism in Bristol through, for example, efforts such as the Bristol – Newport Heritage Trail and similar initiatives.

Goal 4. Educate and motivate the public to encourage involvement and increased awareness of every person's responsibility to preserve and protect the natural, historical and cultural character of the town.

A. Regulate growth and development so as to protect natural, historical, and cultural resources for future generations.

B. Educate the public to the long-term value of the natural, cultural, historical resources and their relation to the quality of life.

E. To encourage creative deliberation among interested public and private parties focused on utilizing our natural, historical and cultural resources as engines for economic development.

Goal 5. Promote environmental education and conservation for children and adults.

A. Conduct environmental education classes that coincide with existing recreational programs and partnerships with local organizations such as Save Bristol Harbor, Bristol Land Trust, Audubon Society of Rhode Island, and Bristol Recycles.

B. Install environmental and conservation related signage and kiosks where appropriate to educate the public to ongoing environmentally beneficial projects.

C. Promote education relating to water quality and protection of water resources recognizing that Bristol is a peninsula that is surrounded by and dependent upon water.

D. Promote environmental stewardship of land and water resources in school and recreational programs geared towards children.

Goal 6. Promote water quality improvements to bay and other waterways in Bristol.

H. Incorporate water quality benefits in all developments and reconstruction projects undertaken by the Town.

Chapter 7: Open Space, Conservation & Recreation

Goal 2. Increase and improve land area reserved for passive recreation, conservation, and open space.

A. Acquire additional land in appropriate areas for passive recreation and trails (walking, biking, bridle, etc.) to enhance the quality of life of Bristol's increasing population.

B. Acquire additional land for purely conservation purposes, to be left in its original pristine state and also to protect diminishing ecologically sensitive areas.

C. Protect areas which provide greenbelts, open space, and relief from development — including Town-owned parks and open space parcels — through various layers of protection, such as conservation easements.

D. Continue efforts to increase, acquire, and protect existing areas of the Silver Creek Watershed Area.

Goal 3. Create active recreation programs and facilities to serve the full range of Bristol residents.

B. Maintain emphasis upon a variety of imaginative new programs for recreation.

C. Support recreation's role as a community activity that brings people together.

F. Develop additional small neighborhood parks and open spaces in residential areas.

Goal 4. Plan for recreation and conservation of open space by using a coordinated approach – to include multiple uses of a site, and diverse forms of ownership, management, and financing.

D. While respecting the privacy of residences, connect recreation areas, neighborhoods, and as many other Town facilities as possible with a system of walkways, hiking trails, bikeways, greenbelts, and bridle trails.

F. Continue to act upon the options for acquiring dedicated open space lands through the Subdivision Rules and Regulations including impact fees.

H. Continue to acquire and/or protect land in the area of Mount Hope through local, State and Federal monies, through local and State regulations, and through private foundations and land donations.

Natural Hazard Mitigation Plan, Bristol, Rhode Island, July 2016

Action #4 – Prepare an "After the Storm Recovery" Plan for the Community

GIC note: An important piece to any recovery plan is the long-term recovery of the town's tree canopy. The town could incorporate tree canopy data and identify opportunities and partners for recovering lost canopy from a disaster.

Action #6 – Preserve vacant Open Space within the coastal flood zones

GIC note: Forested open space can provide a buffer against coastal flooding, store floodwaters and improve water quality by reducing runoff into the bay.

Action #8 – Bury Electrical Wires and other suspended cables

GIC note: The town can request funds to install adequately sized tree wells that double as stormwater facilities during excavation to bury overhead utilities.

Action #10 – Retrofit of paved parking areas within the Tanyard Brook and Silver Creek Watershed

GIC note: When retrofitting parking lots with low impact development designs, the town can install recessed tree islands that function as stormwater collectors but also support healthy trees which can increase the functionality of the facility to mitigate stormwater.

Stormwater basins can be planted with trees where maintenance access is not prohibited to provide additional stormwater capture.

Bristol, Municipal Resilience Program, Community Resilience Building Workshop Summary of Findings, August 2020

Environmental Challenges and Concerns: Trees and Forests:

- Increasing impacts to tree health from pests and pathogens resulting in large population of dead and damaged standing trees that pose risks to power lines and increase blockage of roads during emergencies.
- Aging street trees with many over 100 years old increasing risk.

Actions:

- Reduce pollution in the Harbor to ensure long-term resilience of this resource.
- Incorporate resilience designs to reduce vulnerability of structures in coastal downtown/historic area to better withstand future climate impacts.
- Initiate or continue flood mitigation projects within the Silver Creek watershed (i.e. golf course, Tupelo Street).

Residential properties play a key role in the stewardship of the urban forest.

The town can engage with students and faculty at Roger Williams University on tree canopy projects and stewardship of the community forest.

- Install green stormwater infrastructure at Police Station parking lot.
- Restore wetland habitat at the golf course to increase flood storage.
- Implement Mt. Hope High School drainage master plan.
- Continue to plant trees in Wood Street Neighborhood to protect elderly population from heat, and expand the current tree canopy.
- Initiate stream restoration project to increase flood storage capacity along the East Branch of Silver Creek (i.e. Mt. Hope High School, Leila Jean Drive, Chestnut Street).
- Expand green stormwater infrastructure projects in parking lots and front yards.
- Expand bicycle infrastructure and sidewalks to promote health and alternative transportation, while encouraging residents to use sustainable transportation methods.
- Consider establishing a stormwater utility with dedicated funds to address flooding using a variety of approaches including green stormwater infrastructure.
- Continue working with Save the Bay to monitor stormwater impact.
- Continue use of trees in stormwater mitigation.
- Continue implementing best management practices and low-impact development.
- Review town-wide Hazard Mitigation Plan and reevaluate prioritization of projects across neighborhoods.
- Educate university students about the challenges of a coastal community and provide opportunities for them to help develop long term solutions.
- Install green stormwater infrastructure at Gooding Plaza shopping center.
- Allocate more funding towards tree trimming and protecting power lines.
- Ensure that minimizing environmental impact is a priority in every development project.

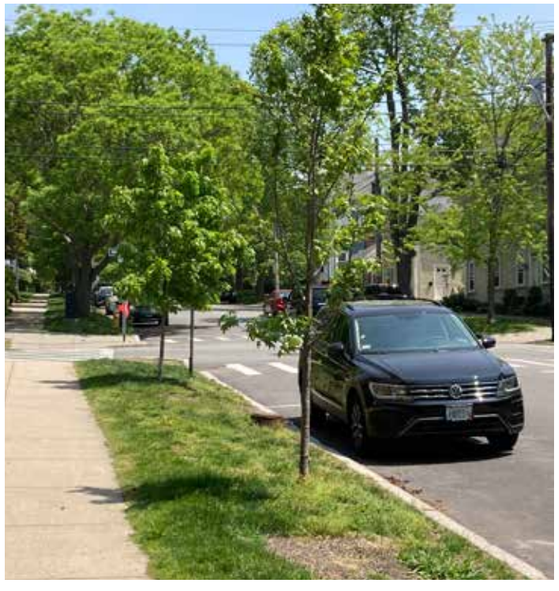
Strategies and Recommendations

The strategies in this report were developed in workshops with the steering committee and voted on by community members. GIC made additional recommendations. All strategies and recommendations are based on the land cover and ecosystem service modeling, analysis of the tree canopy and potential planting areas and the codes, or ordinances and policy review.

The top strategies and recommendations to improve tree canopy cover in Bristol listed in priority order include:

1 Plant more trees in Right-of-ways where canopy is less than 10%.

Trees in the public rights-of-way (ROWs) provide shade, mitigate stormwater runoff, clean the air of pollutants and create wildlife habitat. People are less likely to walk or bike on streets with little to no canopy. Increasing the canopy in the ROWs where canopy cover is low can provide these benefits to residents and visitors of Bristol. The data from this study can help the town identify low-canopied street segments and prioritize sections for new tree plantings. This data will also be useful if the town creates a street tree planting plan and program to increase canopy within public ROWs.



The town has an active street tree planting program. The data from this study can help the town prioritize which street sections they will plant over the next 5-10 years.

2 Adopt a town policy that states trees are a part of the community's infrastructure.

An adopted local policy of trees as green infrastructure can help the town make the case to the Federal Emergency Management Agency that trees are part of its green infrastructure and eligible for reimbursement under its public assistance grants if a federally-declared disaster occurred in Bristol. However, an adopted policy alone is not enough. In addition to an adopted policy the town needs to document the role trees play in managing the municipal stormwater system and keep records through tree inventories and work orders that it is managing and tracking maintenance of this public resource. An updated tree inventory that includes photos, locations and metrics of publicly owned trees is a great first step towards having this documentation.

Additional GIC Recommendations

- **Codify the role of trees as green infrastructure within the Hazard Mitigation Plan.**
  The Federal Emergency Management Agency's (FEMA), Public Assistance grants support "*Plantings (such as trees, shrubs, and other vegetation) are eligible [for funding] when they are part of the restoration of an eligible facility for the purpose of erosion control, to minimize sediment runoff, or to stabilize slopes, including dunes on eligible improved beaches. Plantings required to mitigate environmental impacts, … are only eligible if required by a Federal, State, Territorial, Tribal, or local code or standard permit that meets the criteria described in Chapter 2:VII.B.7.*" (FEMA, 2020). In order for trees to be eligible by FEMA under the Public Assistance Grants for reimbursement, documentation on the role those trees play in mitigating stormwater or erosion is necessary. Adopting trees as a hazard mitigation strategy and policy can establish precedent for the role of trees as green infrastructure (note: additional documentation steps are required). Adding trees as green infrastructure can also be used to justify funding tree planting as green infrastructure under FEMA's Hazard Mitigation and Building Resilient Infrastructure and Communities (BRIC) grant programs.

- **Use public tree inventory data to track town assets.**
  Once the town finishes collecting a tree inventory for all public trees, the data should be integrated into the town's asset management tracking systems where other types of public infrastructure are tracked and managed. This will allow the town to track and monitor its assets for tree locations, condition and maintenance needs as further work is conducted over time. These data are critical for securing future FEMA reimbursement to replace trees under its Public Assistance grants available after federally-declared disasters.

3 Inventory Heritage trees in the historic district and Champion trees elsewhere in the community.

The historic district is a key area of town and major attraction for tourists and visitors to the community. The history and culture are on display in the beautiful buildings, the local shops and educational signage around the district. The district also contains some of the biggest, most beautiful and most visible trees in the town. An inventory of these trees and educational signage can create further interest for visitors who want to learn and explore more about the Bristol community.

4 Make a 5-year or 10-year street tree planting plan.

A street tree planting plan can help the town prioritize, appropriately budget and track the progress of tree plantings in the rights-of-way (ROW). The town will need to make sure they are adequately replacing the numbers of new trees within the public rights-of-way to sustain the tree canopy. This type of plan can be integrated into other municipal planning efforts such as capital improvements or the maintenance of the rights-of-way, so when the town or other public agencies are upgrading or maintaining grey infrastructure such as roads and utilities, then new trees can be replaced or better tree wells installed that give more soil area and volume that support healthier tree growth and longevity. This plan can also build greater collaboration with Rhode Island Department of Transportation and the local electrical utility to better manage the tree canopy in ROWs.

The trees in the historic district help tell their own story about the history of Bristol and are part of the fabric of the community.

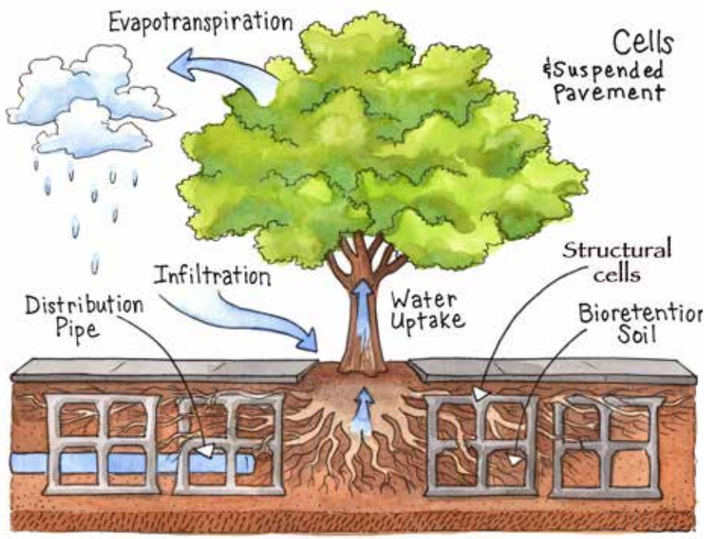
Additional GIC Recommendations

- **Update tree inventory data in Rights-of-way and on public property.**
  Another proposed strategy that would complement the street tree planting plan, is completing a tree inventory to inform the plan. A tree inventory tracks data such as tree species, size (which can relate to tree age), tree condition or health, and identifies any conflicts or hazards that could increase the risk of tree parts failing. Inventory data allows for analysis of the species composition of the town's urban forest, identifies hazardous trees needing maintenance or removal and is an integral part of an urban forest management plan. The town has an older dataset that needs to be updated. DEM's Division of Forest Environment has software available for a nominal fee to communities for collecting tree inventory data and provides additional grant funds to municipalities for analysis and quality control of the data.

- **Develop an urban forest management plan for the town.** An urban forest management plan (UFMP) details the state of public trees, sets goals and outlines the process for managing the town's tree canopy. It is used to proactively manage the town's canopy and achieve long term benefits. A UFMP also informs budgeting for urban forest maintenance or tree planting. An urban forest management plan requires data to inform the goals, actions and benchmarks including canopy and tree inventory data. An urban forest management plan prioritizes maintenance needs for all public trees and estimates the resource needed. Then it develops a timeline for implementing the necessary maintenance. UFMP are typically on a 5-year cycle and need updating as the work is completed or new challenges arise such as damage from storms. Once the town has updated its tree inventory data it can develop an urban forest management plan for its public trees and make sure that it is adequately funded to meet maintenance needs. A street tree planting plan can be an important component that informs an urban forest management plan.

5 Retrofit properties with new tree plantings and green infrastructure to reduce impervious surfaces.

The town and local partners are focusing efforts to better manage stormwater in the Annawamscutt, Sowams and Silver Creek neighborhoods. The town has plans to enhance Leahys Pond while local community partners such as the Eastern Rhode Island Conservation District have a program to give residential homeowners rain barrels. Integrating other green infrastructure elements such as tree plantings or tree giveaways, residential rain gardens or infiltration trenches can all support more holistic management of stormwater in Bristol neighborhoods. Many local conservation and watershed groups are working to educate the public and complete projects that reduce stormwater impacts and enhance water quality in the bay. The town should build partnerships for trees and green infrastructure around the East Bay with groups such as Save the Harbors Coalition.



Structural Cells and Suspended Pavement are techniques to integrate trees in highly impervious areas.

Photo credit: Acton Wakefield Watersheds Alliance (AWWA)

Infiltration trenches are a low-cost, low-tech way of reducing urban stormwater runoff on private property. This type of practice is compatible with tree plantings for added stormwater mitigation value.

Additional GIC Recommendations

- **Require and enforce 600, 1,000, and 1,500 cubic feet soil volume planting requirements for small, medium, and large trees respectively.**
  At a minimum, canopy trees require 1,000 cubic feet of soil volume to thrive, as recommended by the Environmental Protection Agency (Stormwater to Street Trees, 2013). Soil volume allows for adequate room for root growth which will help keep the tree healthier for longer, further extending the return on investment of green infrastructure. Greater soil volume and soil areas will also decrease a tree's risk of failure during a storm by providing adequate area for root anchoring. When planting sites are narrow or surrounded by impervious surfaces then municipalities can consider structural cells which provide the support and hard surface needs for high trafficked areas, but also provide the adequate soil volume needed for healthy tree growth. These structural cells can also function, depending on the design, as a way to capture stormwater runoff and irrigate the tree.

Tree giveaways are one of the most popular and cost-effective ways to get trees planted on private property and provide an opportunity to educate the public on proper tree planting, care and maintenance.

6 Establish a community wide Tree Planting Campaign for Bristol. Hold public tree giveaways.

The Town of Bristol secured a $113,225 grant through the Rhode Island Infrastructure Bank's Municipal Resilience Program for growing and managing the town's urban forest. The town plans to plant 238 trees on public properties and along street rights-of-way in the Silver Creek, Tanyard Brook and Mt. Hope Bay watersheds. This investment in new tree plantings and leadership by the local government can inspire and leverage the wider community to get involved to plant new trees on private property. The town could jump start this effort by promoting the role trees play in the community, provide information on the proper types of trees to plant and could host a tree giveaway with community groups. Tree giveaways are one of the most popular and cost-effective ways to get trees planted on private property and provide an opportunity to educate the public on proper tree planting, care and maintenance.

7 Educate the public on tree removals, risks of tree hazards and the importance of proper tree placement, tree care and pruning to reduce tree loss.

The public should be made aware that proper maintenance and care of existing trees can significantly reduce risk of failure during storms. While risk can never be zero there are best practices that can reduce overall risk. Another important educational component is sharing information on "Right Tree, Right Place" (*see graphic page 48*) . Include infographics with social media posts, tree giveaways, and planting brochures to aid in proper siting and planting of trees on private property, particularly as it relates to plantings in or near the rights-of-way (ROWs). Proper placement will result in fewer conflicts with other infrastructure such as overhead utilities and can give adequate soil volume to the tree which will make it more resilient during wind-driven storms.

Additional GIC Recommendations

- **Create a webpage on the town's website with resources and links on trees and the community forest.**
  A dedicated centralized webpage about the Town's tree canopy can host important education material and links for the public to access information and resources on tree care, placement and municipal tree programs. The town could eventually create a story map of its tree canopy data to allow residents access to see where canopy is and lacking in the community

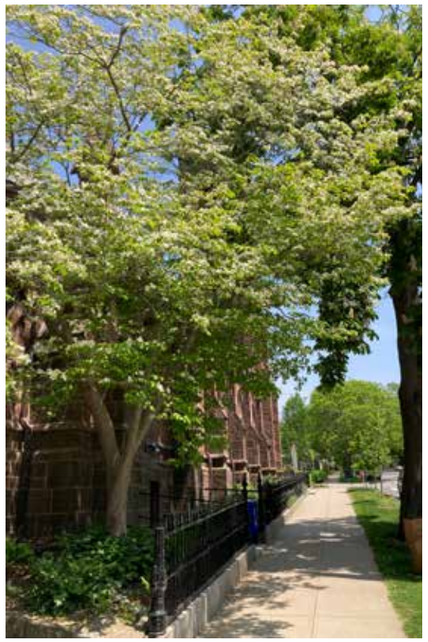
Residential and community rain gardens along with tree plantings are another low impact way of managing stormwater on sites.

8 Build partnerships for trees and green infrastructure around the East Bay with groups such as Save the Harbors Coalition.

The community forest resource is a natural asset that spans the public-private continuum and as such is a community responsibility for stewardship that requires the engagement and participation of a diverse range of public and private stakeholders. Building these partnerships is key to the long-term success of any tree planting efforts or sustainability of the community forest resource. Identifying special interest groups and targeting messages toward their needs and goals can build the coalition necessary to maintain this valuable community resource.

9 Beautify downtown by planting smaller flowering trees.

The historic downtown waterfront is a dense commercial and residential area of the town. It is a major attractor for visitors to the community and is a key gateway into exploring Bristol. Despite its density the district still has room for additional tree plantings. According to the data, the district could hold an additional 833 trees, with 393 being large canopy trees (40-feet diameter crowns) and 440 being small canopy trees (20-feet diameter crowns). The data needs to be groundtruthed for any potential conflicts with nearby infrastructure or buildings in the district, but a strategy is to plant more small flowering trees that can provide an additional beautification of the area. These types of plantings can make the district even more attractive to tourists when visiting.



Smaller flowering trees can further beautify the historic district and attract visitors in various seasons.

Additional GIC Recommendations

- **Update the tree protection ordinance to include protecting trees on private property and require tree mitigation when significant trees must be removed to accommodate development.**
  As recommended during the codes and ordinances audit, trees are part of the town's infrastructure and impact both public and private properties alike. By increasing the protection of trees on private property, the town can conserve and minimize tree canopy loss over time. Tree mitigation should be strong enough to limit the wholesale clearing of trees on a site, but not so punitive to limit necessary development. A tree mitigation fund should also be flexible to allow for tree plantings on both public and private property.

- **Incentivize developers to incorporate and retain mature trees on sites and protect those trees during construction**. Large mature trees provide greater and more immediate ecosystem service benefits than newly planted trees used for mitigation. The town's code can be amended to incentivize retention of mature trees for meeting stormwater requirements. Other types of incentives include faster permitting for preserved trees or patches of forest. The tree preservation code should also provide specific protections for mature trees during the construction process such as require fencing a distance of 1.5' times the tree's diameter at breast height (DBH) from the tree, exclude storage and staging of materials near the tree, place clearly visible signage and avoid trenching utilities that would impact tree roots. Existing large trees should be indicated on site plans along with tree protection measures.

- **Continue the integration of planning for trees in all planning and pre-development activities**. Holding pre-development conferences before sites are designed allows for creative solutions for tree retention to be considered as well as to calculate potential stormwater impacts from tree removal or planting. Sketching these site design ideas to protect trees early on allows for exploration of ideas for tree conservation before extensive funds are spent on site planning.

- **Proactively conduct annual tree risk assessments in highly trafficked areas of the town**.
  Tree risk assessments can be used to determine and develop plans to mitigate tree risks, such as diseased limbs that may fall. This information is a great baseline dataset the town can use to develop a risk management program for town trees. In highly trafficked areas, a Level-1 assessment, also known as a windshield survey, should be done annually for all public trees. Implementing proactive tree risk assessments will reduce overall risks and potential losses. The town should develop a formalized tree risk assessment program to ensure this work is being done consistently every year.

- **Conduct a land cover assessment every four to six years to compare tree canopy coverage change over time**. Tree canopy coverage should be expanded and maintained to promote public health, walkability, water quality and groundwater recharge. Regular updates to land cover maps also track trends (losses or gains) in the canopy over time, monitoring and support adaptive management for prioritizing planting strategies. This will also be useful measure to help the town track its progress and outcomes of its state grant from the Rhode Island Infrastructure Bank.

This ash tree is suffering from Emerald Ash Borer (EAB) an invasive insect pest that will eventually kill the tree. Assessing the health and condition of trees routinely will allow the town to mitigate risk over time through various best management practices.

Conclusion

The community of Bristol has started to collect data for the management of its community forest. These data (canopy data, codes audit) provide a variety of assessments that can inform actions and strategies moving forward. Other new types of data (tree inventory, risk assessments) can support further decision-making around its green infrastructure assets. Implementing these strategies and recommendations will significantly reduce the impact of stormwater sources (impervious cover) and benefit the local ecology by using native species (trees and other vegetation) to uptake and clean stormwater along with other ecosystem service benefits (air quality, urban heat island, etc.). It will also lower costs of tree cleanup after storms since proper pruning or removal of trees deemed to be at risk can be done before storms occur.

Bristol should use the canopy map and updates to track canopy change over time and prioritize increasing canopy by neighborhoods to restore lost canopy. The town 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.

Next Steps

An urban forest management plan is another key plan the town should develop to ensure that it has detailed and actionable processes to care for and manage its trees. Grant funding is available from the Rhode Island Division of Forest Environment's Urban and Community Forestry Program for such activities. A key aspect of urban forest management is integrating urban forestry within emergency response plans. This should be coordinated with the Rhode Island Emergency Management Agency and adjacent communities who share similar concerns about storm debris and removal or repurposing. Given the many benefits that trees provide (increased groundwater infiltration, soil stability, and reduced runoff and flooding, shade and better air quality), the town should plan for funding and replacement tree plantings following natural disasters. Codifying trees as green infrastructure to mitigate stormwater and erosion will make them eligible for replacement under FEMA's Public Assistance grants. Tree inventory data (location, species, trunk diameter, photo) the town collects will support the necessary documentation to claim a tree as eligible for reimbursement if lost or damaged by a federally-declared storm or other natural disaster. Including tree maintenance records and expenditures as part of the town's asset management system will demonstrate the role trees play as critical green infrastructure.

Lastly, it is recommended that the town conduct a land cover assessment every four to six years to compare tree canopy change over time and track progress towards the 45% coverage goal. Keeping tree canopy coverages at levels that promote public health, walkability, and clean water is vital for livability and for meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place and to identify and address negative trends as well. 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.

Appendixes

Appendix A: Land Cover Analysis Methods

This section provides technical documentation for the methodology used to classify land cover and create Potential Planting Spots (PPS) and Potential Canopy Area (PCA) scenarios for the town. 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 (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?

Method

Satellite imagery from the National Agricultural Imagery Program (NAIP) distributed by the USDA Farm Service Agency was classified to determine the types and extent of different land covers in Bristol.

1. Canopy maps were created using the NAIP imagery, captured in 2021. Current LiDAR data was not available at the time of classification, so we used an ArcGIS extension called Feature Analyst to identify the tree canopy. Feature Analyst employs machine learning for feature classification, and we trained it to complete the classification by digitizing canopy samples, which were then fed to the learning model, along with NDVI values calculated from the NAIP imagery.
2. Once we had an accurate canopy classification, we proceeded with obtaining the remaining land cover classes:
3. **Tree Canopy** over impervious are canopy features that overlapped Impervious surfaces primarily created from existing vector data.
4. **Wetlands** were identified using the National Wetlands Inventory dataset (NWI).
5. **Wooded wetlands** were identified based on where NDVI is above 0 OR feature height is above 10 ft and intersects NWI water/wetland.
6. **Turf/Pervious** are features identified as "green" or typically above 0 in NDVI but were not identified as canopy by Feature Analyst.
7. **Impervious surfaces** were created by buffering road centerlines, along with building
8. **Bare earth** is sometimes confused with Impervious surfaces, but typically had a NDVI value closer to 0.

A Confusion matrix was run to test the accuracy of the canopy data which resulted in ....

CLASS VALUE	Tree Canopy	Pervious	Water*	Impervious	Bare Earth	Wetland	Total	Accuracy	Kappa
Tree Canopy	32	0	0	0	0	0	32	100.0%	0
Pervious	0	23	0	2	0	0	25	92.0%	0
Water*	0	1	4	0	0	0	5	80.0%	0
Impervious	0	1	0	26	0	0	27	96.3%	0
Bare Earth	0	0	0	0	6	0	6	100.0%	0
Wetland	0	0	0	0	0	5	5	100.0%	0
Total	32	25	4	28	6	5	100	0.0%	0
P_Accuracy	1	0.92	1	0.93	1	1	0	96.0%	0
Kappa	0	0	0	0	0	0	0	0.0%	0.95

The result of this confusion matrix allowed GIC to determine that the overall land cover classification had an accuracy of 96%.

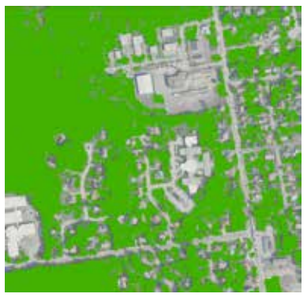
Note: Bare earth is easily misidentified with pervious surfaces. Curve numbers in the TSW Calculator are similar and this does not affect analysis. In some places, sidewalks or golf cart paths were identified as bare earth under canopy. There are few places like this, and the overall area of the class is small – so the percentage may appear high.

NAIP Imagery from 2021 was used for the land cover classification.

NAIP Image 2021

Potential Planting Area (PPA)

Potential Planting Spots (PPS)



Potential Canopy Area (PCA)

Potential Planting Area Dataset

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

- **Potential Planting Area (PPA)**
- **Potential Planting Spots (PPS)**
- **Potential Canopy Area (PCA)**

The Potential Planting Area (PPA) is created by selecting the landcover 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 class.

Exclusion features applied:

- The pervious surfaces were buffered in 10 ft. from all impervious surfaces including buildings and roads.
- Playing fields (i.e.: baseball, soccer, football) as well as golf courses, cemeteries, airports and other incompatible land uses were identified where visually possible. (Digitized by GIC)
- Power Line Corridors and Major Road Median exclusions were created by buffering their representative line data.
- Once this initial phase was completed, the Potential Planting Area data were reviewed by the town and manually edited to best represent town expectations of where planting was allowed (e.g., not on play fields). In addition, areas that were known to be planned for development were removed.

This additional work to exclude known areas that cannot be planted resulted in a more accurate and realistic calculation of plantable areas and the number of new trees that can be added.

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

- Tree planting scenarios were based on a 20 ft. and 40 ft. mature tree canopy with a 30% overlap. Therefore, the planting spots are 16 ft. and 32 ft. apart respectively.

Potential Canopy Area. The Potential Canopy Area (PCA) is created from the PPS. The possible planting spots are given a buffer around each point that represents a tree's mature canopy. First, larger canopy trees are digitally added, followed by smaller trees in the remaining spaces. Planting spots were assigned a buffer of 10 or 20 ft. to result in 20 and 40 ft. tree canopy that overlaps by 30%. This reduces gaps that would be found at the corners of adjacent circles and reflects the reality that trees overhang and intermingle with adjacent trees.

Appendix B: Trees to Offset Stormwater Calculator

The trees and stormwater calculator (TSW) tool developed by GIC uses modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers. 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).

Tree over street

Trees over forest

Tree over lawn

Tree over parking lot

Cities usually use TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to generate expected runoff amounts. The modified TR55 curve numbers (CN) provided by GIC includes a factor for canopy interception. Cities can use the stormwater calculator tool for setting goals at the watershed scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff. Curve numbers produced for this study can be utilized in the town's modeling and design reviews.

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 (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

This new approach allows for more detailed assessments of stormwater uptake based on the landscape conditions of the town'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 and the soils in which the tree is living affect the amount of water the tree can intercept.

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. This methodology was developed and tested in 13 communities in the south under a grant from the Southern Region of the USDA Forest Service. For more about the project, please visit: https://gicinc.org/projects/resiliency/trees-and-stormwater/

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