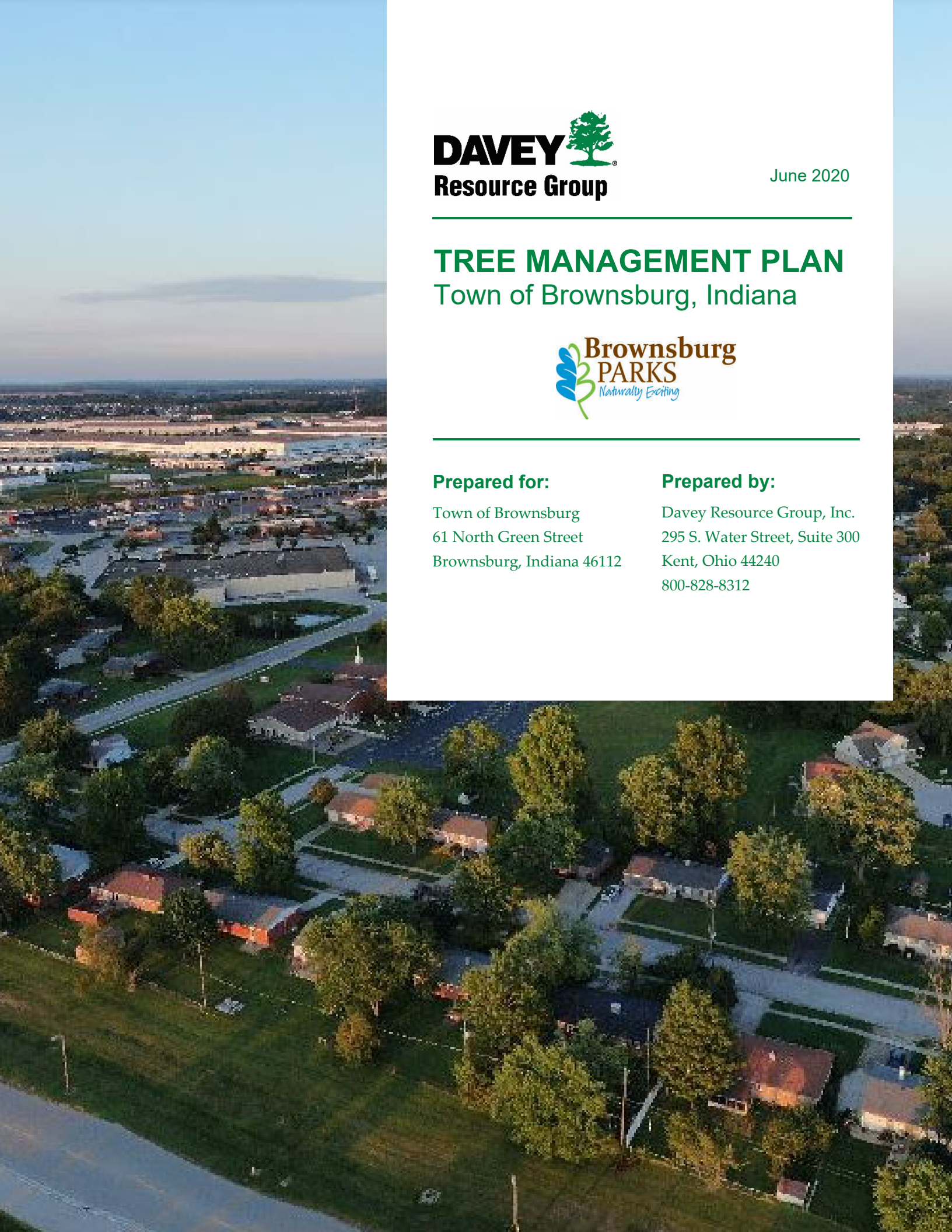

DAVEY Resource Group

June 2020

TREE MANAGEMENT PLAN

Town of Brownsburg, Indiana

Brownsburg PARKS Naturally Exciting

Prepared for:

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ACKNOWLEDGMENTS

This project supports the Town of Brownsburg's vision to promote and enhance community well-being through public tree conservation and improved forestry management practices. This *Tree Management Plan* offers expertise in preserving and expanding urban canopy so the environmental, economic, and social benefits it provides continue for generations.

Brownsburg is thankful for the grant funding it received from the Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry program (IDNR CUF) in cooperation with U.S. Forest Service (USFS) through its Urban and Community Forestry (U&CF) Grant Program. The IDNR CUF grant program is designed to encourage communities to create and support long-term and sustained urban forestry programs throughout Indiana.

Brownsburg recognizes the support of the following town leadership:

- Town Council
  - Travis Tschaenn, President
  - Dennis Dawes, Vice President
  - Jeff Gracey, Member
  - Brian Jessen, Member
  - Matt Simpson, Member
- Park Board
  - Cari Palma, President
  - Judith Kenninger, Vice President
  - Kent Fillinger, Member
  - Amy Hobrock, Member
  - Phil Utterback, Member
  - Michael Zonder, Member
- Town Staff
  - Jeffery A. Eder, Town Manager
  - Al Geans, Assistant Town Manager
- Parks & Recreation Staff
  - Travis Tranbarger, Director
  - Jonathan K. Blake, AICP, Assistant Director Park Operations & Development
  - Philip Cornelius, Assistant Director Recreation Services
  - Amber Lane, Business Services Manager
  - Mary Louise Bewley, Community Engagement Manager
  - Greg Dickenson, Natural Resources Supervisor
  - Kris Myers, ISA Certified Arborist

Recommended Management Program

TREE MANAGEMENT PLAN EXECUTIVE SUMMARY

The Town of Brownsburg's *Tree Management Plan*, written by Davey Resource Group, Inc. "DRG", focuses on providing a tree resource analysis provided by the tree inventory, quantifying the benefits of the tree resource, and addressing the tree resource maintenance needs. DRG completed a tree inventory for the Town of Brownsburg in April 2020 and analyzed the inventory data to understand the structure of the town's inventoried tree resource. DRG also estimated the economic values of the various environmental benefits provided by this public tree resource by analyzing inventory data with TreeKeeper® and recommended a prioritized management program for future tree care.

The functions of Brownsburg's inventoried tree population provide benefits with an estimated total value of $228,971 annually. The town's annual tree maintenance budget is between $95,000 and $120,000, making Brownsburg's return on investment 241-191% annually. This budget includes direct labor and subcontractor costs for tree planting, maintenance, pruning, and removals. Supporting and funding proactive maintenance of the public tree resource is a sound long-term investment that will reduce tree management costs over time.

Figure 1 shows high-priority tree removal and pruning is costly, so mitigation of these elevated risk trees accounts for the higher costs in the first year of the eight-year program. Tree maintenance costs decrease after high-priority work has been completed and management transitions from reactive to proactive maintenance. This also reduces the number of elevated risk trees over time by preventing deteriorating conditions of trees with initially minor defects. Therefore, budgets for later years are projected to stabilize around $114,000 as work becomes routine, making it possible to predict adequate staffing from year to year. The activities schedule is based on inventory data and Best Management Practices and the costs are from a combination of projected maintenance needs and public bid tabulations.

Figure 1. Eight-year management program budget vs. labor over time with projection into future.

Recommended Maintenance Types

Tree Removal

Trees designated for removal have defects that cannot be cost-effectively or practically corrected. Most of the trees in this category have a large percentage of dead crown.

Total = 1,759 trees
Extreme Risk = 0 trees
High Risk = 9 trees
Moderate = 121 trees
Low Risk = 1,629 trees
Stumps = approximately 623

Priority Pruning

Priority pruning removes defects such as Dead and Dying Parts or Broken and/or Hanging Branches. Pruning the defected branch(es) can lower risk associated with the tree while promoting healthy growth.

Total = 944 trees
Extreme Risk = 0 trees
High Risk = 2 trees
Moderate Risk = 42 trees
Low risk = 900 trees

Routine Pruning Cycle

Over time, routine pruning can minimize reactive maintenance, limit instances of elevated risk, and provide the basis for a robust risk management program.

Total = 1,975 trees
Discretionarily Prune = 395 trees each year

Replacement and New Tree Planting

Planting trees to replace lost canopy and planting trees in areas that have poor canopy continuity is important to ensure that tree benefits are distributed evenly across the community.

Scheduled Removal Replacement = 623 trees
New Tree Planting = at least 53 trees (after replacements)
Natural Mortality Replacement= approximately 216 (over 8 years)
Average Planting Rate = near 118 trees annually

Young Tree Training Cycle

Younger trees can have branch structures that lead to potential problems as the tree ages, requiring training to ensure healthy growth. Training is completed from the ground with a pole pruner or pruning shear.

Total = 688 trees
Training Prune = at least 230 trees each year

Routine Tree Inspection

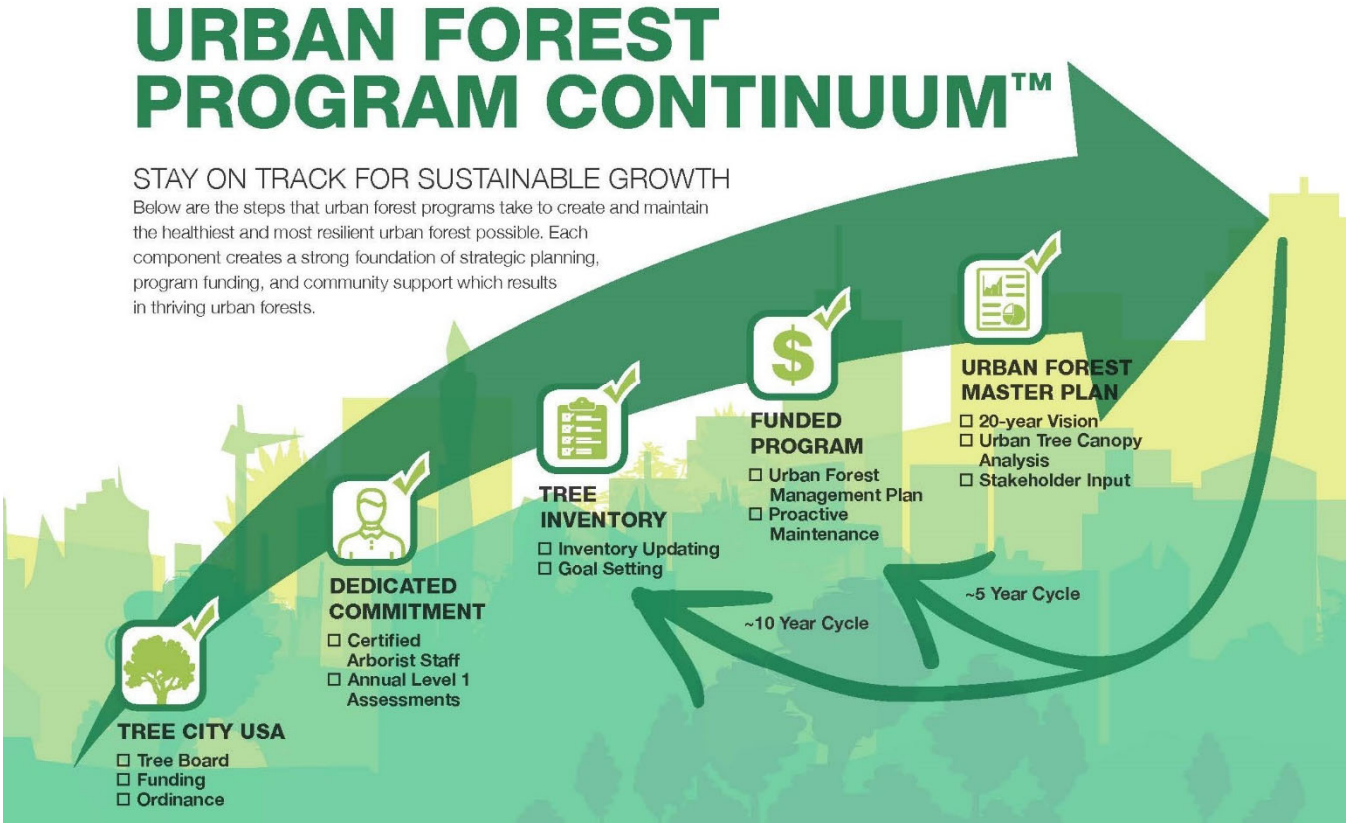
Routine inspections are essential to uncovering potential problems with trees and a qualified arborist trained in the art and science of planting, caring for, and maintaining individual trees should perform this task.

Total = 4,641 trees
Detailed Inspection = at least 929 trees
Limited Inspection = at least 3,712 trees

INTRODUCTION

The Town of Brownsburg is home to 26,397 residents (U.S. Census Bureau 2018) benefitting from public trees in their community. The town's urban forestry program manages all trees, stumps, and planting sites along the street rights-of-way (ROW) and throughout public parks, trails, and other properties. For years, Brownsburg's staff in the Department of Parks and Recreation have shown continued commitment to developing a thriving public tree resource.

The urban forestry program is funded through General Fund (property taxes) and Food & Beverage Tax revenues. Brownsburg has a centralized authority for the urban forestry program in the Parks and Recreation Department, has a tree ordinance, spends approximately more than $2 per capita on tree maintenance, celebrates Arbor Day, and has been a Tree City USA. community for 5 years.



Past urban forestry projects have demonstrated Brownsburg's dedicated commitment to sustaining the public tree resource with higher levels of tree care. Brownsburg has 2 ISA Certified Arborists and will soon be able to set goals and perform proactive maintenance using this *Tree Management Plan*. The town's urban forestry program is well on its way to creating a sustainable and resilient public tree resource, and it is important to stay on track by consistently renewing program funding and routinely updating the tree inventory.

RECOMMENDED APPROACH TO TREE MANAGEMENT

An effective approach to tree resource management follows a proactive and systematic program that sets clear and realistic goals, prescribes future action, and periodically measures progress. A robust urban forestry program establishes tree maintenance priorities and utilizes modern tools, such as a tree inventory accompanied by TreeKeeper® or other asset management software.

February through April of 2020, Brownsburg worked with DRG to inventory its public trees and develop this management plan. Consisting of three sections, this plan considers the diversity, distribution, and condition of the inventoried tree population and provides a prioritized system for managing the town's public tree resource.

- *Section 1: Structure and Composition* summarizes the inventory data with trends representing the current state of the tree resource.
- *Section 2: Functions and Benefits* summarizes the estimated value of benefits provided to the community by public trees' various functions.
- *Section 3: Management Program* details a prioritized management program and provides an estimated budget for recommended maintenance activities over an eight-year period.

Section 1:

Structure and Composition

of the Public Tree Resource

SECTION 1: STRUCTURE AND COMPOSITION

February through April of 2020, DRG arborists collected data on trees and stumps along the street ROW, in public parks and other designated public property (parks), and along trails and greenways for a tree inventory contracted by the Town of Brownsburg. Of the total 4,641 sites inventoried, 30% were collected along the street ROW, 33% were collected in parks, and the remaining 40% were collected along trails and greenways. Figure 2 breaks down the total sites inventoried by type for each location. See Appendix A for details about DRG's methodology for collecting site data.

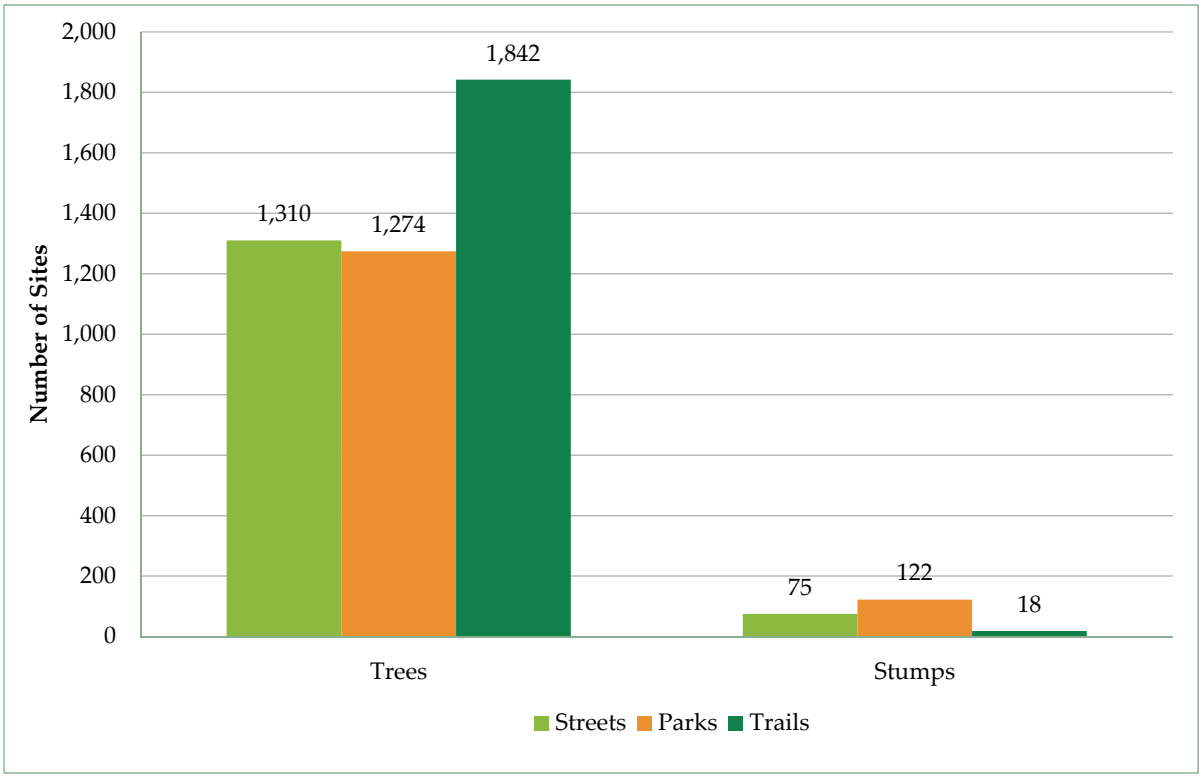


Figure 2. Number of inventoried sites by location and type.

The Town of Brownsburg designated town-managed street ROW, five public parks, five public properties, and four trails and greenways for DRG to collect site data for the tree inventory. Inventoried parks include Arbuckle Acres, Cardinal Park, Stephens Park, Veterans Memorial Park, and Williams Park. Inventoried public properties include Arbuckle Commons, Police Training Facility, Tague Property, Town Hall, Water Treatment, and West Wynne Farms. Inventoried trails or greenways include Arbuckle Acres trails, B&O Trail, White Lick Creek Greenway, and Williams Park trails.

SPECIES, GENUS, AND FAMILY DISTRIBUTION

The 10-20-30 rule is a common standard for tree population distribution, in which a single species should compose no more than 10% of the tree population, a single genus no more than 20%, and a single family no more than 30% (Santamour 1990).

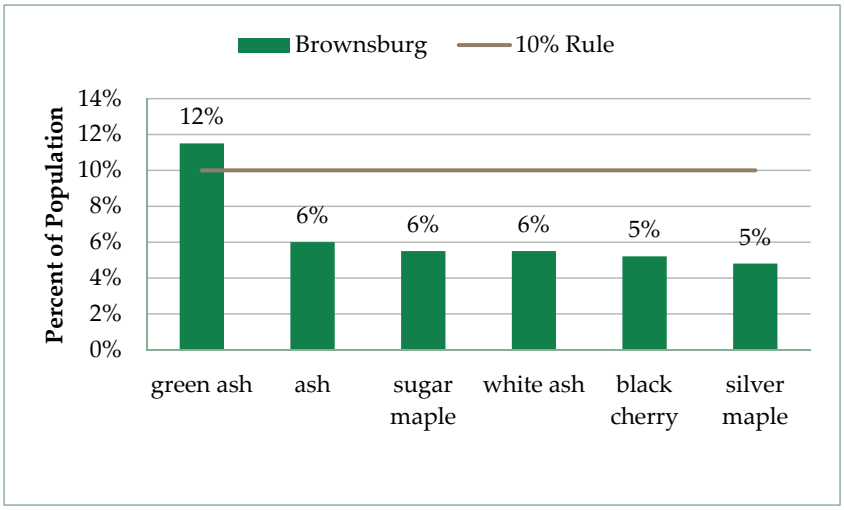


Figure 3. Inventoried tree population distribution of most abundant species.

Figure 3 shows Brownsburg's distribution of the most abundant tree species inventoried compared to the 10% threshold. The inventory recorded 73 species and green ash (*Fraxinus pennsylvanica)* as the most abundant species, representing 12% of the population. The green ash population is over the 10% threshold and two other ash species each represent more than 5% of the distribution. This is concerning from the species distribution perspective, but not overly concerning as 93% of the ash were located along trails and greenways. Excluding trails and greenways, silver maple (*Acer saccharinum,* 8%), red maple (*A. rubrum,* 7%), Norway spruce (*Picea abies,* 6%), eastern white pine (*Pinus strobus,* 5%), and callery pear (*Pyrus calleryana,* 5%) were most prevalent.

RESILIENCE THROUGH DIVERSITY

The Dutch elm disease epidemic of the 1930s provides a key historical lesson on the importance of diversity (Karnosky 1979). The disease killed millions of American elm trees, leaving behind enormous gaps in the urban canopy of many Midwestern communities. In the aftermath, ash trees became popular replacements and were heavily planted along city streets. History repeated itself in 2002 with the introduction of the emerald ash borer into America. This invasive beetle devastated ash tree populations across the Midwest. Other invasive pests spreading across the country threaten urban forests, so it is vital that we learn from history and plant a wider variety of tree genera to develop a resilient public tree resource.

Ash trees in an urban forest killed by emerald ash borer have become a gap in the canopy.

USDA Forest Service (2017)

The inventory recorded 43 genera. Figure 4 shows the town's distribution of the most abundant tree genera inventoried, and ash (*Fraxinus*) is slightly higher than the 20% threshold. This is concerning because ash compose 23% of the inventoried population. Maple (*Acer*) is trending close to the 20% threshold. **Brownsburg should closely monitor how many maple they plant. The Town of Brownsburg should not plant ash or maple until species distribution becomes ideal.** Excluding trails and greenways, *Acer* (25%), *Picea* (11%), *Pinus* (6%), *Quercus* (6%), and *Pyrus* (5%) were most prevalent.

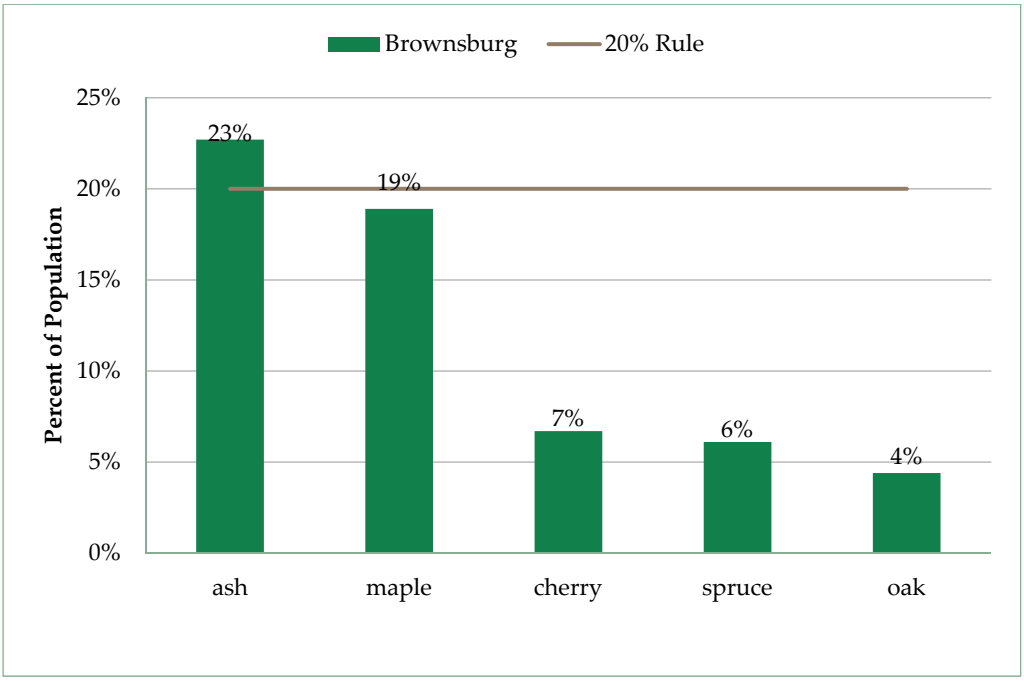


Figure 4. Inventoried tree population distribution of most abundant genera.

This illustrates how species distribution alone does not completely represent tree population diversity. Genus distribution is an important consideration because some pests, such as emerald ash borer (EAB, *Agrilus planipennis*), target a single genus as its host. Some pests also target a single family as its host, such as the bacterium *Erwinia amylovora*, commonly known as fireblight. Fireblight only affects plants in the rose family (*Rosaceae*), such as serviceberry, hawthorn, apple/crabapple, cherry/plum, and pear.

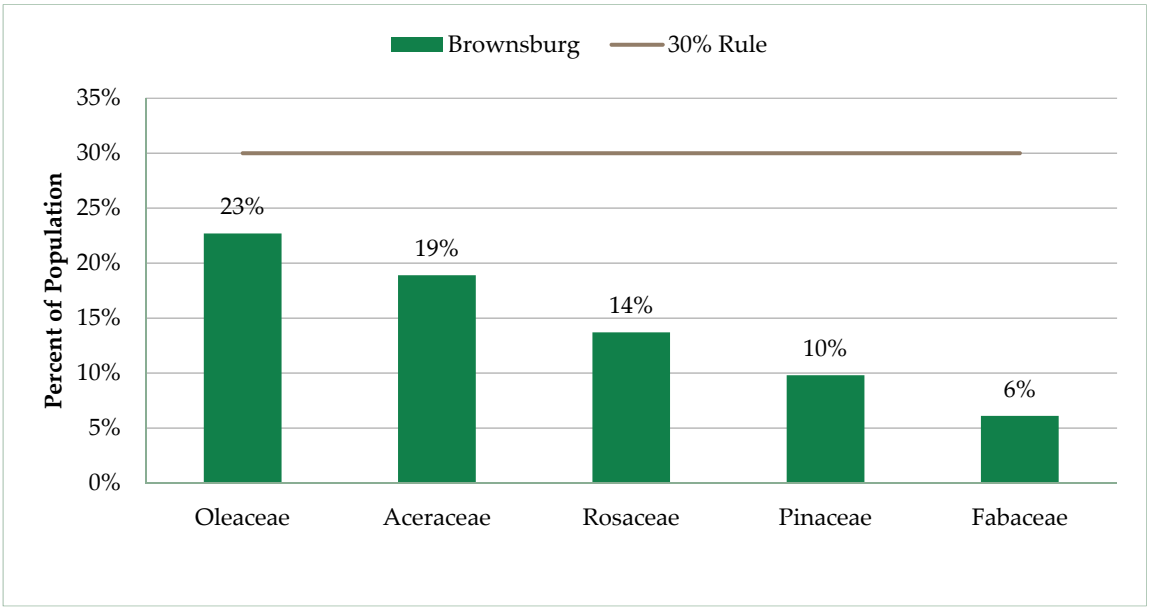


Figure 5. Inventoried tree population distribution of most abundant families.

Figure 5 shows the town's distribution of the most abundant tree families inventoried compared to the 30% threshold. *Oleaceae* (23%) is the only family within 10% of the threshold. *Aceraceae* is close behind at 19%.

PEST SUSCEPTIBLITY

Early diagnosis of disease and infestation is essential to ensuring the health and continuity of Brownsburg's public tree resource. See Appendix B for some information about the pests listed below and websites where to find additional information.

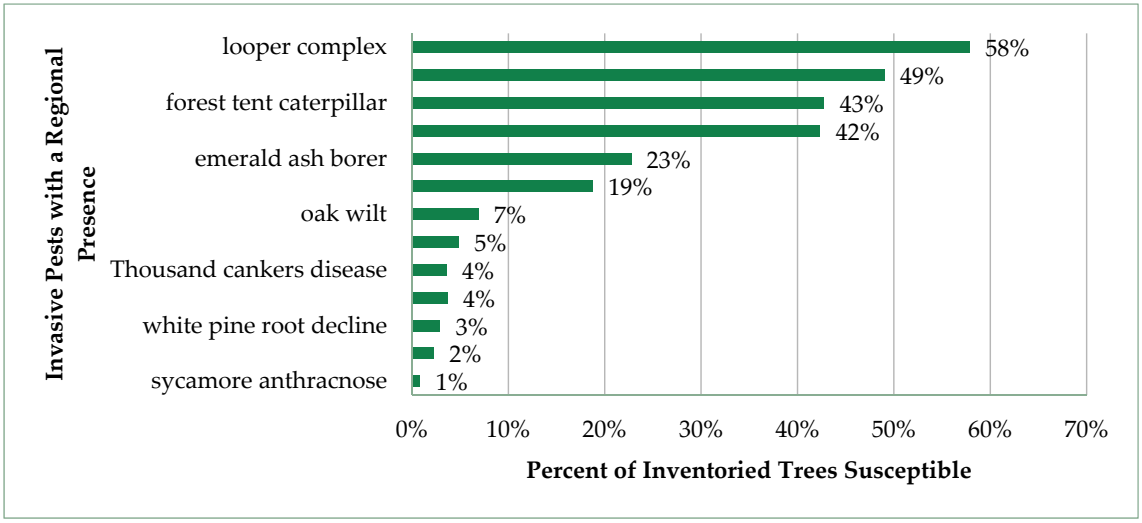


Figure 6. Public tree resource susceptibility to pests with a regional presence.

Figure 6 shows the percent of inventoried trees susceptible to some of the known pests in and around Indiana. It is important to remember that this figure only represents data collected during the inventory. Many more trees throughout Brownsburg, especially those in wooded areas of public property and those on private property, may be susceptible to hosting these invasive pests. Looper complex (58%), Asian longhorned beetle (*Anoplophora glabripennis, 49%*), forest tent caterpillar (*Malacosoma disstria,* 43%), and spotted lantern fly (*Lycorma delicatula, 42%)* are known threats to a large percentage of the inventoried tree resource.

Pest Susceptibility Recommendations

The abundance of ash and maple in Brownsburg's tree resource is a management concern because it creates unnecessary risk in the event of an invasive pest outbreak. This abundance is not only the significant loss of a tree resource but is also a significant host habitat for invasive pests, such as ALB or emerald ash borer (EAB, *Agrilus planipennis*). An overabundance of host trees will make it easier for invasive pests to spread throughout the community.

While it might be prudent for the town to limit planting species in the *Oleaceae* or *Aceraceae* families, efforts to improve diversity at the genus level are a better use of short-term resources until there is more research available on family diversity as a mechanism for promoting resilience within a public tree resource. For this reason, Brownsburg should use its management program resources to increase species and genus diversity.

Brownsburg will need to develop an action plan to address species diversity over the short term and long term. Examples of some actions are:

- Stop the planting of ash trees and limit the large plantings of maple, specifically sugar and silver maple.
- Develop and routinely revise a list of recommended tree species and cultivars for various public planting applications.
- Plant a mix of native and non-native species suitable to central Indiana soils and climate zone.
- Remove all Dead and Poor condition ash and maple.
- Remove all ash and maple with a trunk diameter less than 8 inches.
- Routinely assess ash and maple trees and evaluate their usefulness based on their returned benefit related to health and maintenance need.
- Develop master planting plans for streetscapes and highly maintained park and public properties
- Develop educational materials explaining the need to plant species other than ash or maple.

These actions will leave ash and maple performing at their best from a health and benefit provider perspective. Managing the potential for invasive pest outbreaks before they start is a critical goal that will help Brownsburg's tree resource be resilient in the event of future pest invasions.

CONDITION

Several factors affecting condition were considered for each tree, including root characteristics, branch structure, trunk, canopy, foliage condition, and the presence of pests. DRG arborists rated the condition of each inventoried tree as Good, Fair, Poor, or Dead. The most prevalent condition assigned during the inventory characterizes the general health of the inventoried tree population.

Figure 7 shows Fair (36%) was the most recorded condition of the inventoried trees. Based on these data, the general health rating of the inventoried tree population is Fair. Brownsburg has a high percentage of Dead trees mostly along trails and greenways.

Condition Recommendations

Dead trees and trees in Poor condition should be removed because the health of these trees is unlikely to recover even with increased care.

Trees rated in Fair condition may benefit from structural pruning to improve their health over time. Pruning should follow *ANSI A300 (Part 1)* guidelines.

Overtime, Good and Fair trees will likely require corrective pruning and intensive plant health care to improve their vigor and should be routinely monitored for changes of conditions.

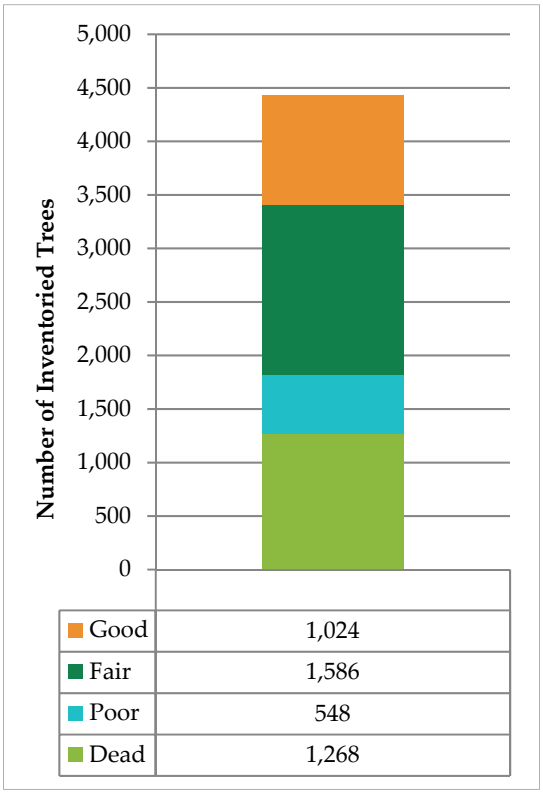


Figure 7. Condition of inventoried trees.

RELATIVE AGE DISTRIBUTION

Analysis of a tree population's relative age distribution is performed by assigning age classes to the size classes of inventoried trees, offering insight into the maintenance needs of Brownsburg's tree resource. The inventoried trees are grouped into the following relative age classes:

- Young trees (0–8 inches diameter at breast height [DBH])
- Established trees (9–17 inches DBH)
- Maturing trees (18–24 inches DBH)
- Mature trees (greater than 24 inches DBH)

These size classes were chosen so that the inventoried tree resource can be compared to the ideal relative age distribution, which tells that the largest proportion of the inventoried tree population (approximately 40%) should be young trees, while a smallest proportion (approximately 10%) should be mature trees (Richards 1983). Since tree species have different lifespans and mature at different diameters, actual tree age cannot be determined from diameter size class alone. Size classifications are an extrapolation of relative age classes.

Figure 8 compares Brownsburg's relative age distribution of the inventoried tree population to the ideal. The town's inventoried tree resource trends toward the ideal. There are more young and established trees than maturing and mature trees.

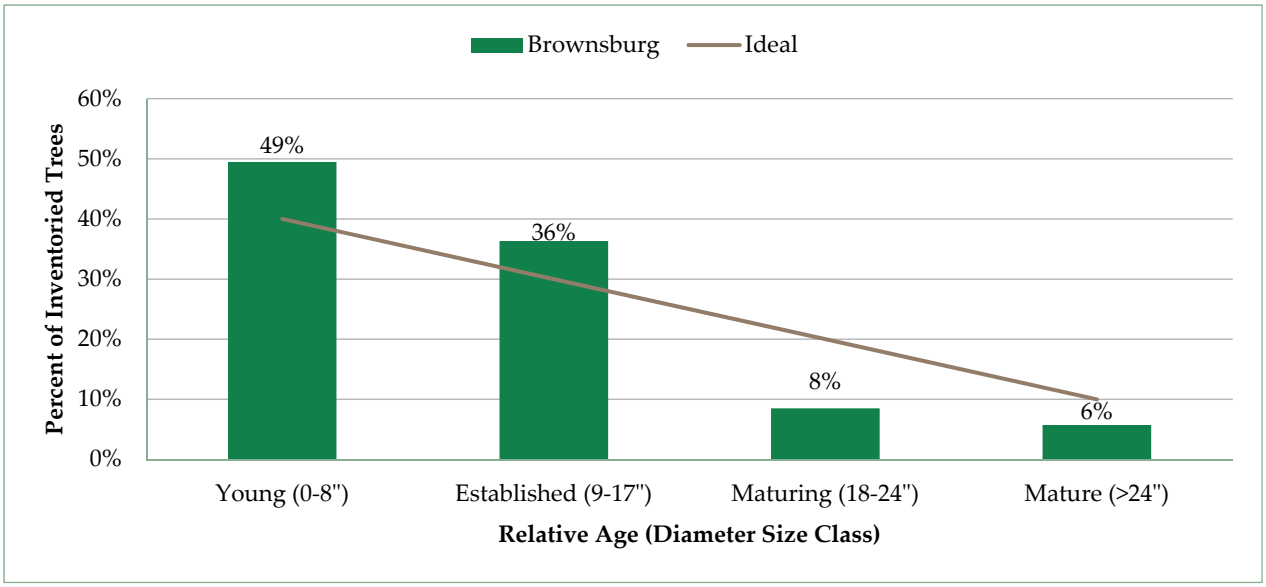


Figure 8. Relative age distribution of the inventoried trees.

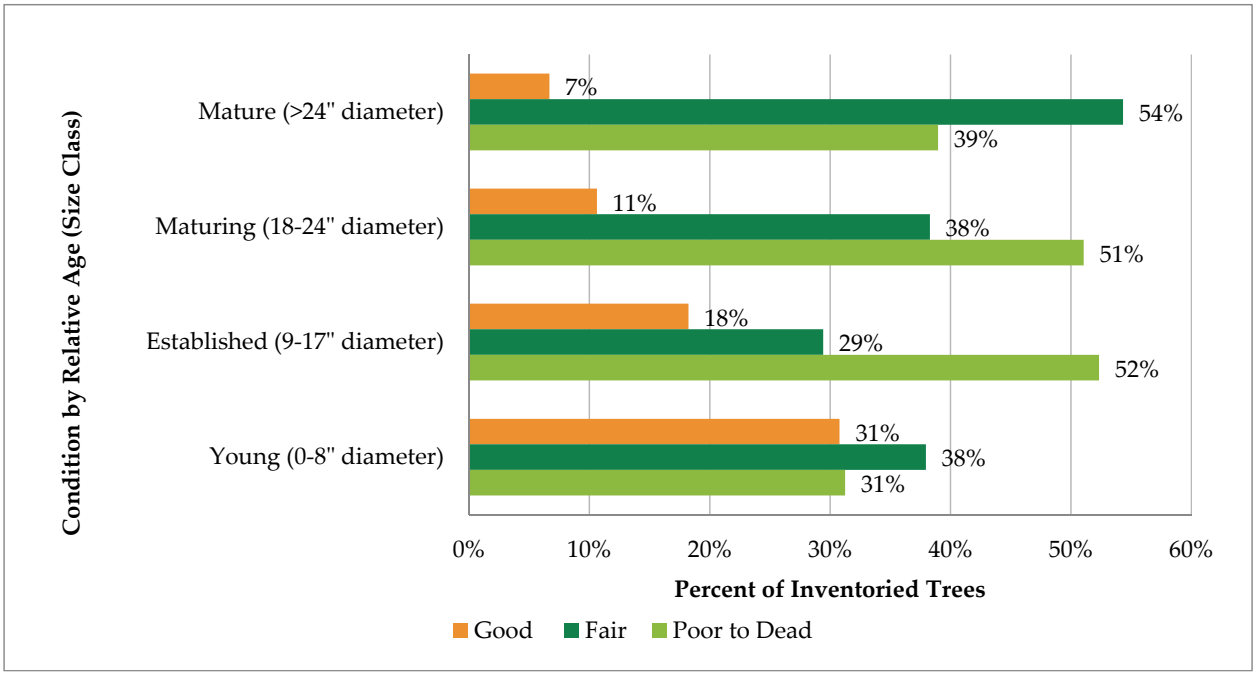


Figure 9. Condition of inventoried trees by relative age (size class).

Figure 9 cross analyzes the condition of the inventoried tree resource with its relative age distribution, providing insight into the inventoried population's stability. Established and maturing trees have high concentrations of Poor condition trees. Young and mature trees have high concentrations of Fair condition trees. It is important to provide the maintenance trees need to remain healthy as they age and grow.

Relative Age Recommendations

Brownsburg has the above recommended populations of young and established trees and recommended populations of maturing and mature trees. The young trees have a high percentage of trees in Good condition, and if well maintained, they have the potential of reaching maturity still healthy and in Good condition. DRG recommends that Brownsburg implement a robust maintenance program. **The town should preserve the condition of young trees as they age so they replace trees removed and fill canopy gaps in maturity and focus on tree preservation and proactive care of mature and maturing trees to protect them from unnecessary removal and to prevent them from succumbing to treatable defects.** Prioritizing proactive maintenance above tree planting, not stopping planting, will shift the relative age distribution towards the ideal over time.

DEFECT OBSERVATIONS

For each tree inventoried, DRG assessed the presence of structural defects and recorded the most significant defect. Defects were limited to the following categories:

- Dead and dying branches
- Broken and/or hanging branches
- Branch attachment (adventitious, codominant, multiple, overextended)
- Trunk condition (canker, bulges, ridges)
- Cracks
- Decay or cavity (large trunk wound)
- Tree architecture (lean, bows, taper, live crown ratio)
- Root problems (dead, decayed, missing, abnormal, girdling, lack of flare)

Table 1. Defect observations recorded during the tree inventory

Defects	Number of Trees	Percent
None	2,325	53%
Decay or cavity	522	12%
Dead and dying branches	497	11%
Branch attachment	409	9%
Root problems	385	9%
Broken and/or hanging branches	161	4%
Tree architecture	82	2%
Trunk condition	38	1%
Cracks	8	0%
Total	4,427	100%

The two most frequently recorded defects were Decay or Cavity at 12% of the inventoried trees and Dead and Dying branches at 11% (Table 1). Recommended for removal were 405 of the 522 (78%) trees with Decay or Cavity present. Recommended for prune were 453 of 497 (91%) trees with Dead and Dying branches.

Defect Observation Recommendations

When considering the defect recorded for each tree, there are two important qualifiers to keep in mind. First, the categories are broadly inclusive. For example, the "Dead and Dying branches" category can include trees with just one or two smaller diameter dead limbs as well as trees found with large-diameter dead limbs or entire sections of dead canopy. Therefore, derived inferences on overall tree condition or risk rating cannot happen solely from the presence or absence of a defect recorded during the inventory. Second, an inventoried tree may have multiple defects; the 2020 Brownsburg inventory recorded only the most significant defect observed for each tree. These two qualifiers are important to keep in mind when considering urban forest management planning and the prioritization of maintenance or monitoring activities.

DRG recommends inspecting trees regularly regardless of previously noted defect. Upon regular inspection if their condition worsens, removal or a higher priority removal may be required. Take corrective actions when warranted.

INFRASTRUCTURE CONFLICTS

In an urban setting, space is limited both above and below ground. Trees in this environment may conflict with infrastructure, such as buildings, sidewalks, utility wires, and pipes, which could pose risks to public safety. Existing or possible conflicts between trees and infrastructure recorded during the inventory include:

- *Overhead Utilities*—The presence of overhead utility lines above a site was noted; it is important to consider these data when planning pruning activities and selecting tree species for planting.
- *Hardscape Damage*—Tree roots can adversely impact hardscape such as curbs and sidewalks, causing these features to lift and crack. Use this data to schedule pruning and plan repairs to damaged infrastructure. To limit hardscape damage caused by trees, only plant trees in growing spaces with adequate above ground and below ground space.

Table 2. Trees noted to be conflicting with infrastructure

Conflict	Presence	Number of Trees	Percent
Overhead Utilities	Present and Conflicting	76	2%
	Present and Not Conflicting	95	2%
	Not Present	4,256	96%
	Sub Total	4,427	100%
Hardscape Damage	Present	53	1%
	Not Present	4,374	99%
	Sub Total	4,427	100%
	Total	8,854	100%

Table 2 shows 129 infrastructure conflicts recorded. Conflicts with overhead utilities were a majority (59%) of those. There were 171 trees with utilities directly above, or passing through, the tree canopy. Hardscape damage was minimal: only 1% of the tree population raised sidewalk slabs or curbs.

Infrastructure Recommendations

Planting only small-growing trees within 20 feet of overhead utilities, medium-size trees within 20–40 feet, and large-growing trees outside 40 feet will help improve future tree conditions, minimize future utility line conflicts, and reduce the costs of maintaining trees under utility lines.

When planting around hardscape, it is important to give the tree enough growing room above ground. Guidelines for planting trees among hardscape features are as follows: give small-growing trees 4–5 feet, medium-growing trees 6–7 feet, and large-growing trees 8 feet or more between hardscape features. In most cases, this will allow for the spread of a tree's trunk taper, root collar, and immediate larger-diameter structural roots.

GROWING SPACE

Growing space provides a description about the type of space where the tree is growing. Categorized growing space types are as follows:

- *Island*—surrounded by pavement or hardscape (for example, parking lot divider).
- *Median*—located between opposing lanes of traffic.
- *Natural Area* – sites developed through natural growth instead of design or planning.
- *Open/Restricted*—open sites with restricted growing space on two or three sides.
- *Open/Unrestricted*—open sites with unrestricted growing space on at least three sides.
- *Raised Planter*—in an above-grade or elevated planter.
- *Tree Lawn/Parkway*—located between the street curb and the public sidewalk.
- *Unmaintained*—located in areas that do not appear regularly maintained.
- *Well/Pit*—at grade level and completely surrounded by sidewalk.

Most (83%) trees along the street ROW were located in tree lawns or in open/unrestricted areas. The majority (99%) of park trees were located in open/unrestricted areas or natural areas.

Growing Space Recommendations

To prolong the useful life of public trees, plant small-growing tree species in tree spaces no smaller than 4 feet wide, medium-growing tree species in space no smaller than 6 feet wide, and large-growing tree species in spaces no smaller than 8 feet wide. The useful life of a public tree ends when the cost of maintenance exceeds the value contributed by the tree. This can be due to increased maintenance required by a tree in decline, or it can be due to the costs of repairing damage caused by the tree's presence in a restricted site.

Section 2:

Functions and Benefits

of the Public Tree Resource

SECTION 2: FUNCTIONS AND BENEFITS

Trees occupy a vital role in the urban environment by providing of a wide array of economic, environmental, and social benefits far exceeding the investments in planting, maintaining, and removing them. Trees reduce air pollution, improve public health, reduce stormwater runoff, sequester and store carbon, reduce energy use, and increase property value. Advanced analytics, such as TreeKeeper® and other i-Tree suite benefit models, continue to expand. The i-Tree software suite helps urban foresters communicate the importance of trees to a community by providing tools to estimate monetary values of the various benefits provided by a public tree resource. TreeKeeper® values tree benefits by using built-in calculations based on i-Tree Street modeling.

Environmental Benefits

- Trees decrease energy consumption and moderate local climates by providing shade and acting as windbreaks.
- Trees act as mini reservoirs, helping to slow and reduce the amount of stormwater runoff that reaches storm drains, rivers, and lakes. One hundred mature tree crowns intercept roughly 100,000 gallons of rainfall per year (U.S. Forest Service 2003a).
- Trees help reduce noise levels, cleanse atmospheric pollutants, produce oxygen, and absorb carbon dioxide.
- Trees can reduce street-level air pollution by up to 60% (Coder 1996). Lovasi (2008) suggested that children who live on tree-lined streets have lower rates of asthma.
- Trees stabilize soil and provide a habitat for wildlife.

Economic Benefits

- Trees in a yard or neighborhood increase residential property values by an average of 7%.
- Commercial property rental rates are 7% higher when trees are on the property (Wolf 2007).
- Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State University 2012, Heisler 1986).
- On average, consumers will pay about 11% more for goods in landscaped areas, with this figure being as high as 50% for convenience goods (Wolf 1998b, Wolf 1999, and Wolf 2003).
- Consumers also feel that the quality of products is better in business districts surrounded by trees than those considered barren (Wolf 1998b).
- The quality of landscaping along the routes leading to business districts had a positive influence on consumers' perceptions of the area (Wolf 2000).

Social Benefits

- Tree-lined streets are safer; traffic speeds and the amount of stress drivers feel are reduced, which likely reduces road rage/aggressive driving (Wolf 1998a, Kuo and Sullivan 2001a).
- Chicago apartment buildings with medium amounts of greenery had 42% fewer crimes than those without any trees (Kuo and Sullivan 2001b).
- Chicago apartment buildings with high levels of greenery had 52% fewer crimes than those without any trees (Kuo and Sullivan 2001a).
- Employees who see trees from their desks experience 23% less sick time and report greater job satisfaction than those who do not (Wolf 1998a).
- Hospital patients recovering from surgery who had a view of a grove of trees through their windows required fewer pain relievers, experienced fewer complications, and left the hospital sooner than similar patients who had a view of a brick wall (Ulrich 1984, 1986).

TREE BENEFIT ANALYSIS

TreeKeeper® calculates the ecosystem benefits of individual trees, groups of trees, or an entire urban forest using inventory data. TreeKeeper® ecosystem benefits value is based on the science of i-Tree Streets. i-Tree Streets, a component of i-Tree Tools, analyzes an inventoried tree population's structure to estimate the benefits of that tree population. See Appendix C for details about DRG's tree benefit methodology.These quantified benefits are described below.

- *Aesthetic/Other Benefits:* Shows the tangible and intangible benefits of trees reflected by increases in property values (in dollars).
- *Stormwater:* Presents reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons.
- *Energy:* Presents the contribution of the urban forest towards conserving energy in terms of reduced natural gas use in the winter (measured in therms [thm]) and reduced electricity use for air conditioning in the summer (measured in Megawatt-hours ([MWh]).
- *Carbon Sequestered and Avoided:* Presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reductions in energy use measured pounds. The model accounts for CO_2 released as trees die and decompose and CO_2 released during the care and maintenance of trees.
- *Air Quality:* Quantifies the air pollutants (ozone [O_3], nitrogen dioxide [NO2], sulfur dioxide [SO_2], particulate matter less than 10 micrometers in diameter [PM_{10}]) deposited on tree surfaces, and reduced emissions from power plants (NO_2, PM_{10}, volatile organic compounds [VOCs], SO_2) due to reduced electricity use in pounds. The potential negative effects of trees on air quality due to biogenic volatile organic compounds (BVOC) emissions is also calculated.

ANNUAL RETURN ON INVESTMENT FROM THE PUBLIC TREE RESOURCE

TreeKeeper® estimated that the Town of Brownsburg's inventoried trees provide a total annual benefit of $228,971, or $8.67 per citizen. Essentially, the mere presence of trees in the urban landscape saved $228,971 annually by cooling buildings, managing stormwater, and cleaning the air. In addition, community aesthetics were improved and property values increased because of the presence of trees. On average, one of Brownsburg's trees provides an annual benefit of $60.41. The town's annual tree maintenance budget is $95,000–$120,000, making Brownsburg's return on investment almost 190–241% annually. Urban environments have unique challenges that make the estimated $228,971 of functional benefits provided by Brownsburg's inventoried tree population an essential asset to the town (Figure 10).

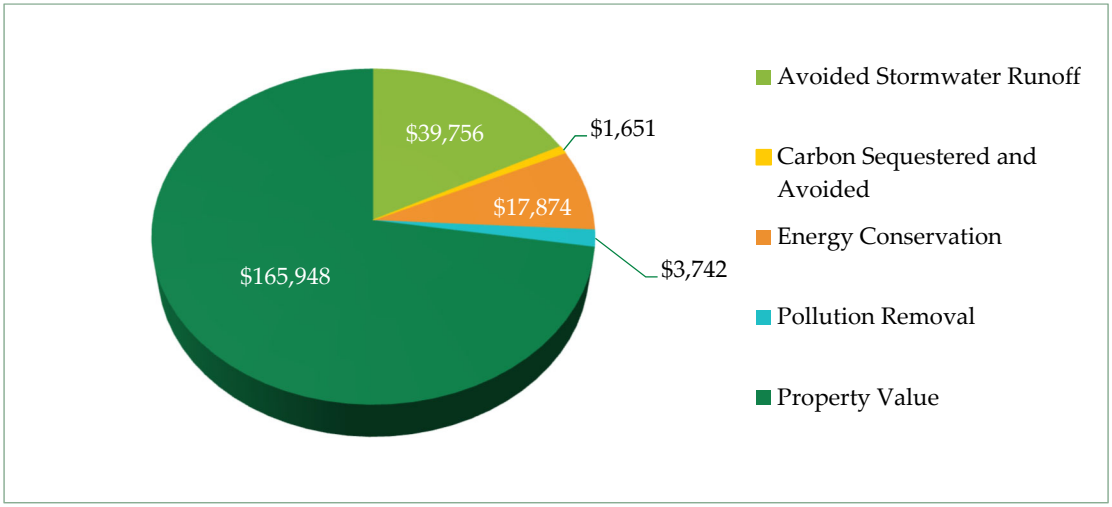


Figure 10. Estimated annual value of the inventoried tree resource functional benefits.

In Brownsburg, only ten species account for almost half of the public tree resource and half of the functional benefits it provides. If any of these species were lost to invasive pests, disease, or other threats, its loss would have significant costs. It is critical to promote species diversity with future plantings to minimize susceptibility to potential threats, and to plant large-growing broadleaf tree species wherever possible to maximize potential environmental and economic benefits.

A list of suggested tree species is present in Appendix D. This list is not exhaustive but used as a guide for species selection can help meet community species diversity and tree section objectives and enhance any existing list of approved species.

SEQUESTERING AND AVOIDING CARBON

Trees are carbon sinks, which are the opposite of carbon sources. Compared to rural landscapes, urban landscapes have high carbon emissions in a relatively small area. While carbon sources like cars and smokestacks emit carbon, trees absorb carbon during photosynthesis and store it in their tissue as they grow. Carbon dioxide (CO_2) also affects people, property, and the environment as the primary greenhouse gas driving climate change. TreeKeeper® estimates the amount of carbon sequestered and avoided each year. Brownsburg's inventoried trees have sequestered 324,226 lbs. of carbon and avoided 236,555 lbs. of carbon all valued at $1,651. Silver maple (*Acer saccharinum*) and northern red oak (*Quercus rubra*) sequester and avoid the most carbon: 64 lbs. per tree per year and 45 lbs. per tree per year, respectively.

Table 3. Summary of benefits provided by inventoried trees ranked by species total benefit

Most Common Trees Collected During Inventory		Number Trees	Percent of Total Trees	Total Benefit	Benefit per Tree	Performing Above Average (YES/NO/AVG)
Common Name	Botanical Name		(%)	($)	($)	
green ash	*Fraxinus pennsylvanica*	510	12%	27,786	54	YES
sugar maple	*Acer saccharum*	246	6%	15,360	62	YES
white ash	*Fraxinus americana*	244	6%	13,482	55	YES
black cherry	*Prunus serotina*	232	5%	12,631	54	YES
silver maple	*Acer saccharinum*	212	5%	16,295	77	YES
red maple	*Acer rubrum*	171	4%	6,907	40	NO
black walnut	*Juglans nigra*	158	4%	9,662	61	YES
Norway spruce	*Picea abies*	153	3%	4,234	28	NO
boxelder	*Acer negundo*	148	3%	8,237	56	YES
northern hackberry	*Celtis occidentalis*	144	3%	13,286	92	YES
eastern white pine	*Pinus strobus*	128	3%	6,068	47	NO
callery pear	*Pyrus calleryana*	123	3%	3,162	26	NO
apple	*Malus species*	110	2%	2,558	23	NO
American elm	*Ulmus americana*	100	2%	7,998	80	YES
thornless honeylocust	*Gleditsia triacanthos inermis*	96	2%	4,164	43	NO
blue spruce	*Picea pungens*	90	2%	2,399	27	NO
white mulberry	*Morus alba*	80	2%	5,513	69	YES
black locust	*Robinia pseudoacacia*	75	2%	4,129	55	YES
northern red oak	*Quercus rubra*	74	2%	4,305	58	YES
plum	*Prunus species*	66	1%	1,425	22	NO
eastern cottonwood	*Populus deltoides*	58	1%	5,237	90	YES
eastern redbud	*Cercis canadensis*	56	1%	1,185	21	NO
swamp white oak	*Quercus bicolor*	54	1%	2,855	53	YES
tulip tree	*Liriodendron tulipifera*	49	1%	2,952	60	YES
arborvitae	*Thuja species*	47	1%	576	12	NO
other trees	~48 varying species	1004	23%	46,565	46	---
Total	~73 species	4,428	100%	228,971	52	AVG

CONTROLLING STORMWATER

Trees intercept rainfall with their leaves and branches, helping lower stormwater management costs by avoiding runoff. Avoiding stormwater runoff reduces the risk of flooding and combined sewer overflow, both of which affect people, property, and the environment, valuing the 6,412,327 gallons of runoff avoided with Brownsburg's tree resource at an estimated $39,756. Avoided runoff accounts for 17% of the annual functional benefits provided by Brownsburg's public tree resource.

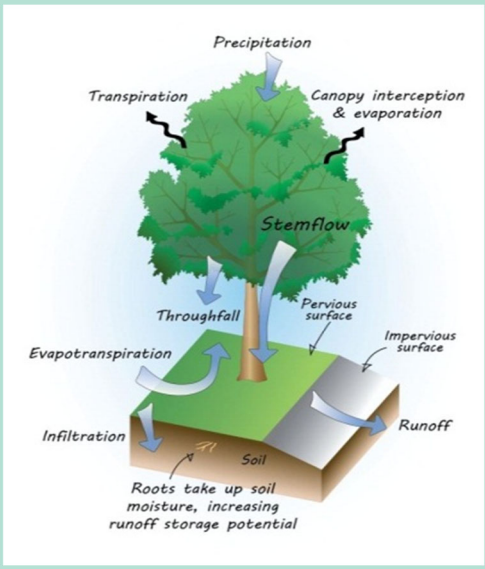
Of all species inventoried, sugar maple (*Acer saccharum*) contributed the most annual stormwater benefits. The most abundant species in the inventoried tree population, red maple (*A. rubrum*) (6%), sequestered and avoided approximately 435, 976 gallons of runoff. Not the dominant species of the inventoried population, sugar maple sequestered and avoided 653,101 gallons of runoff.

On a per-tree basis, large trees with leafy canopies provided the most functional benefits. Callery pear (*Pyrus calleryana*) and silver maple comprised 6% and 2% of the inventoried tree resource, respectively. Silver maple sequestered and avoided twice as much as callery pear, despite only having about a third of its population size. This illustrates how large-growing trees with wide canopies provide significantly greater benefits.

IMPROVING AIR QUALITY

The inventoried tree population annually removes 26,049 lbs. of air pollutants, including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter ($PM_{2.5}$). TreeKeeper® estimates the value of this benefit at $3,742. The trees that provided the highest annual air quality benefits were silver maple and London planetree (*Platanus* × *acerifolia*), which removed 0.72 lbs. of pollutants per tree per year and 0.50 lbs. of pollutants per tree per year, respectively.

CANOPY FUNCTIONS



Trees provide many functions and benefits all at once simply by existing, such as:

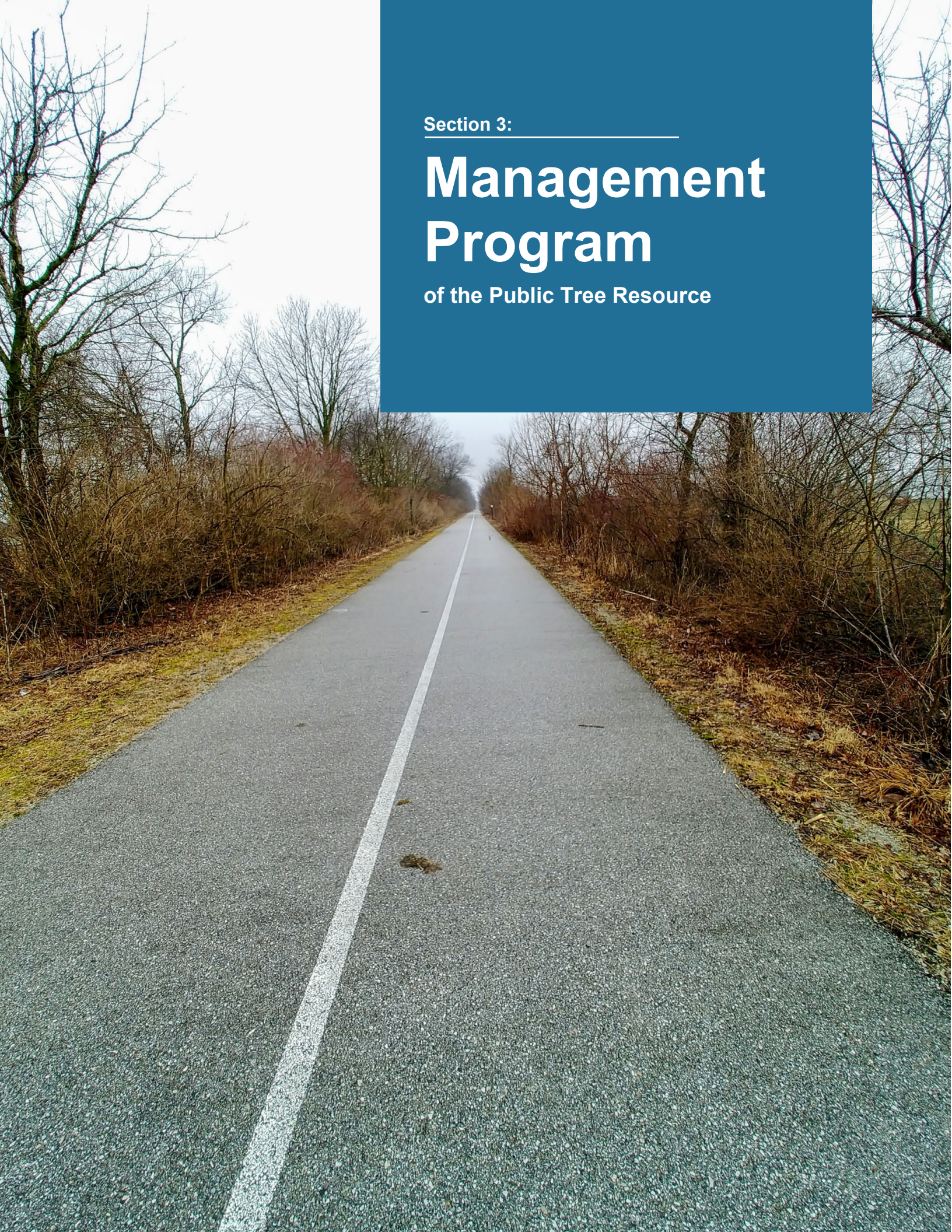
- Catching rainfall in their crown so it drips to the ground with less of an impact or flows down their trunk.
- Helping stormwater soak into the ground by slowing down runoff.
- Creating more pore space in the soil with their roots, helping stormwater to move through the ground.
- Cooling the surrounding landscape by casting shade with their canopy and releasing water from their leaves.
- Catching airborne pollutants on their leaves and absorbing them with their roots when they wash off in the rain.
- Transforming some pollutants into less harmful substances and preventing other pollutants from forming.

TANGIBLE AESTHETIC ENHANCEMENT

The total annual benefit associated with property value increases and other tangible benefits of inventoried public trees was $165,948, which is 38% of the value of all annual benefits. The average benefit per tree equaled $37.49 per year.

ENERGY CONSERVATION

Public trees conserve energy by shading structures and surfaces, which reduces electricity use for air conditioning in the summer. Trees divert wind in the winter to reduce natural gas use. The annual electric and natural gas savings conserved by the inventoried public trees is equivalent to 201,2389 kWh saved of electricity and 4,306 therms saved of natural gas, which accounts for an annual savings of $17,874 in energy consumption at $4.04 per tree.



Section 3:

Management Program

of the Public Tree Resource

SECTION 3: MANAGEMENT PROGRAM

During the inventory, assigned to each tree was a risk rating and a recommended maintenance activity. DRG recommends prioritizing and completing each tree's recommended maintenance activity based on the assigned risk rating. This eight-year tree management program takes a multi-faceted and proactive approach to public tree resource management. See Appendix E for details about DRG's risk assessment/priority and proactive maintenance.

Extreme & High Risk

- All Extreme and High Risk tree maintenance should be completed as soon as possible, because these trees have serious defects that cause elevated risk and liability for public safety.

Further Inspection

- Trees with a requirement in the Further Inspection data field have defects that could become worse and increase their risk, which should be assessed by an arborist as soon as possible.

Moderate & Low Risk

- All Moderate and Low Risk tree maintenance should be performed after all Extreme and High Risk tree maintenance has been completed, because these trees have defects with lower risk and liability for public safety.

Routine Inspection

- Inventoried trees should be Routinely Inspected to detect significant defects before their risk level increases.

Routine Pruning

- Routine Pruning cycles correct defects before their risk level increases, and should begin after all Prioirty Pruning tree maintenance has been completed.

Young Tree Training

- Young Tree Training cycles improve tree structure so they do not develop defects that become risks in the future, and should begin as soon as possible.

Stump Removal

- Stump removals should be performed when convenient, ideally before a planting season begins, so additional planting sites become available.

Tree Planting

- Tree planting is important for replacing removed trees, reaching ideal stocking level, and meeting canopy goals, but tree maintenance is often a greater priority.

RISK MANAGEMENT AND RECOMMENDED MAINTENANCE

Tree removal, usually considered a last resort, may sometimes create a reaction from the community. Removal is necessary in many circumstances. Trees fail from natural causes such as diseases, insects, and weather conditions, and from physical injury due to vehicles, vandalism, and root disturbances. DRG recommends that trees removal occur when corrective pruning will not adequately mitigate risk or when correcting problems would be cost-prohibitive. DRG recommends prioritizing and completing tree maintenance activities based on the risk rating that assigned to each tree during the inventory. The following sections describe recommended maintenance for each maintenance category.

HIGH PRIORITY RECOMMENDED MAINTENANCE

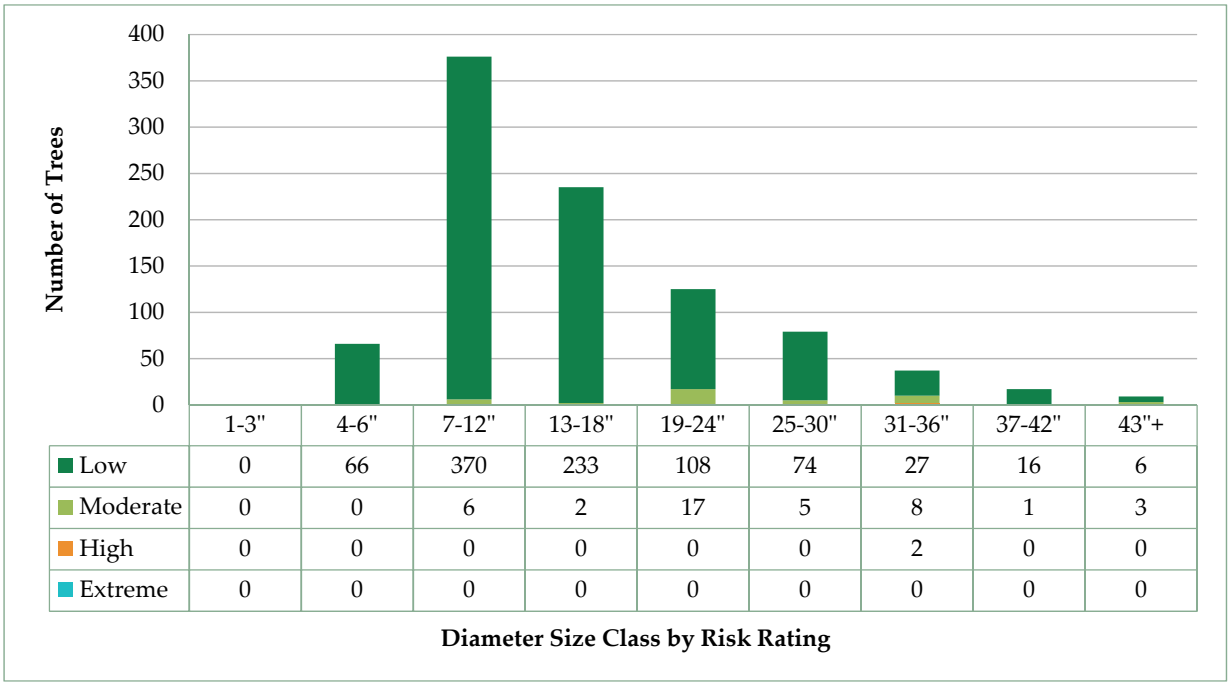
Pruning or removing Extreme and High Risk trees is strongly recommended to be prioritized and completed as soon as possible. In general, maintenance activities should be completed first for the largest diameter trees that pose the greatest risk. Once addressed, recommended tree maintenance activities should be completed for smaller diameter trees that pose the greatest risk. Addressing Extreme and High Risk trees in a timely and proactive manner often requires significant resources to be secured and allocated. However, peforming this work expediently will mitigate risk, improve public safety, and reduce long-term costs.

Remove trees that cause obstructions or interfere with power lines or other infrastructure when pruning or other maintenance practices cannot correct their conflict. Diseased and nuisance trees also warrant removal. Even though large short-term expenditures may be required, it is important to secure the funding needed to complete priority tree removals. Expedient removal reduces risk and promotes public safety. Figures 11 and 12 present tree pruning and tree removals by risk rating and diameter size class. The following subsections briefly summarize the high priority maintenance activities recommended during the inventory.

Extreme and High Pruning Recommendations

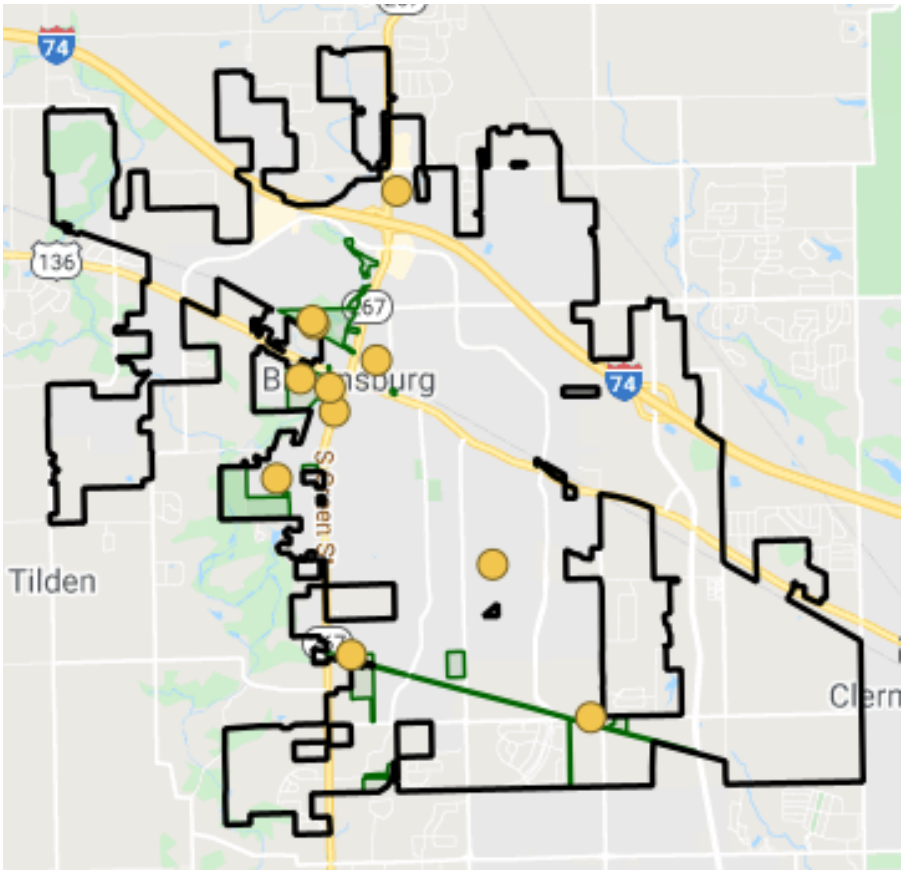
Pruning Extreme and High Risk trees immediately based on assigned risk rating generally requires removing defects such as dead and dying parts, broken and/or hanging branches, and missing or decayed wood that may be present in tree crowns, even when most of the tree is sound. In these cases, when pruning out the defected branch(es) to correct the problem the associated tree risk is reduced while promoting healthy growth. If pruning cannot correct a tree's defects and/or adequately mitigate risk, then remove the tree.

The inventory identified 2 High Risk trees recommended for pruning. The diameter size classes for trees were 31–36 inches DBH. Perform this maintenance immediately based on the assigned risk rating.



	1-3"	4-6"	7-12"	13-18"	19-24"	25-30"	31-36"	37-42"	43"+
Low	0	66	370	233	108	74	27	16	6
Moderate	0	0	6	2	17	5	8	1	3
High	0	0	0	0	0	0	2	0	0
Extreme	0	0	0	0	0	0	0	0	0

Figure 11. Recommended pruning by size class and risk rating.



Map 1. Locations of Extreme and High Risk Trees

Extreme and High Removal Recommendations

DRG identified 9 High Risk trees recommended for removal. The diameter size classes for High Risk trees ranged between 7–12 inches DBH and >42 inches DBH.

DRG recommends trees be removed when pruning will not correct their defects, eliminate the risks that their defects cause, or when corrective pruning would be cost-prohibitive. Remove these trees immediately based on their risk rating and size class.

	1-3"	4-6"	7-12"	13-18"	19-24"	25-30"	31-36"	37-42"	43"+
Low	85	239	851	303	101	29	10	7	4
Moderate	0	1	19	45	25	14	10	3	4
High	0	0	1	1	1	2	2	0	2
Extreme	0	0	0	0	0	0	0	0	0

Figure 12. Recommended removals by size class and risk rating.

Further Inspection Recommendations

In the ANSI A300 system, there are three levels of risk assessment. Each level built on the one before it. The lowest level is designed to be a cost-effective approach to quickly identifying tree risk concerns; whereas, the highest level is intended to provide in-depth information to decide about a tree. These levels are:

- **Level 1** inspection is a Limited Visual assessment conducted as a walk through or windshield survey designed to identify obvious defects or specified conditions.
- **Level 2** inspection is a Basic assessment conducted as a 360-degree visual inspection from the ground and of the tree parts and its surrounding site.
- **Level 3** inspection is an Advanced assessment performed using specialized tools to provide detailed information about specific tree parts, defects, targets, or site conditions.

The Further Inspection data field indicates whether a tree requires additional and/or future inspections to assess and/or monitor conditions that may cause it to become more of a risk to people, property, or other trees. The inventory identified 83 trees requiring one of these four inspection types. Further Inspections are beyond the scope of a standard tree inventory, and can be one of the following:

- Recent Damage OR Annual Inspection (e.g., a healthy tree that has been impacted by recent construction, weather, or other damage).
- Advanced Risk Assessment (e.g., a tree with a defect requiring additional or specialized equipment for investigation).
- Insect/Disease Monitoring (e.g., a tree that appears to have an emerging insect or disease problem).
- No further inspection required.

Trees with a Further Inspection requirement assessed by an ISA Certified Arborist should occur as soon as possible. Ideally, the ISA Certified Arborist also holds the ISA Tree Risk Assessment Qualification credential. The longer left unaddressed, serious defects could become a greater risk for that tree. For the same reason, perform the management the arborist recommended as soon as possible to minimize risk.

The inventory found 6 trees recommended for an Advanced Risk Assessment, 11 trees recommended for Annual Inspections, and 66 trees noted for Insect/Disease Monitoring. Take corrective action as soon as possible unless it will not adequately eliminate the defect, in which case tree removal is likely to be the safest and most cost-effective management.

Moderate and Low Pruning Recommendations

Pruning Moderate and Low Risk trees are generally the next priorities for maintenance activities after Extreme and High Risk recommended pruning is complete. Pruning adjacent Moderate and Low Risk trees may be an efficient use of resources. If corrective pruning cannot correct a tree's defects and/or adequately mitigate risk, then remove the tree.

DRG identified 42 Moderate Risk trees recommended for pruning. The diameter size classes for Moderate Risk trees ranged between 7–12 inches DBH and >42 inches DBH.

There were 900 Low Risk trees recommended for pruning. The diameter size classes for Low Risk trees ranged between 4–6 inches DBH and >42 inches DBH.

Moderate and Low Removal Recommendations

DRG identified 121 Moderate Risk trees recommended for removal. Most Moderate Risk trees recommended for removal were smaller than 25 inches DBH. Remove Moderate Risk trees after Extreme and High Risk removals are completed. Performing Moderate Risk tree removals concurrently with Low Risk tree removals may be an efficient use of resources.

DRG identified 1,629 Low Risk trees recommended for removal and recommends performing Low Risk removals when convenient. Low Risk removals pose little threat; these trees are generally small, dead, invasive, or poorly formed trees that need removed. Eliminating these trees will reduce breeding site locations for insects and diseases and will increase the aesthetic value of the area. Healthy trees growing in poor locations or undesirable species are also included in this category.

ROUTINE INSPECTIONS

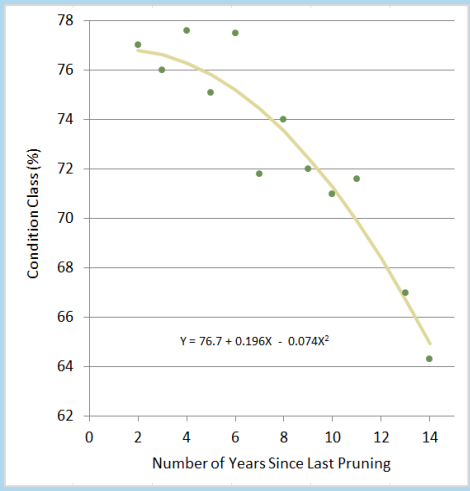
Inspections are essential as they uncover potential problems with trees. A qualified arborist trained in the art and science of planting, caring for, and maintaining individual trees should perform the routine inspections. Arborists are knowledgeable about the needs of trees and are trained and equipped to provide proper care. Ideally, the arborist will be an ISA Certified Arborist and hold the ISA Tree Risk Assessment Qualification credential.

Routine Inspection Recommendations

Routine inspections provide an opportunity to look for signs and symptoms of pests and diseases and identify newly developing defects. DRG recommends that Brownsburg perform two types of routine inspections. First, annually and after all severe weather events, to identify defects with heightened risk, signs of pest activity, and symptoms of disease conduct a Level 1 windshield assessment of inventories trees. Second, annually conduct a Level 2 basic assessment of a portion of the town's street ROW, parks, and trails/greenways. Following through with this recommendation will keep the inventory up to date and make maintenance scheduling most efficient. The Level 2 assessment should precede the routine pruning cycle discussed in the next section.

DRG recommends regularly inspecting public trees and assigning an appropriate maintenance as needed to mitigate risk. When trees require maintenance to reduce risk, they need added to the maintenance schedule and the budget needs updated to reflect the additional work. Utilize computer management software such as TreeKeeper® to make updates, edits, and keep a log of work records.

PROACTIVE PRUNING



Relationship between tree condition and years since previous pruning.

(adapted from Miller and Sylvester 1981)

Miller and Sylvester studied the pruning frequency of 40,000 street trees in Milwaukee, Wisconsin. Trees that had not been pruned for more than 10 years had an average condition rating 10% lower than trees that had been pruned in the previous several years. Their research suggests that a five-year pruning cycle is optimal for urban trees.

Routine pruning cycles help detect and correct most defects before they reach higher risk levels. Generally, DRG recommends that pruning cycles begin after all Extreme and High Risk tree maintenance is completed.

DRG recommends two pruning cycles: a Young Tree Training cycle and a Routine Pruning cycle. Newly planted trees will enter the Young Tree Training cycle once they become established and will move into the Routine Pruning cycle when they reach maturity. A tree should be removed and eliminated from the Routine Pruning cycle when it outlives its usefulness.

ROUTINE PRUNING CYCLE

The Routine Pruning cycle includes all Discretionary Prune maintenance recommendation. These trees pose some risk but have a smaller defect size and/or a lower probability of impacting a target. Over time, routine pruning can minimize reactive maintenance, limit instances of elevated risk, and provide the basis for a robust risk management program.

Based on Miller and Sylvester's research, DRG recommends a five-year Routine Pruning cycle to maintain the condition of the inventoried tree resource. However, not all municipalities are able to remain proactive with a five-year cycle based on budgetary constraints, the size of the public tree resource, or both. In these cases, extending the length of the Routine Pruning cycle is an option; however, it is in the municipality's best interest to not approach or exceed a 7-year pruning cycle. The reason is that this is tree condition deteriorates significantly without regular pruning, because their once-minor defects have worsened, reducing tree health and potentially increasing risk (Miller and Sylvester 1981).

Routine Pruning Cycle Recommendations

Brownsburg's inventory has 1,035 trees assigned as Discretionary Prune and DRG recommends that the town establish a five-year Routine Pruning cycle. A five-year cycle projects approximately 207 trees pruned each year. If this is not feasible for Brownsburg, a six-year Routine Pruning cycle projects approximately 173 trees pruned each year, or a seven-year Routine Pruning cycle projects approximately 148 trees pruned each year.

Approximately 23% of the inventoried tree population would benefit from routine pruning. Figure 13 shows that a variety of size classes recommended for pruning; however, most of the trees were 7–12 inches DBH.

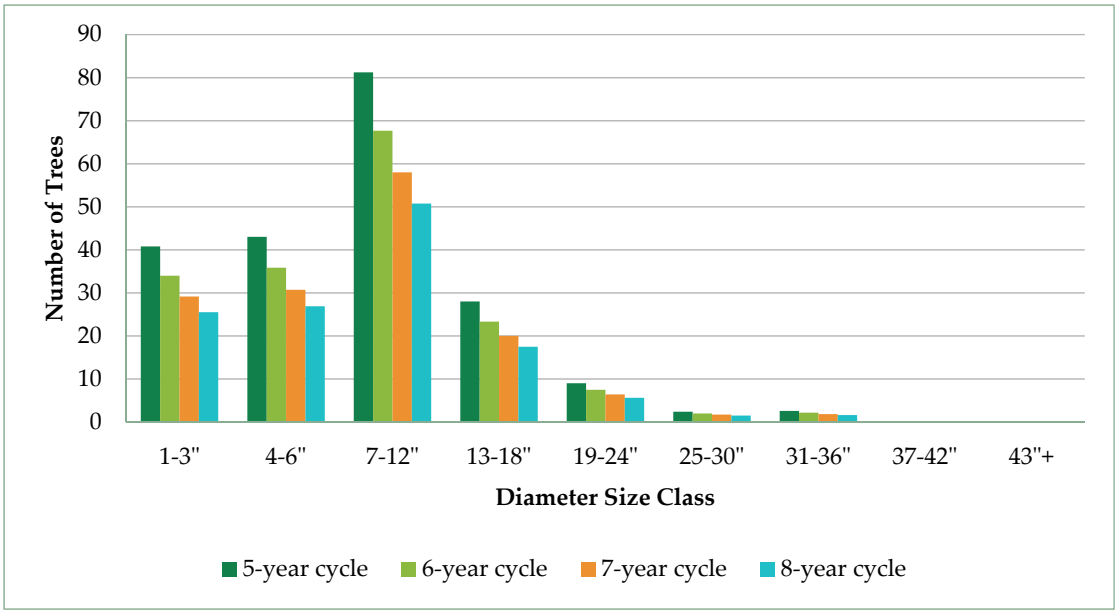


Figure 13. Pruning by diameter class.

YOUNG TREE TRAINING CYCLE

Trees included in the Young Tree Training cycle are generally less than 8 inches DBH. These younger trees sometimes have branch structures that can lead to potential problems as the tree ages. Potential structural problems include codominant leaders, multiple limbs attaching at the same point on the trunk, or crossing/interfering limbs. If the correction of these problems is incomplete, they may worsen as the tree grows, increasing its risk rating and creating potential liability. The recommended length of a Young Tree Training cycle is three years because young trees tend to grow at faster rates than mature trees. The Young Tree Training cycle differs from the Routine Pruning cycle in that the Young Tree Training cycle generally only include trees that are pruned from the ground with a pole pruner or pruning shear.

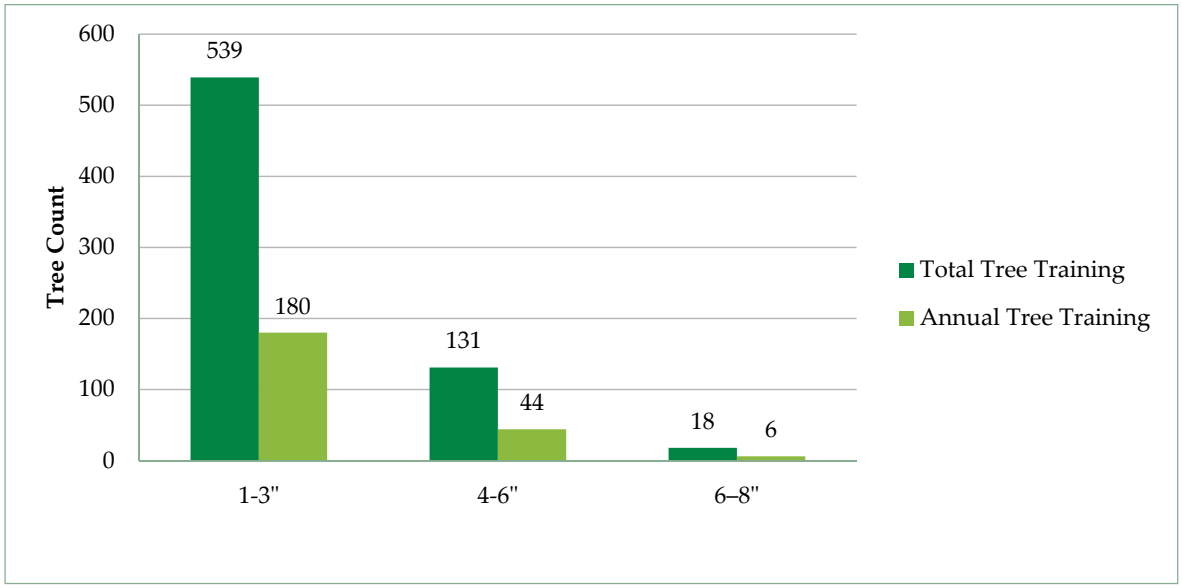


Figure 14. Young Tree Training Cycle.

Young Tree Training Cycle Recommendations

DRG recommends that Brownsburg implement a three-year Young Tree Training cycle beginning as soon as possible, because training young trees is vital for the future condition of the inventoried tree population. During the inventory, 688 trees less than or equal to 8 inches DBH were inventoried and recommended for young tree training. DRG recommends an average of 230 trees be trained with structural pruning each year over three years.

Newly planted trees should enter the Young Tree Training cycle after establishment, typically within 2–3 years after planting. In future years, base the number of trees in the Young Tree Training cycle on tree planting efforts and growth rates of young trees. The town should strive to training prune approximately one-third of its young trees each year.

TREE PLANTING AND STUMP REMOVAL

When trees removal occurs, those tree trunks become stumps, and when stump removal occurs, the location where the stump was has a potential of being a planting site. When planning to plant trees, plant selectively and with purpose. Without proactively providing follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the community. The goal of planting trees is valuable, but tree species need to be carefully chosen, trees need correctly planted, and new trees need to receive the proper amount of care.

Planting new trees in areas where there is sparse canopy is a simple and important goal. It is also simple and important to plant in areas with poor canopy continuity or gaps exist in the canopy. Brownsburg receives value from the functional services the tree resource provides, but those benefits are not evenly distributed across town. Equitable tree planting is sometimes difficult to achieve but an important goal as well. Purposely planting trees for the need of creating economic, environmental, and social benefits will provide Brownsburg the greater return on their investment.

The Right Tree in the Right Place is a mantra for tree planting used by the Arbor Day Foundation and many utility companies nationwide. Trees come in many different shapes and sizes, and often change dramatically over their lifetimes. Before selecting a tree for planting, check that it is the right tree—know how tall, wide, and deep it will be at maturity. Equally important to selecting the right tree is choosing the right spot to plant it. Blocking an unsightly view or creating some shade may be a priority, but it is important to consider how a tree may affect existing utility lines and hardscape as it grows taller, wider, and deeper. If the tree at maturity will reach overhead lines, or conflict with sidewalks and curbs, it is best to choose another tree or a different location.

Tree Planting and Stump Removal Recommendations

The inventory identified 215 stumps recommended for removal, with a wide range of sizes from 2″ to >42″ in diameter. In addition to the stumps inventoried, 1,759 tree removals may also need stumps removed. Stump removals should occur when convenient and be replanted if the site would be feasible for planting after the stump removal.

A no net loss policy for public trees is the replacement of all removed trees and stumps where sites are suitable for trees based on assessment of tree growth restrictions. If restrictions for new trees are present, leave that location void and locate a new site for the removed tree. Brownsburg's 2020 inventory suggests a no net loss of the street and park tree population equal to the planting of 623 trees (excluding trail/greenway trees). Additionally, annual mortality (approximately 1% of the population) is accounted with the additional estimate of about 27 trees a year. **Over the next eight years, Brownsburg will need to plant a minimum of 839 trees to achieve a no net loss of the tree resource.**

DRG recommends Brownsburg establish goals for tree planting along street ROW and in parks and along trails and greenways. **A goal for streets may be to meet the state's average trees per mile, which is approximately 27 trees per mile for Indiana towns, according to DRG's record of inventories conducted in Indiana.** Brownsburg's trees per mile is currently 10. Another goal may be to achieve 1 tree for every Brownsburg resident throughout street ROW alone or among street ROW, parks, and trails/greenways. Brownsburg's trees per capita ratio of inventoried trees to 2018's resident population is 0.05 or 1 street tree for every 20 residents. DRG's account of street tree per capita for Indiana's towns is 0.26 trees per capita or 1 tree for every 5 residents, while the mean ratio of trees reported for 22 U.S. cities is 0.37 trees per capita (McPherson and Rowntree 1989).

Creating larger growing sites for trees in the street ROW can be the single most beneficial management practice to improve the availability of planting locations and survival rate of planted and developing trees. Increasing planting space can also reduce the amount of tree-related infrastructure conflicts, as the trees are further from curbs and sidewalks. Depending on the site, there are several methods available to create and/or increase the growing space for newly planted trees.

- Install or enlarge tree wells/pits in existing sidewalks of sufficient width. Ideally, the minimum growing space of a small-sized tree is 32 square feet. Where Brownsburg has sidewalks of a sufficient width and length, the town could install tree pits with enough space remaining for the sidewalk to comply still with American Disability Act (ADA) standards.
- Planting trees 4 feet behind a curb without a sidewalk, or 4 feet behind an existing sidewalk, can be a low-cost alternative to more construction intensive methods. This can result in less damage to the sidewalk and give tree roots room to grow into the open soil.
- Re-routing the sidewalk around an area to create designated large tree sites is a relatively cost-effective method to increase growing spaces. This method can apply to existing large trees where tree roots have already come in conflict with the sidewalk.
- A landscape bump-out/curb extension is a vegetative area that protrudes into the parking lane of a street, to provide a growing space for plants or trees. These engineered designs quite effectively beautify a streetscape, provide greater storm water retention, and slow car speeds.

MAINTENANCE SCHEDULE AND BUDGET

Utilizing the 2020 Town of Brownsburg tree inventory data, an annual maintenance schedule developed by DRG recommends tasks to complete each year. DRG made budget projections using industry knowledge and public bid tabulations. A complete table of estimated costs for Brownsburg's eight-year tree management program follows.

This schedule provides a framework for completing the recommended inventoried tree maintenance over the next eight years. DRG recommends that all Extreme and High Risk maintenance be completed in Year One. DRG recommends that the Routine Pruning cycle begins in Year Six, after all Priority Prunes are completed, and include all Discretionary and Priority Pruned trees. The 5-year tree planting goal is approximately 208 trees (excluding 38 ash trees) or 42 trees annually. Following this schedule can shift tree maintenance activities from being reactive to a more proactive tree care program.

To implement the maintenance schedule, Brownsburg's tree maintenance budget should be:

- No less than $218,538 for the first year of implementation.
- No less than $233,628 for the second, third, fourth, and fifth years.
- No less than $207,280 for the sixth year.
- No less than $118,707 for the final two years of the maintenance schedule.

Most importantly, ensure that annual funds allow expedient mitigation of Extreme and High Risk trees so that vital routine inspection, pruning, and training cycles can begin as soon as possible. If routing efficiencies and/or contract specifications allow for more completed tree work in a given year, or if this maintenance schedule requires adjustment to meet budgetary or other needs, then modify accordingly. Unforeseen situations such as severe weather events may arise and change the maintenance needs of trees. If maintenance needs change, then adjust budgets, staffing, and equipment to meet the new demand.

Table 4. Estimated costs for eight-year tree management program.

Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Eight-Year Cost
Activity	Diameter	Cost/Tree	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Extreme and High Risk Removals	1-3"	$43	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$85	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$128	1	$128	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$128
	13-18"	$510	1	$510	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$510
	19-24"	$765	1	$765	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$765
	25-30"	$1,275	2	$2,550	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$2,550
	31-36"	$1,530	2	$3,060	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$3,060
	37-42"	$2,040	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$2,550	2	$5,100	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$5,100
Activity Total(s)			**9**	**$12,113**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$12,113**
Moderate and Low Risk Removals	1-3"	$43	0	$0	0	$0	0	$0	0	$0	85	$3,655	0	$0	0	$0	0	$0	$3,655
	4-6"	$85	1	$85	0	$0	0	$0	0	$0	239	$20,315	0	$0	0	$0	0	$0	$20,400
	7-12"	$128	19	$2,432	0	$0	0	$0	361	$46,208	490	$62,720	0	$0	0	$0	0	$0	$111,360
	13-18"	$510	45	$22,950	0	$0	231	$117,810	72	$36,720	0	$0	0	$0	0	$0	0	$0	$177,480
	19-24"	$765	25	$19,125	92	$70,380	9	$6,885	0	$0	0	$0	0	$0	0	$0	0	$0	$96,390
	25-30"	$1,275	14	$17,850	29	$36,975	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$54,825
	31-36"	$1,530	10	$15,300	10	$15,300	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$30,600
	37-42"	$2,040	3	$6,120	7	$14,280	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$20,400
	43"+	$2,550	4	$10,200	4	$10,200	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$20,400
Activity Total(s)			**121**	**$94,062**	**142**	**$147,135**	**240**	**$124,695**	**433**	**$82,928**	**814**	**$86,690**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$535,510**
Stump Removals	1-3"	$22	0	$0	0	$0	0	$0	0	$0	85	$1,870	37	$814	0	$0	0	$0	$2,684
	4-6"	$28	0	$0	0	$0	0	$0	0	$0	38	$1,064	47	$1,316	0	$0	0	$0	$2,380
	7-12"	$43	8	$344	0	$0	0	$0	127	$5,461	0	$0	48	$2,064	0	$0	0	$0	$7,869
	13-18"	$85	35	$2,975	0	$0	30	$2,550	0	$0	0	$0	27	$2,295	0	$0	0	$0	$7,820
	19-24"	$107	18	$1,926	24	$2,568	0	$0	0	$0	0	$0	28	$2,996	0	$0	0	$0	$7,490
	25-30"	$128	12	$1,536	11	$1,408	0	$0	0	$0	0	$0	16	$2,048	0	$0	0	$0	$4,992
	31-36"	$150	7	$1,050	5	$750	0	$0	0	$0	0	$0	7	$1,050	0	$0	0	$0	$2,850
	37-42"	$170	2	$340	0	$0	0	$0	0	$0	0	$0	3	$510	0	$0	0	$0	$850
	43"+	$210	4	$840	2	$420	0	$0	0	$0	0	$0	2	$420	0	$0	0	$0	$1,680
Activity Total(s)			**86**	**$9,011**	**42**	**$5,146**	**30**	**$2,550**	**127**	**$5,461**	**123**	**$2,934**	**215**	**$13,513**	**0**	**$0**	**0**	**$0**	**$38,615**
Priority Pruning	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	66	$1,980	0	$0	0	$0	0	$0	$1,980
	7-12"	$75	6	$450	0	$0	0	$0	0	$0	370	$27,750	0	$0	0	$0	0	$0	$28,200
	13-18"	$120	2	$240	0	$0	0	$0	230	$27,600	3	$360	0	$0	0	$0	0	$0	$28,200
	19-24"	$170	17	$2,890	0	$0	90	$15,300	18	$3,060	0	$0	0	$0	0	$0	0	$0	$21,250
	25-30"	$225	5	$1,125	0	$0	74	$16,650	0	$0	0	$0	0	$0	0	$0	0	$0	$17,775
	31-36"	$305	10	$3,050	0	$0	27	$8,235	0	$0	0	$0	0	$0	0	$0	0	$0	$11,285
	37-42"	$380	1	$380	16	$6,080	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$6,460
	43"+	$590	3	$1,770	6	$3,540	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$5,310
Activity Total(s)			**44**	**$9,905**	**22**	**$9,620**	**191**	**$40,185**	**248**	**$30,660**	**439**	**$30,090**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$120,460**

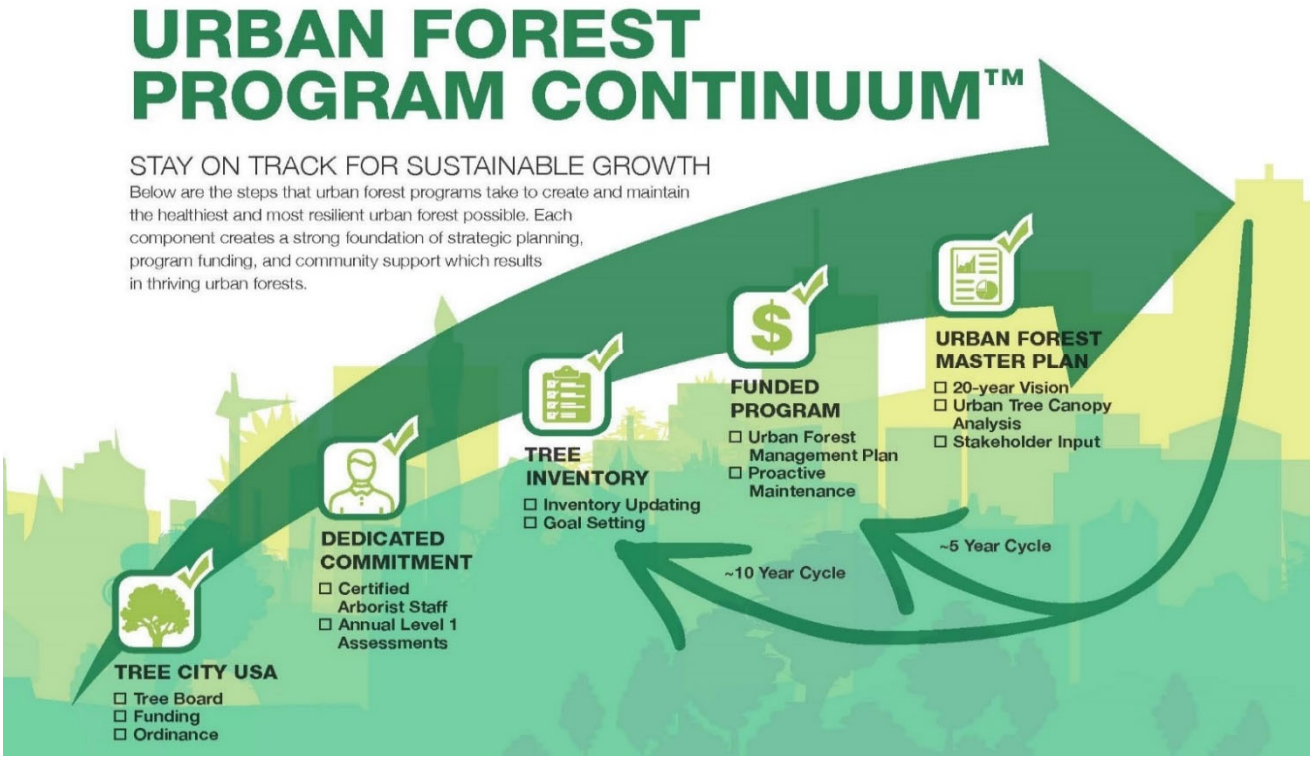
Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Eight-Year Cost
Activity	Diameter	Cost/Tree	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Further Inspection	Level 3 Risk Assessment	$100 per hour	6	$600	0	$0	0	$0	0	$0	6	$600	0	$0	0	$0	0	$0	$1,200
	Annual/Multi-year Inspections	$10 per hour	11	$110	11	$110	11	$110	11	$110	11	$110	11	$110	11	$110	11	$110	$880
	Insect and Disease Monitoring	$10 per hour	66	$660	66	$660	66	$660	66	$660	66	$660	66	$660	66	$660	66	$660	$5,280
	Recent Damage Inspection	$100 per hour	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**83**	**$1,370**	**77**	**$770**	**77**	**$770**	**77**	**$770**	**83**	**$1,370**	**77**	**$770**	**77**	**$770**	**77**	**$770**	**$7,360**
Routine Inspection	Level 2 Risk Assessment	$10	929	$9,290	929	$9,290	929	$9,290	929	$9,290	929	$9,290	929	$9,290	929	$9,290	929	$9,290	$74,320
	Level 1 Risk Assessment	$5	3712	$18,560	3712	$18,560	3712	$18,560	3712	$18,560	3712	$18,560	3712	$18,560	3712	$18,560	3712	$18,560	$148,480
Activity Total(s)			**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**4641**	**$27,850**	**$222,800**
Routine Pruning (5-year cycle)	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	41	$820	41	$820	41	$820	$2,460
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	0	$0	56	$1,680	56	$1,680	56	$1,680	$5,040
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	0	$0	156	$11,700	156	$11,700	156	$11,700	$35,100
	13-18"	$120	0	$0	0	$0	0	$0	0	$0	0	$0	75	$9,000	75	$9,000	75	$9,000	$27,000
	19-24"	$170	0	$0	0	$0	0	$0	0	$0	0	$0	34	$5,780	34	$5,780	34	$5,780	$17,340
	25-30"	$225	0	$0	0	$0	0	$0	0	$0	0	$0	18	$4,050	18	$4,050	18	$4,050	$12,150
	31-36"	$305	0	$0	0	$0	0	$0	0	$0	0	$0	10	$3,050	10	$3,050	10	$3,050	$9,150
	37-42"	$380	0	$0	0	$0	0	$0	0	$0	0	$0	3	$1,140	3	$1,140	3	$1,140	$3,420
	43"+	$590	0	$0	0	$0	0	$0	0	$0	0	$0	2	$1,180	2	$1,180	2	$1,180	$3,540
Activity Total(s)			**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**395**	**$38,400**	**395**	**$38,400**	**395**	**$38,400**	**$115,200**
Young Tree Training (3-year cycle)	1-3"	$20	180	$3,600	180	$3,600	180	$3,600	266	$5,320	222	$4,440	210	$4,200	393	$7,860	345	$6,900	$39,520
	4-6"	$30	44	$1,320	44	$1,320	44	$1,320	44	$1,320	44	$1,320	44	$1,320	44	$1,320	44	$1,320	$10,560
	6-8"	$75	6	$450	6	$450	6	$450	6	$450	6	$450	6	$450	6	$450	6	$450	$3,600
Activity Total(s)			**230**	**$5,370**	**230**	**$5,370**	**230**	**$5,370**	**316**	**$7,090**	**272**	**$6,210**	**260**	**$5,970**	**443**	**$9,630**	**395**	**$8,670**	**$53,680**
Replacement Tree Planting	Purchasing	$170	86	$14,620	42	$7,140	30	$5,100	127	$21,590	123	$20,910	215	$36,550	0	$0	0	$0	$105,910
	Planting	$110	86	$9,460	42	$4,620	30	$3,300	127	$13,970	123	$13,530	215	$23,650	0	$0	0	$0	$68,530
	Mulching	$100	86	$8,600	42	$4,200	30	$3,000	127	$12,700	123	$12,300	215	$21,500	0	$0	0	$0	$62,300
	Watering	$100	86	$8,600	42	$4,200	30	$3,000	127	$12,700	123	$12,300	215	$21,500	0	$0	0	$0	$62,300
Activity Total(s)			**344**	**$41,280**	**168**	**$20,160**	**120**	**$14,400**	**508**	**$60,960**	**492**	**$59,040**	**860**	**$103,200**	**0**	**$0**	**0**	**$0**	**$299,040**
New Tree Planting	Purchasing	$170	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	53	$9,010	53	$9,010	$18,020
	Planting	$110	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	53	$5,830	53	$5,830	$11,660
	Mulching	$100	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	53	$5,300	53	$5,300	$10,600
	Watering	$100	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	53	$5,300	53	$5,300	$10,600
Activity Total(s)			**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**212**	**$25,440**	**212**	**$25,440**	**$50,880**
Natural Mortality (1%)	Tree Removal	$128	27	$3,456	27	$3,456	27	$3,456	27	$3,456	27	$3,456	27	$3,456	27	$3,456	27	$3,456	$27,648
	Stump Removal	$43	27	$1,161	27	$1,161	27	$1,161	27	$1,161	27	$1,161	27	$1,161	27	$1,161	27	$1,161	$9,288
	Replacement Tree	$480	27	$12,960	27	$12,960	27	$12,960	27	$12,960	27	$12,960	27	$12,960	27	$12,960	27	$12,960	$103,680
Activity Total(s)			**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**81**	**$17,577**	**$140,616**
Activity Grand Total			**5639**		**5403**		**5610**		**6431**		**6945**		**6529**		**5849**		**5801**		
Cost Grand Total				**$218,538**		**$233,628**		**$233,397**		**$233,296**		**$231,761**		**$207,280**		**$119,667**		**$118,707**	**$1,596,274**

CONCLUSION

When properly maintained, the valuable benefits trees provide over their lifetime far exceed the time and money invested in planting, pruning, and inevitably removing them. The 4,426 public trees inventoried provide $228,971 in estimated annual economic value, which is 241-191% of the town's annual tree maintenance budget of $95,000–$120,000. Successfully implementing the eight-year program may increase Brownsburg's return on investment over time, or at least maintain it over the years.

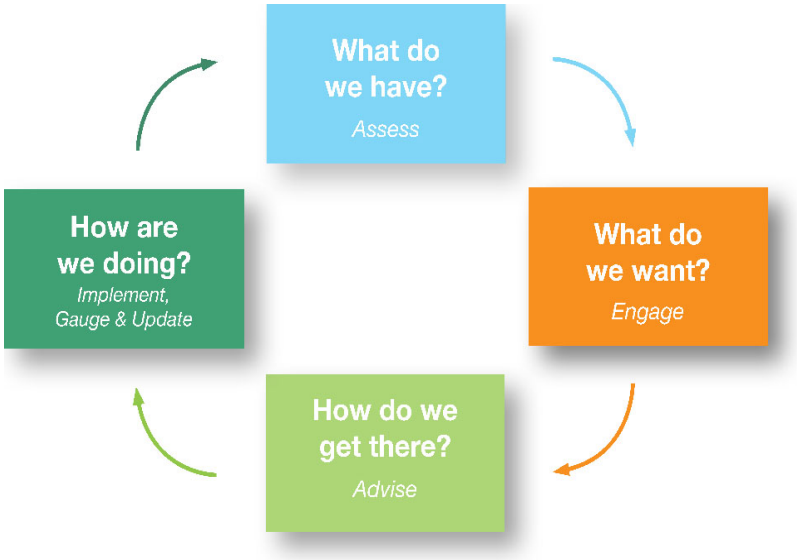
The program is ambitious and is a challenge to complete in eight years but becomes easier after all High Priority tree maintenance is completed. This *Tree Management Plan* could potentially help the town advocate for an increased urban forestry budget to fund the recommended maintenance activities. Getting started is the most difficult part because the expensive maintenance the first five years is priority work, which represents the transition from reactive maintenance to proactive maintenance. Significant investment early on can reduce tree maintenance costs over time.

As the urban forest grows, the benefits enjoyed by the Town of Brownsburg and its residents will increase as well. Inventoried trees are only a fraction of the total trees in Brownsburg when including private property, which is why it is important to incentivize private landowners to care for their trees and to plant new ones. The town's urban forestry program is well on its way to creating a sustainable and resilient public tree resource, and can stay on track by setting goals, updating inventory data to check progress, and setting more goals once they are reached.



EVALUATING AND UPDATING THIS PLAN

This *Tree Management Plan* provides management priorities for the next eight years, and it is important to update the tree inventory using TreeKeeper® as work is completed. Software can provide updated species distribution, benefit estimates, maintenance need. This empowers Brownsburg to self-assess the town's progress over time and set goals to strive toward by following the adaptive management cycle. Below are some ways of implementing the steps of this cycle:



- Conduct inspections of trees after all severe weather events. Record changes in tree condition (and risk and risk mitigation) in the inventory database. Prioritize and schedule work based on condition/risk.
- Perform routine inspections of public trees as needed.
  - Windshield surveys (inspections performed from a vehicle) in line with *ANSI A300 (Part 9)* (ANSI 2011) will help city staff stay apprised of quickly changing conditions/risk. Prioritize and schedule work based on condition/risk.
  - Keep the inventory up to date and add new inventory by conducting a portion of the inventory every year over the course of five to seven years. Prioritize and schedule work based on condition/risk.
- Annually compare the number of high priority tree work completed and scheduled, and then adjust future priority work backlog and budget accordingly.
- Annually compare the number of completed cyclical inspections, training, and pruning, and then adjust resources accordingly to manage better public tree health and safety.
- Annually compare the number of trees planted to the number of trees and/or stumps removed and the number of new trees planted, and then adjust future planting plans accordingly.
- Annually compare the species distribution of the inventoried tree resource with the previous year after completing planting plans to monitor changes and abundance.
- Revise the *Tree Management Plan* after five to eight years.

REFERENCES

American National Standards Institute. 2017. *ANSI A300 (Part 1): Tree, Shrub, and Other Woody Plant Management—Standard Practices (Pruning)*. Tree Care Industry Association, Inc.

———. 2011. *ANSI A300 (Part 9): Tree, Shrub, and Other Woody Plant Management Standard Practices (Tree Risk Assessment a. Tree Failure).* Tree Care Industry Association, Inc.

Coder, K. D. 1996. Identified Benefits of Community Trees and Forests. University of Georgia Cooperative Extension Service: Forest Resources Unit. Publication FOR96-39. Retrieved from https://nfs.unl.edu/documents/communityforestry/coderbenefitsofcommtrees.pdf

Heisler, G. M. 1986. Energy Savings with Trees. *Journal of Arboriculture* 12(5):113–125. Retrieved from https://www.nrs.fs.fed.us/pubs/jrnl/1986/nrs_1986_heisler_002.pdf

Karnosky, D. F. 1979. Dutch Elm Disease: A Review of the History, Environmental Implications, Control, and Research Needs. *Environmental Conservation* 6(4): 311–322.

Kuo, F. E., & Sullivan, W. C. 2001a. Environment and Crime in the Inner City: Does Vegetation Reduce Crime? *Environment and Behavior* 33(3): 343–367. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.644.9399&rep=rep1&type=pdf

———. 2001b. Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue. *Environment and Behavior* 33(4): 543–571. Retrieved from https://pdfs.semanticscholar.org/9ca8/a34eee31d42ac2235aa6d0b9b6e7a5f32386.pdf

Lovasi, G. S., Quinn, J. W., Neckerman, K. M., Perzanowski M., Rundle, A. 2008. Children living in areas with more street trees have lower prevalence of asthma. *Journal of Epidemiology and Community Health* 62(7): 647-649. Retrieved from https://www.researchgate.net/publication/5401459_Children_living_in_areas_with_more_trees_have_lower_prevalence_of_asthma

McPherson, E. G., Rowntree, R. A. 1989. Using Structural Measures to Compare Twenty-Two U.S. Street Tree Populations. *Landscape Journal* 8(1): 13–23. Retrieved from https://www.fs.fed.us/psw/topics/urban_forestry/products/1/psw_cufr745_structuralmeasures.pdf

Miller, R. W., & Sylvester, W.A. 1981. An Economic Evaluation of the Pruning cycle. *Journal of Arboriculture* 7(4): 109–112. Retrieved from http://webcache.googleusercontent.com/search?q=cache:VENBQXq9EmcJ:joa.isa-arbor.com/request.asp%3FJournalID%3D1%26ArticleID%3D1724%26Type%3D2+&cd=2&hl=en&ct=clnk&gl=us

Evans, E. 2012. Americans are Planting Trees of Strength. North Carolina State University College of Agriculture & Life Sciences: Department of Horticultural Science. http://www.treesofstrength.org/benefits.htm

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution* 178: 229-236. Retrieved from https://www.fs.fed.us/nrs/pubs/jrnl/2013/nrs_2013_nowak_001.pdf

Richards, N. A. 1983. Diversity and Stability in a Street Tree Population. *Urban Ecology* 7(2): 159–171.

Santamour, F.S. 1990. Trees for Urban Planting: Diversity Uniformity, and Common Sense. *U.S. National Arboretum: Agricultural Research Service*. Retrieved from https://pdfs.semanticscholar.org/26a2/4c5361ce6d6e618a9fa307c4a34a3169e309.pdf?_ga=2.266051527.959145428.1587418896-558533249.1587418896

Ulrich, R. 1984. View through Window May Influence Recovery from Surgery. *Science* 224: 420–422. Retrieved from https://pdfs.semanticscholar.org/43df/b42bc2f7b212eb288d2e7be289d251f15bfd.pdf

———. 1986. Human Responses to Vegetation and Landscapes. *Landscape and Urban Planning* 13: 29–44. Retrieved from https://www.researchgate.net/profile/Roger_Ulrich4/publication/254315158_Visual_Landscapes_and_Psychological_Well-Being/links/0c96053a3fe7796728000000/Visual-Landscapes-and-Psychological-Well-Being.pdf

Ulrich R.S., R.F. Simmons, B.D. Losito, E. Fiority, M.A. Miles and M. Zeison. 1991. Stress Recovery During Exposure to Natural and Urban Environments. *Journal of Environmental Psychology* 11(3): 201-230.

USDA Forest Service. 2003a. Benefits of Urban Trees—Urban and Community Forestry: Improving Our Quality of Life. *Southern Region Forestry Report* R8-FR 71. Retrieved from http://www.sci-links.com/files/Benefits_of_Urban_Trees.pdf

———. 2003b. Is all your rain going down the drain? Look to Bioretainment—trees are a solution. *Center for Urban Forest Research: Pacific Southwest Research Station*. Retrieved from https://www.fs.fed.us/psw/topics/urban_forestry/products/cufr_392_rain_down_the_drain.pdf

———. 2020. Forest Health Highlights. https://www.fs.fed.us/foresthealth/protecting-forest/forest-health-monitoring/monitoring-forest-highlights.shtml

USDA Animal and Plant Health Inspection Service. 2020. Pest Tracker. https://www.aphis.usda.gov/aphis/resources/pests-diseases/hungry-pests/Pest-Tracker

Wolf, K. L. 1998a. Urban Nature Benefits: Psycho-Social Dimensions of People and Plants. *University of Washington: College of Forest Resources* Human Dimensions of the Urban Forest Fact Sheet #1. Retrieved from https://www.naturewithin.info/UF/PsychBens-FS1.pdf

———. 1998b. Trees in Business Districts: Positive Effects on Consumer Behavior! *University of Washington: College of Forest Resources* Human Dimensions of the Urban Forest Fact Sheet #5. Retrieved from https://www.naturewithin.info/CityBiz/Biz3Ps-FS5.pdf

———. 1999. Grow for the Gold: Trees in Business Districts. *Washington State DNR: Community Forestry Program* Number 14. Retrieved from https://www.naturewithin.info/CityBiz/TreeLink.PDF

———. 2000. Community Image: Roadside Settings and Public Perceptions. *University of Washington: College of Forest Resources* Human Dimensions of the Urban Forest Factsheet #10. Retrieved from https://www.naturewithin.info/Roadside/Rsd-Community-FS10.pdf

———. 2003. Social Aspects of Urban Forestry: Public Response to the Urban Forest in Inner-City Business Districts. *Journal of Arboriculture* 29(3): 117–126. Retrieved from https://www.naturewithin.info/CityBiz/JofA_Biz.pdf

———. 2007. City Trees and Property Values. *Arborist News* 16(4): 34-36. Retrieved from https://www.naturewithin.info/Policy/Hedonics.pdf

———. 2009. Trees & Urban Streets: Research on Traffic Safety & Livable Communities. *University of Washington, Seattle USDA Forest Service: Pacific Northwest Research Station*. Retrieved from http://www.naturewithin.info/urban.html

APPENDIX A
DATA COLLECTION AND SITE LOCATION METHODS

DATA COLLECTION METHODS

DRG collects tree inventory data using their proprietary GIS software, called Rover, loaded onto pen-based field computers. At each site, the following data fields were collected:

- Address
- Condition
- Date of Inventory
- Defects
- Further Inspection
- Grow Space Type
- Hardscape Damage
- Land Use
- Multi-stem
- Overhead Utilities
- Park Name
- Primary Maintenance
- Risk Assessment and Rating
- Species
- Tree Size*
- Tree Tag Number

* measured in inches in diameter at 4.5 feet above ground or diameter at breast height (DBH]).

Maintenance needs are based on *Best Management Practices: Tree Risk Assessment* (International Society of Arboriculture 2011). The knowledge, experience, and professional judgment of DRG's arborists ensure the high quality of inventory data.

SITE LOCATION METHODS

Equipment and Base Maps

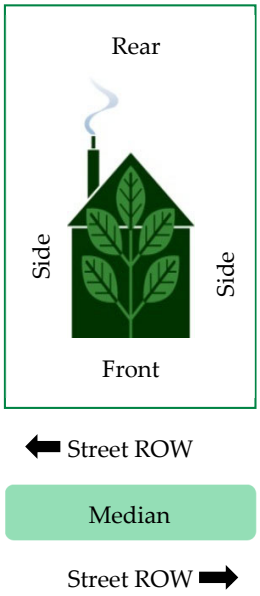
Inventory arborists use FZ-G1 Panasonic Toughpad® units with internal GPS receivers. Geographic information system (GIS) map layers are loaded onto these units to help locate sites during the inventory. The table below lists these base map layers, along with each layer's source and format information.

Base Map Layers Utilized for Inventory

Imagery/Data Source	Date	Projection
Shapefiles Town of Brownsburg - Department of Developmental Services	Most current available as of January, 2020	NAD 1983 StatePlane Indiana West; Feet
4" Aerial Imagery Town of Brownsburg - Department of Developmental Service	2014	NAD 1983 StatePlane Indiana West; Feet

STREET ROW SITE LOCATION

Individual street ROW sites (trees and stumps) were located using a methodology that identifies sites by *address number*, *street name*, *side*, and *on street*. This methodology was developed by DRG to help ensure consistent assignment of location.



Address Number and Street Name

DRG's Rover software transferred the address number and street name from parcel and street centerline GIS layers. The arborist while present on location confirmed the address and street name assigned by reading street signs and building numbers. Where there was no GIS parcel addressing data available for sites by an vacant or occupied lots without a posted address number on a building, the arborist used their best judgment to assign an address number based on opposite or adjacent addresses.

Sites in medians or islands were assigned an address number using parcel and streets geographical data. Each segment was numbered with an assigned address that was interpolated from addresses facing that median/island. If there were multiple median/islands between cross streets, each segment was assigned its own address. The *street name* assigned to a site was determined by street centerline information and posted street name signage.

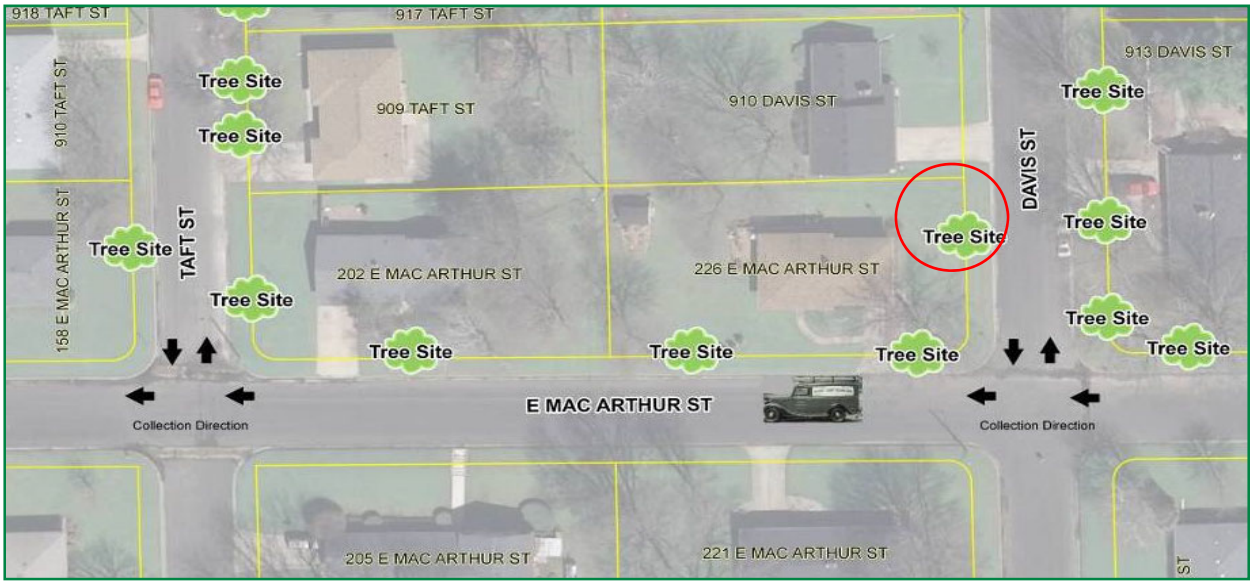
Side Value

Each site was assigned a *side value*. Side values include *front*, *side*, *median*, or *rear* based on the site's location in relation to the lot's street frontage. The *front* is the side facing the address street. *Side* is either side of the lot that is between the front and rear. *Median* indicates a median or island surrounded by pavement. The *rear* is the side of the lot opposite of the address street.

PARK AND PUBLIC SPACE SITE LOCATION

Park and/or public space site locations were collected using the same methodology as street ROW sites; however, they have the additional "Park Name" field filled.

Site Location Example



Address/Street Name:	226 E. Mac Arthur Street
Side:	Side
On Street:	Davis Street

The tree site circled in red signifies the crew's target site. Because the tree is located on the side of the lot, the *on* street is Davis Street, even though it is addressed as 226 East Mac Arthur Street.

APPENDIX B
INVASIVE PESTS AND DISEASES

In today's worldwide marketplace, the volume of international trade brings increased potential for pests and diseases to invade our country. Many of these pests and diseases have seriously harmed rural and urban landscapes and have caused billions of dollars in lost revenue and millions of dollars in cleanup costs. Keeping these pests and diseases out of the country is the number one priority of the USDA's Animal and Plant Inspection Service (APHIS).

Updated pest range maps can be found at: https://www.nrs.fs.fed.us/tools/afpe/maps/ and updated pest information can be found at: https://www.aphis.usda.gov/aphis/resources/pests-diseases/hungry-pests/Pest-Tracker

Although some invasive species naturally enter the United States via wind, ocean currents, and other means, most invasive species enter the country with some help from human activities. Their introduction to the U.S. is a byproduct of cultivation, commerce, tourism, and travel. Many species enter the United States each year in baggage, cargo, contaminants of commodities, or mail.

Once they arrive, invasive pests grow and spread rapidly because controls, such as native predators, are lacking. Invasive pests disrupt the landscape by pushing out native species, reducing biological diversity, killing trees, altering wildfire intensity and frequency, and damaging crops. Some pests may even push species to extinction. The following sections include key pests and diseases that adversely affect trees in America at the time of this plan's development. This list is not comprehensive and may not include all threats.

It is critical to the management of community trees to routinely check APHIS, USDA Forest Service, and other websites for updates about invasive species and diseases in your area and in our country so that you can be prepared to combat their attack.

ASIAN LONGHORNED BEETLE

The Asian longhorned beetle (ALB, *Anoplophora glabripennis*) is an exotic pest that threatens a wide variety of hardwood trees in North America. The beetle was introduced in Chicago, New Jersey, and New York City, and is believed to have been introduced in the United States from wood pallets and other wood-packing material accompanying cargo shipments from Asia. ALB is a serious threat to America's hardwood tree species.

Adult Asian longhorned beetle.

Photograph courtesy of New Bedford Guide (2011)

Adults are large (3/4- to 1/2-inch long) with very long, black and white banded antennae. The body is glossy black with irregular white spots. Adults can be seen from late spring to fall depending on the climate. ALB has a long list of host species; however, the beetle prefers hardwoods, including several maple species. Examples include: box alder (*Acer negundo)*; Norway maple *(A. platanoides)*; red maple *(A. rubrum)*; silver maple (*A. saccharinum)*; sugar maple (*A. saccharum)*; buckeye (*Aesculus glabra)*; horsechestnut (*A. hippocastanum)*; birch (*Betula)*; London planetree (*Platanus* × *acerifolia)*; willow (*Salix)*; and elm (*Ulmus)*.

GYPSY MOTH

The gypsy moth (GM, *Lymantria dispar*) is native to Europe and first arrived in the United States in Massachusetts in 1869. This moth is a significant pest because its caterpillars have an appetite for more than 300 species of trees and shrubs. GM caterpillars defoliate trees, which makes the species vulnerable to diseases and other pests that can eventually kill the tree.

Close-up of male (darker brown) and female (whitish color) European gypsy moths.

Photograph courtesy of USDA APHIS (2019)

Male GMs are brown with a darker brown pattern on their wings and have a 1/2-inch wingspan. Females are slightly larger with a 2-inch wingspan and are nearly white with dark, saw-toothed patterns on their wings. Although they have wings, the female GM cannot fly.

The GMs prefer approximately 150 primary hosts but feed on more than 300 species of trees and shrubs. Some trees are found in these common genera: birch (*Betula)*; cedar *(Juniperus)*; larch *(Larix)*; aspen, cottonwood, poplar *(Populus)*; oak *(Quercus*); and willow *(Salix)*.

EMERALD ASH BORER

Emerald ash borer *(EAB) (Agrilus planipennis*) is responsible for the death or decline of tens of millions of ash trees in 14 states in the American Midwest and Northeast. Native to Asia, EAB has been found in China, Japan, Korea, Mongolia, eastern Russia, and Taiwan. It likely arrived in the United States hidden in wood-packing materials commonly used to ship consumer goods, auto parts, and other products. The first official United States identification of EAB was in southeastern Michigan in 2002.

Close-up of the emerald ash borer.

Photograph courtesy of USDA APHIS (2020)

Adult beetles are slender and 1/2-inch long. Males are smaller than females. Color varies but adults are usually bronze or golden green overall with metallic, emerald-green wing covers. The top of the abdomen under the wings is metallic, purplish-red and can be seen when the wings are spread.

The EAB-preferred host tree species are in the genus ash *(Fraxinus)*.

FOREST TENT CATERPILLAR

Forest tent caterpillar (*Malacosoma disstria*) is possibly the most damaging tent caterpillar in the United States. It attacks ash, various fruit trees, poplar, willow, and many other deciduous trees. The name may be slightly misleading as the larvae do not make a silken tent between the trunk and branches of trees as other tent caterpillars do. Instead, this larva makes a mat on the trunk for masses of caterpillars to rest on. The larval caterpillar is distinctive in the bright blue coloration along its sides with a white "keyhole"-shaped pattern running along its back.

Forest Tent Caterpillar larva with blue stripe and white "keyhole" pattern running down its back.

Photograph courtesy Greg Hume CC-BY-SA-3.0 (2006).

Looper Complex

Loopers pose a threat to tree populations due to defoliation caused by feeding during the larval stage of the insect. Loopers prefer trees such as maple, linden, oak, birch, elm, hickory, and other hardwoods. Moths of the loopers are wingless and will remain on the tree trunk for the male to mate. After mating, females will crawl up the tree to deposit eggs.

Linden looper (*Erannis tiliaria*)

Photo courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2017)

Spiny looper (*Phigalia titea*)

Photo courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2017)

OAK WILT

Oak wilt was first identified in 1944 and is caused by the fungus *Ceratocystis fagacearum*. While considered an invasive and aggressive disease, its status as an exotic pest is debated since the fungus has not been reported in any other part of the world. This disease affects the oak genus and is most devastating to those in the red oak subgenus, such as scarlet oak *(Quercus coccinea)*, shingle oak *(Q. imbricaria)*, pin oak *(Q. palustris)*, willow oak *(Q. phellos)*, and red oak *(Q. rubra)*. It also attacks trees in the white oak subgenus, although it is not as prevalent and spreads at a much slower pace in these trees.

Oak wilt symptoms on red and white oak leaves

Photograph courtesy of USDA Forest Service (2011a)

Just as with DED, oak wilt disease is caused by a fungus that clogs the vascular system of oaks and results in decline and death of the tree. The fungus is carried from tree to tree by several borers common to oaks, but the disease is more commonly spread through root grafts. Oak species within the same subgenus (red or white) will form root colonies with grafted roots that allow the disease to move readily from one tree to another.

SUDDEN OAK DEATH

The causal agent of sudden oak death (SOD), *Phytophthora ramorum* (also known as *Phytophthora* canker disease), was first identified in 1993 in Germany and the Netherlands on ornamental rhododendron. In 2000, the disease was found in California. Since its discovery in North America, SOD has been confirmed in forests in California and Oregon and in nurseries in British Columbia, California, Oregon, and Washington. SOD has been potentially introduced into other states through exposed nursery stock. Through ongoing surveys, APHIS continues to define the extent of the pathogen's distribution in the United States and limit its artificial spread beyond infected areas through quarantine and a public education program.

Drooping tanoak shoot.

Photograph courtesy of Indiana Department of Natural Resources (2012)

Identification and symptoms of SOD may include large cankers on the trunk or main stem accompanied by browning of leaves. Tree death may occur within several months to several years after initial infection. Infected trees may also be infested with ambrosia beetle (*Monarthrum dentiger* and *M. scutellarer*), bark beetle (*Pseudopityophthorus pubipennis*), and sapwood rotting fungus (*Hypoxylon thouarsianum*). These organisms may contribute to the death of the tree. Infection on foliar hosts is indicated by dark grey to brown lesions with indistinct edges. These lesions can occur anywhere on the leaf blade, in vascular tissue, or on the petiole. Petiole lesions are often accompanied by stem lesions. Some hosts with leaf lesions defoliate and eventually show twig dieback.

This pathogen is devastating to oak *(Quercus)* but also affects several other plant species.

PINE SHOOT BEETLE

The pine shoot beetle (*Tomicus piniperda L.*), a native of Europe, is an introduced pest of *Pinus* (pine) in the United States. It was first discovered in the United States at a Christmas tree farm near Cleveland, Ohio in 1992. Following the first detection in Ohio, the beetle has been detected in parts of 19 states (Connecticut, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin).

Mined shoots on a Scotch pine

Photograph courtesy of USDA Forest Service (1993)

The beetle attacks new shoots of pine trees, stunting the growth of the trees. The pine shoot beetle may also attack stressed pine trees by breeding under the bark at the base of the trees. The beetles can cause severe decline in the health of the trees and, in some cases, kill the trees when high populations exist.

Adult pine shoot beetles range from 3 to 5 millimeters long, or about the size of a match head. They are brown or black and cylindrical. The legless larvae are about 5 millimeters long with a white body and brown head. Egg galleries are 10–25 centimeters long. From April to June, larvae feed and mature under the pine bark in separate feeding galleries that are 4–9 centimeters long. When mature, the larvae stop feeding, pupate, and then emerge as adults. From July through October, adults tunnel out through the bark and fly to new or 1-year-old pine shoots to begin maturation feeding. The beetles enter the shoot 15 centimeters or less from the shoot tip and move upwards by hollowing out the center of the shoot for a distance of 2.5–10 centimeters. Affected shoots droop, turn yellow, and eventually fall off during the summer and fall.

Scots pine (P. sylvestris) is preferred, but other pine species, including Jack pine *(P. banksiana)*, Austrian pine *(P. nigra)*, red pine *(P. resinosa)*, and eastern white pine *(P. strobus)*, have been infested in the Great Lakes region.

SPOTTED LANTERNFLY

The spotted lanternfly (SLF, *Lycorma delicatula*) is native to China and was first detected in Pennsylvania in September 2014. SLF feeds on a wide range of fruit, ornamental, and woody trees, with tree-of-heaven being one of its preferred hosts. SLF is a hitchhiker and can be spread long distances by people who move infested material or items containing egg masses.

If allowed to spread in the United States, this pest could seriously impact the country's grape, orchard, and logging industries. Be sure to inspect for the pest. Egg masses, juveniles, and adults can be on trees and plants, as well as on bricks, stone, metal, and other smooth surfaces. Also thoroughly check vehicles, trailers, and even the clothes you are wearing to prevent accidently moving SLF.

Symptoms of SLF are plants oozing or weeping with a fermented odor, buildup of a sticky fluid called honeydew on the plant or on the ground underneath them, and sooty mold growing on plants. The following trees are susceptible to SLF: almonds, apples, apricots, cherries, maples, nectarines, oaks, peaches, pines, plums, poplars, sycamores, walnuts, and willows, as well as grape vines and hop plants.

Pinned spotted lanternfly

Photograph courtesy of PA Dept of Agriculture

Pinned spotted lanternfly nymph with wingspan open

Photograph courtesy of USDA APHIS

THOUSAND CANKERS DISEASE

A complex disease referred to as Thousand Cankers disease (TCD) was first observed in Colorado in 2008 and is now thought to have existed in Colorado as early as 2003. TCD is considered to be native to the United States and is attributed to numerous cankers developing in association with insect galleries.

Walnut twig beetle, side view

Photograph courtesy of USDA Forest Service (2011)

TCD results from the combined activity of the *Geosmithia morbida* fungus and the walnut twig beetle (WTB, *Pityophthorus juglandis*). The WTB has expanded both its geographical and host range over the past two decades, and coupled with the *Geosmithia morbida* fungus, *Juglans* (walnut) mortality has manifested in Arizona, California, Colorado, Idaho, New Mexico, Oregon, Utah, and Washington. In July 2010, TCD was reported in Knoxville, Tennessee. The infestation is believed to be at least 10 years old and was previously attributed to drought stress. This is the first report east of the 100th meridian, raising concerns that large native populations of black walnut *(J. nigra)* in the eastern United States may suffer severe decline and mortality.

The tree species preferred as hosts for TCD are walnut.

REFERENCES

Cranshaw, W. 2004. *Garden Insects of North America: The Ultimate Guide to Backyard Bugs* (pp. 114, 118). Princeton University Press.

DiOrio, A. 2011. *Volunteers Needed for Asian Longhorned Beetle Survey.* New Bedford Guide. Retrieved from http://www.newbedfordguide.com/volunteers-needed-for-asian-longhorned- beetle-survey/2011/03/30

Indiana Department of Natural Resources. 2019. *Sudden Oak Death*. Entomology and Plant Pathology. Retrieved from http://www.in.gov/dnr/entomolo/4532.htm

Miller, F. 2016. *2016 Illinois Forest Health Highlights*. The Morton Arboretum. Retrieved from http://www.mortonarb.org/files/2016-FHH-Final-Version-12-28-16-Submitted.pdf

University of Georgia. *Invasive Species*. Center for Invasive Species and Ecosystem Health. Retrieved from www.bugwood.org

USDA Animal and Plant Health Inspection Service. 2019. *Hungry Pests: Your Move Gypsy Moth Free.* Retrieved from https://www.aphis.usda.gov/aphis/resources/pests-diseases/hungry-pests/thethreat/gypsy-moth-free

USDA Animal and Plant Health Inspection Service. 2019. *Pest Alert: Spotted Lantern Fly* (Lycorma delicatula). Retrieved from https://www.aphis.usda.gov/publications/plant_health/alert-spotted-lanternfly.pdf

USDA Animal and Plant Health Inspection Service. 2020. *Plant Pests and Diseases: Emerald Ash Borer.* Retrieved from https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and- disease-programs/pests-and-diseases/emerald-ash-borer/emerald-ash-borer

USDA Forest Service. 2013. *Pest Alert: Thousand Cankers Disease*. Northeastern Area State and Private Forestry, NA–PR–02–10. Retrieved from https://www.fs.usda.gov/naspf/sites/default/files/thousand_cankers_disease_print_res.pdf

APPENDIX C
TREE BENEFIT METHOLOGY

i-Tree Streets regionalizes the calculations of its output by incorporating detailed reference city project information for 16 climate zones across the United States. Brownsburg falls within the Lower Midwest Climate Zone. Sample inventory data from Indianapolis represent the basis for the Lower Midwest Reference City Project for the Lower Midwest Community Tree Guidelines. The basis for the benefit modeling in this study compares the inventory data from Carmel to the results of Lower Midwest Reference City Project to obtain an estimation of the annual benefits provided by Brownsburg's resource.

Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to or removed from the existing population. Calculations of carbon dioxide (CO_2) released due to decompositions of wood from removed trees did consider average annual mortality. This approach directly connects benefits with tree-size variables such as diameter at breast height (DBH) and leaf-surface area. Many benefits of trees are related to processes that involve interactions between leaves and the atmosphere (e.g., interception, transpiration, photosynthesis); therefore, benefits increase as tree canopy cover and leaf surface area increase.

For each of the modeled benefits, an annual resource unit was determined on a per-tree basis. Resource units are measured as megawatt-hours of electricity saved per tree; therms of natural gas conserved per tree, pounds of atmospheric CO_2 reduced per tree; pounds of nitrogen dioxide (NO_2), particulate matter (PM_{10}), and volatile organic compounds (VOCs) reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values.

Prices were assigned to each resource unit using economic indicators of society's willingness to pay for the environmental benefits trees provide. Estimates of benefits are initial approximations as some benefits are difficult to quantify (e.g., impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions make estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification provides first-order approximations. It is meant to be a general accounting of the benefits produced by urban trees—an accounting with an accepted degree of uncertainty that can, nonetheless, provide science-based platform for decision-making.

A detailed description of how the default benefit prices are derived, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper and others 2008) and the *Lower Midwest Community Tree Guide* (Peper and others 2009). i-Tree Streets' default values from the Lower Midwest Climate Zone were used for air quality and stormwater benefit prices and local values were used for energy usage and aesthetics and other benefits.

Brownsburg's Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$0.0680	$/Kwh	Duke rate
Natural Gas	$0.973	$/Therm	Vectren rate
CO_2	$0.0033	$/lb	Streets default- Lower Midwest
PM_{10}	$0.99	$/lb	Streets default- Lower Midwest
NO_2	$0.82	$/lb	Streets default- Lower Midwest
O_3	$0.82	$/lb	Streets default- Lower Midwest
SO_2	$1.50	$/lb	Streets default- Lower Midwest
VOC	$0.30	$/lb	Streets default- Lower Midwest
Stormwater	$0.0062	$/gallon	Streets default- Lower Midwest
Average Home Resale	$135,400	$	Zillow rate

Using these prices, the magnitude of the benefits provided by the public tree resource was calculated based on the science of i-Tree Streets using DRG's TreeKeeper® inventory management software. For a detailed description of how the magnitudes of benefit prices are calculated, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper and others 2008).

APPENDIX D
SUGGESTED TREE SPECIES

Proper landscaping and tree planting are critical components of the atmosphere, livability, and ecological quality of a community's urban forest. The tree species listed below have been evaluated for factors such as size, disease and pest resistance, seed or fruit set, and availability. The following list is offered to assist all relevant community personnel in selecting appropriate tree species. These trees have been selected because of their aesthetic and functional characteristics and their ability to thrive in the soil and climate conditions throughout Zone 5 on the USDA Plant Hardiness Zone Map.

DECIDUOUS TREES

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer rubrum	red maple	Red Sunset®
Acer nigrum	black maple	
Acer saccharum	sugar maple	'Legacy'
*Acer saccharinum**	silver maple	
*Aesculus glabra**	Ohio buckeye	
*Aesculus flava**	yellow buckeye	
Betula nigra	river birch	Heritage®
*Carya illinoensis**	pecan	
*Carya laciniosa**	shellbark hickory	
*Carya ovata**	shagbark hickory	
*Castanea mollissima**	Chinese chestnut	
Celtis occidentalis	common hackberry	'Prairie Pride'
Cercidiphyllum japonicum	katsuratree	'Aureum'
*Diospyros virginiana**	common persimmon	
*Fagus grandifolia**	American beech	
*Fagus sylvatica**	European beech	(numerous exist)
Ginkgo biloba	ginkgo	(male trees only)
Gleditsia triacanthos inermis	thornless honeylocust	'Shademaster'
Gymnocladus dioica	Kentucky coffeetree	Prairie Titan®
*Juglans regia**	English walnut	'Hansen'
*Larix decidua**	European larch	
Liquidambar styraciflua	American sweetgum	Cherokee™
Liriodendron tulipifera	tuliptree	'Fastigiatum'
Maclura pomifera	osage-orange	'White Shield','Witchita'
*Magnolia acuminata**	cucumbertree magnolia	(numerous exist)
*Magnolia macrophylla**	bigleaf magnolia	
Metasequoia glyptostroboides	dawn redwood	'Emerald Feathers'

Large Trees: Greater than 45 Feet in Height at Maturity (Continued)

Scientific Name	Common Name	Cultivar
Nyssa sylvatica	black tupelo	
Platanus × acerifolia	London planetree	'Yarwood'
*Platanus occidentalis**	American sycamore	
Quercus alba	white oak	
Quercus bicolor	swamp white oak	
Quercus coccinea	scarlet oak	
Quercus ellipsoidalis	northern pin oak	
Quercus frainetto	Hungarian oak	
Quercus imbricaria	shingle oak	
Quercus lyrata	overcup oak	
Quercus macrocarpa	bur oak	
Quercus montana	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus phellos	willow oak	
Quercus robur	English oak	Heritage®
Quercus rubra	northern red oak	'Splendens'
Quercus shumardii	Shumard oak	
Quercus texana	Texas oak	
*Sassafras albidum**	Sassafras	
Styphnolobium japonicum	Japanese pagodatree	'Regent'
Taxodium distichum	common baldcypress	'Shawnee Brave'
Tilia americana	American linden	'Redmond'
Tilia cordata	littleleaf linden	'Greenspire'
Tilia tomentosa	silver linden	'Sterling'
Ulmus parvifolia	Chinese elm	Allée®
Zelkova serrata	Japanese zelkova	'Green Vase'

Note: * denotes species **not** recommended for use as street trees.

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Aesculus × carnea	red horsechestnut	
Carpinus betulus	European hornbeam	'Franz Fontaine'
Cladrastis kentukea	American yellowwood	'Rosea'
Eucommia ulmoides	hardy rubbertree	
Koelreuteria paniculata	goldenraintree	
Ostrya virginiana	eastern hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Phellodendron amurense	amur corktree	'Macho'
Prunus maackii	amur chokecherry	'Amber Beauty'
Prunus sargentii	Sargent cherry	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
Sorbus alnifolia	Korean mountainash	'Redbird'

Note: * denotes species **not** recommended for use as street trees.

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer buergerianum	trident maple	Streetwise®
Acer campestre	hedge maple	Queen Elizabeth™
Acer cappadocicum	coliseum maple	'Aureum'
Acer ginnala	amur maple	Red Rhapsody™
Acer griseum	paperbark maple	
*Acer pensylvanicum**	striped maple	
Acer truncatum	Shantung maple	
*Aesculus pavia**	red buckeye	
Amelanchier arborea	downy serviceberry	
Amelanchier canadensis	shadblow serviceberry	(numerous exist)
Amelanchier laevis	Allegheny serviceberry	
Carpinus caroliniana	American hornbeam	
Cercis canadensis	eastern redbud	'Forest Pansy'
Chionanthus virginicus	white fringetree	
Cornus alternifolia	pagoda dogwood	
Cornus kousa	Kousa dogwood	(numerous exist)
*Cornus mas**	corneliancherry dogwood	'Spring Sun'
Corylus avellana	European filbert	'Contorta'
*Cotinus coggygria**	common smoketree	'Flame'
*Cotinus obovata**	American smoketree	
Crataegus phaenopyrum	Washington hawthorn	Princeton Sentry™
Crataegus viridis	green hawthorn	'Winter King'
Euonymus atropurpureus	eastern wahoo	
*Franklinia alatamaha**	Franklinia	

Small Trees: 15 to 30 Feet in Height at Maturity (Continued)

Scientific Name	Common Name	Cultivar
Halesia tetraptera	Carolina silverbell	'Arnold Pink'
*Magnolia × soulangiana**	saucer magnolia	'Alexandrina'
*Magnolia stellata**	star magnolia	'Centennial'
*Magnolia tripetala**	umbrella magnolia	
*Magnolia virginiana**	sweetbay magnolia	Moonglow®
Malus spp.	flowering crabapple	(disease resistant only)
Oxydendrum arboreum	sourwood	'Mt. Charm'
Prunus americana	American plum	
Prunus subhirtella	Higan cherry	pendula
Prunus virginiana	common chokecherry	'Schubert'
*Rhus aromatic**	fragrant sumac	
*Rhus glabra**	smooth sumac	
*Rhus typhina**	staghorn sumac	
*Staphylea trifolia**	American bladdernut	
Styrax japonicus	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'

Note: * denotes species **not** recommended for use as street trees.

CONIFEROUS AND EVERGREEN TREES

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Abies balsamea	balsam fir	
Abies concolor	white fir	'Violacea'
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica	Japanese cryptomeria	'Sekkan-sugi'
Ilex opaca	American holly	
Picea omorika	Serbian spruce	
Picea orientalis	Oriental spruce	
Pinus densiflora	Japanese red pine	
Pinus strobus	eastern white pine	
Pinus sylvestris	Scotch pine	
Psedotsuga menziesii	Douglasfir	
Thuja plicata	western arborvitae	(numerous exist)
Tsuga canadensis	eastern hemlock	

Note: * denotes species **not** recommended for use as street trees.

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Chamaecyparis thyoides	Atlantic whitecedar	(numerous exist)
Juniperus virginiana	eastern redcedar	
Pinus bungeana	lacebark pine	
Pinus flexilis	limber pine	
Thuja occidentalis	eastern arborvitae	(numerous exist)

Note: * denotes species **not** recommended for use as street trees.

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Ilex × attenuata	Foster's holly	
Pinus aristata	bristlecone pine	
Pinus mugo	mugo pine	

Note: * denotes species **not** recommended for use as street trees.

Dirr's *Hardy Trees and Shrubs* (Dirr 2013) and *Manual of Woody Landscape Plants (5th Edition)* (Dirr 1988) were consulted to compile this suggested species list. Cultivar selections are recommendations only and are based on DRG's experience. Tree availability will vary based on availability in the nursery trade.

APPENDIX E
RISK ASSESSMENT/PRIORITY AND PROACTIVE MAINTENANCE

RISK ASSESSMENT

Every tree has an inherent risk of tree failure or defective tree part failure. During the inventory, DRG performed a Level 2 qualitative risk assessment for each tree and assigned a risk rating based on the ANSI A300 (Part 9), and the companion publication *Best Management Practices: Tree Risk Assessment* (ISA 2011). Trees can have multiple failure modes with various risk ratings. One risk rating per tree will be assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. The specified time period for the risk assessment is one year.

- **Likelihood of Failure**—Identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions.
  - Improbable—The tree or branch is not likely to fail during normal weather conditions and may not fail in many severe weather conditions within the specified time period.
  - Possible—Failure could occur but is unlikely during normal weather conditions within the specified time period.
  - Probable—Failure may be expected under normal weather conditions within the specified time period.
  - Imminent---Failure is expected within days or is actively failing.
- **Likelihood of Impacting a Target**—The rate of occupancy of targets within the target zone and any factors that could affect the failed tree as it falls towards the target.
  - Very low—The chance of the failed tree or branch impacting the target is remote.
    - Rarely used sites
    - Examples include rarely used trails or trailheads
    - Instances where target areas provide protection
  - Low—It is not likely that the failed tree or branch will impact the target.
    - Occasional use area fully exposed to tree
    - Frequently used area partially exposed to tree
    - Constant use area that is well protected
  - Medium—The failed tree or branch may or may not impact the target.
    - Frequently used areas that are partially exposed to the tree on one side
    - Constantly occupied area partially protected from the tree

- High—The failed tree or branch will most likely impact the target.
  - Fixed target is fully exposed to the tree or tree part

- **Categorizing Likelihood of Tree Failure Impacting a Target**—The likelihood for failure and the likelihood of impacting a target are combined in the matrix below to determine the likelihood of tree failure impacting a target.

Likelihood of Failure	Likelihood of Impacting Target			
	Very Low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very Likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

- **Consequence of Failure**—The consequences of tree failure are based on the categorization of target and potential harm that may occur. Consequences can vary depending upon size of defect, distance of fall for tree or limb, and any other factors that may protect a target from harm. Target values are subjective and should be assessed from the client's perspective.
  - Negligible—Consequences involve low value damage and do not involve personal injury.
    - Small branch striking a fence
    - Medium-sized branch striking a shrub bed
    - Large tree part striking structure and causing monetary damage
    - Disruption of power to landscape lights
  - Minor—Consequences involve low to moderate property damage, small disruptions to traffic or communication utility, or very minor injury.
    - Small branch striking a house roof from a high height
    - Medium-sized branch striking a deck from a moderate height
    - Large tree part striking a structure, causing moderate monetary damage
    - Short-term disruption of power at service drop to house
    - Temporary disruption of traffic on neighborhood street
  - Significant—Consequences involve property damage of moderate to high value, considerable disruption, or personal injury.
    - Medium-sized part striking a vehicle from a moderate or high height
    - Large tree part striking a structure resulting in high monetary damage
    - Disruption of distribution of primary or secondary voltage power lines, including individual services and street-lighting circuits
    - Disruption of traffic on a secondary street

- Severe—Consequences involve serious potential injury or death, damage to high-value property, or disruption of important activities.
  - Injury to a person that may result in hospitalization
  - Medium-sized part striking an occupied vehicle
  - Large tree part striking an occupied house
  - Serious disruption of high-voltage distribution and transmission power line disruption of arterial traffic or motorways

- **Risk Rating**—The overall risk rating of the tree will be determined based on combining the likelihood of tree failure impacting a target and the consequence of failure in the matrix below.

Likelihood of Failure	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Trees have the potential to fail in more than one way and can affect multiple targets.

Tree risk assessors will identify the tree failure mode having the greatest risk, and report that as the tree risk rating. Generally, trees with the highest qualitative risk ratings should receive corrective treatment first. The following risk ratings will be assigned:

- None—Used for planting and stump sites only.
- Low—The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.
- Moderate—The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.
- High—The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.
- Extreme—The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

Trees with elevated (Extreme or High) risk levels are usually recommended for removal or pruning to eliminate the defects that warranted their risk rating. However, in some situations, risk may be reduced by adding support (cabling or bracing) or by moving the target away from the tree. Davey Resource Group recommends only removal or pruning to alleviate risk. But in special situations, such as a memorial tree or a tree in a historic area, Manchester may decide that cabling, bracing, or moving the target may be the best option for reducing risk.

Determination of acceptable risk ultimately lies with city managers. Since there are inherent risks associated with trees, the location of a tree is an important factor in the determination and acceptability of risk for any given tree. The level of risk associated with a tree increases as the frequency of human occupation increases in the vicinity of the tree. For example, a tree located next to a heavily traveled street will have a higher level of risk than a similar tree in an open field.

PRIORITY MAINTENANCE

Identifying and ranking the maintenance needs of a tree population enables tree work to be assigned priority based on observed risk. Once prioritized, tree work can be systematically addressed to eliminate the greatest risk and liability first (Stamen 2011).

Risk is a graduated scale that measures potential tree-related hazardous conditions. A tree is considered hazardous when its potential risks exceed an acceptable level. Managing trees for risk reduction provides many benefits, including:

- Lower frequency and severity of accidents, damage, and injury
- Less expenditure for claims and legal expenses
- Healthier, long-lived trees
- Fewer tree removals over time
- Lower tree maintenance costs over time

Regularly inspecting trees and establishing tree maintenance cycles generally reduce the risk of failure, as problems can be found and addressed before they escalate.

In this plan, all tree removals and Extreme and High Risk prunes are included in the priority maintenance program.

PROACTIVE MAINTENANCE

Proactive tree maintenance requires that trees are managed and maintained under the responsibility of an individual, department, or agency. Tree work is typically performed during a cycle. Individual tree health and form are routinely addressed during the cycle. When trees are planted, they are planted selectively and with purpose. Ultimately, proactive tree maintenance should reduce crisis situations in the urban forest, as every tree in the inventoried population is regularly visited, assessed, and maintained. DRG recommends proactive tree maintenance that includes pruning cycles, inspections, and planned tree planting.