DAVEY Resource Group

December 2021

STANDARD INVENTORY ANALYSIS AND MANAGEMENT PLAN

Town of Ayer, Massachusetts

Prepared for:

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ACKNOWLEDGMENTS

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

Ayer is grateful for the grant funding it received from the Massachusetts Department of Conservation and Recreation (DCR) in cooperation with U.S. Forest Service through its Urban and Community Forestry Challenge Grant (U&CF Grant) Program. The U&CF Grant Program is designed to encourage communities to create and support sustainable urban forestry programs throughout the United States.

Ayer also recognizes the support of the following people:

Dan Van Schalkwyk, Director of Public Works (DPW)

Mark Wetzel, DPW Project Manager

Robert Pontbriand, Town Manager

Five-year Tree Resource Maintenance Schedule

EXECUTIVE SUMMARY

The Town of Ayer *Standard Inventory Analysis and Management Plan*, written by Davey Resource Group, Inc. "DRG", focuses on quantifying the benefits provided by the inventoried tree resource and addressing its maintenance needs. DRG completed a tree inventory for the Town of Ayer in September–October 2021 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 i-Tree Eco and recommended a prioritized management program for future tree care.

The 2021 inventory included 5,035 trees, stumps, and vacant planting sites, and included 9 public parks/properties as well as many public rights-of-way (ROW) in the Town. Maple, particularly red maple, and oak, particularly black oak, were overabundant in both parks and along streets. Young trees comprised only 30% of the park tree population but 47% of the street tree population. These two factors could lead to significant consequences, especially in parks, in the event of a major forest disturbance such as pest or disease infestation or climate-change driven weather alterations. Invasive pests with the potential to cause the greatest harm to Ayer's urban forest include spotted lanternfly, fall cankerworm, Asian longhorned beetle, *Lymantria dispar*, and oak wilt. However, 84% of the inventoried street trees and 91% of the inventoried park trees were rated in Fair or better condition, indicating the urban forest is currently stable and young trees have the potential to reach maturity if they are well maintained. The functions of Ayer's inventoried tree population provide benefits with an estimated total value of nearly $7,000 annually. The Town's annual tree maintenance budget has been around $30,000, making Ayer's return on investment almost 23% annually. The replacement value of Ayer's inventoried tree population is estimated at over $4.5 million, and its carbon storage capacity is valued at over $281,000. Supporting and funding proactive maintenance of the public tree resource is a sound long-term investment that will reduce tree management costs over time and increase the benefits provided to Town residents.

Since Ayer is working toward growing its tree care program, budgets in the earlier years of the ten-year management plan are lower and increase over time (Figure 1). After the work recommended during the 2021 inventory has been completed, around year 8, budgets are expected to decrease and stabilize as tree management transitions from reactive to proactive maintenance. This also reduces the number of new elevated risk trees over time by preventing trees with initially minor defects from deteriorating further.

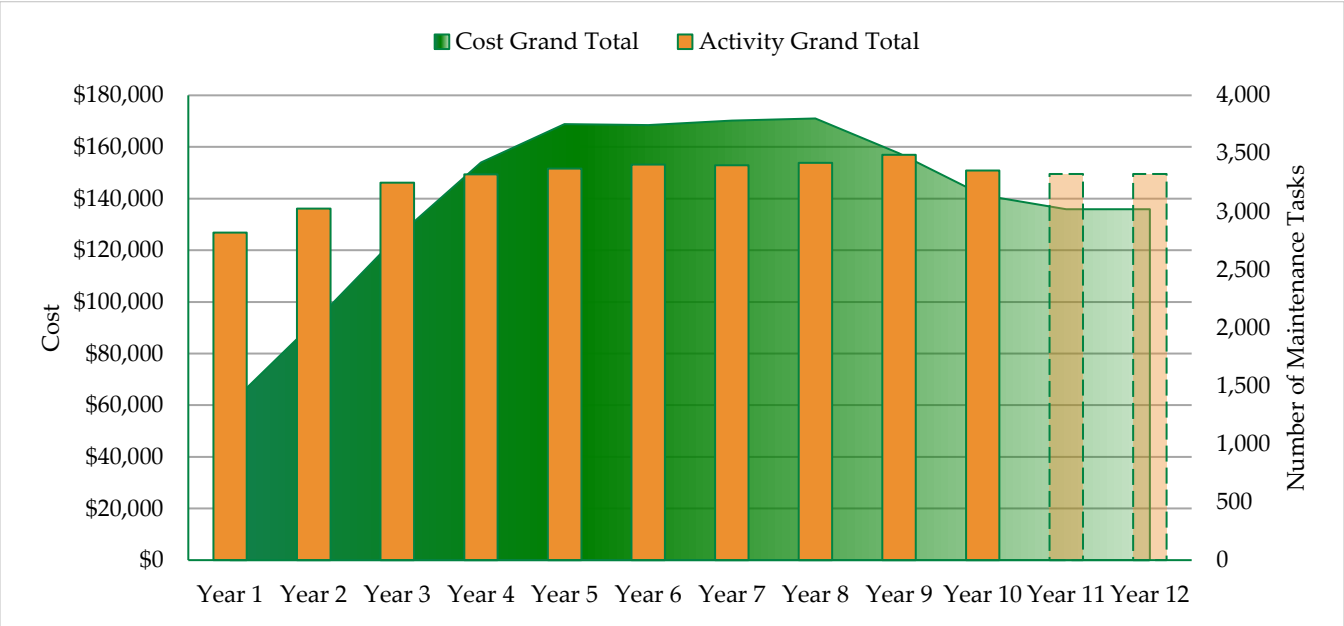


Figure 1. Maintenance tasks and costs for the ten-year management plan.

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 = 352 trees
High Risk = 5 trees
Moderate Risk = 29 trees
Low Risk = 318 trees
Stumps = 227

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 = 46 trees
High Risk = 0 trees
Moderate Risk = 46 trees

Routine Pruning Cycle

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

Total = 1,990 trees
Number in cycle each year = around 250 trees

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 = 581 trees
Number in cycle each year = at least 193 trees

Tree Planting

Planting new trees in areas that have poor canopy continuity is important, as is planting trees where there is sparse canopy, to ensure that tree benefits are distributed evenly across the city.

Total replacement plantings = 765 trees
Total new plantings = 100 trees

Routine Tree Inspection

Routine inspections are essential to uncovering potential problems with trees and should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees.

Total = 2,645 existing trees + 865 new trees
Number in drive-by assessment cycle each year = near 700 trees
Number in walk-by assessment cycle each year = near 350 trees

INTRODUCTION

The Town of Ayer is home to around 8,000 residents (U.S. Census Bureau estimate, 2019) benefitting from public trees in their community. The Town's Department of Public Works (DPW) manages all trees, stumps, and planting sites along the street rights-of-way (ROW) and throughout public parks. Urban forestry program budgets are funded by the Town's Omnibus Budget. Ayer is beginning to plan out a systematic approach to tree care and has taken a crucial first step by conducting this tree inventory. Town arborists will soon be able to set goals and perform proactive maintenance using this *Standard Inventory Analysis and Management Plan*.

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.

In September–October 2021, Ayer 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 of the Public Tree Resource* summarizes the inventory data with trends representing the current state of the tree resource.
- *Section 2: Functions and Benefits of the Public Tree Resource* summarizes the estimated value of benefits provided to the community by public trees' various functions.
- *Section 3: Recommended Management of the Public Tree Resource* details a prioritized management program and provides an estimated budget for recommended maintenance activities over a ten-year period.

Section 1:

Structure and Composition

of the Public Tree Resource

SECTION 1: STRUCTURE AND COMPOSITION OF THE PUBLIC TREE RESOURCE

In September–October 2021, DRG arborists collected site data on trees, stumps, and planting sites along the street ROW and on trees in public parks and other public properties for a tree inventory contracted by the Town of Ayer. The public properties inventoried included the Ayer Dog Park, Ayer Fire Department, Ayer Police Department, Ayer Public Works Department, Ayer Town Hall, Ayer Wastewater Treatment Facility, John A. Martin Jr. Square, Pirone Park, and Woodlawn Cemetery. Of the total 5,035 sites inventoried, 92% were collected along the street ROW and the remaining 8% were collected in parks. Figure 2 breaks down the total sites inventoried by type for each location. Note that planting sites were not collected in parks, and stump collection in parks was limited to just stumps which could cause a tripping hazard for park users. See Appendix A for details about DRG's methodology for collecting site data.

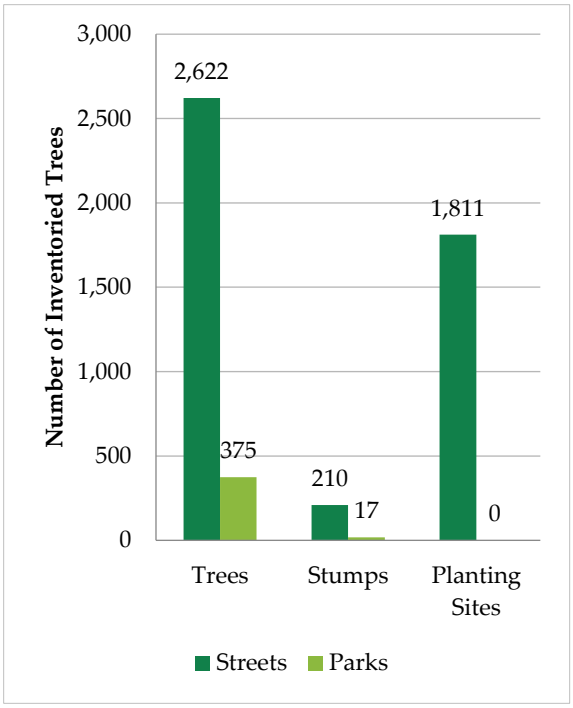
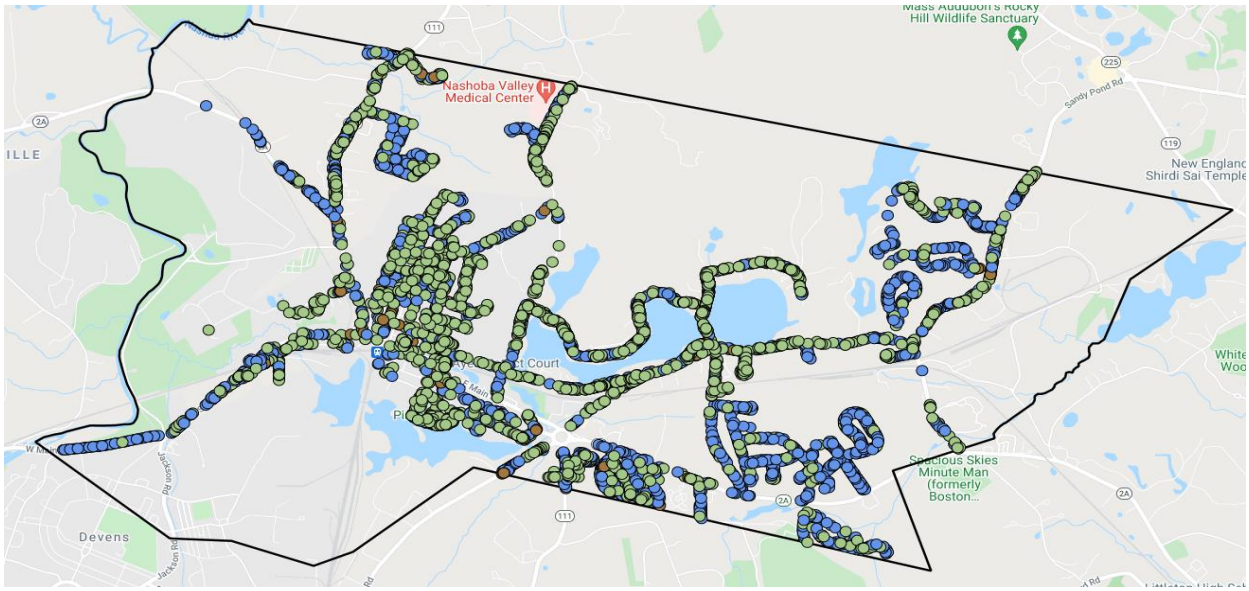


Figure 2. Number of inventoried sites by location and type.

Due to budgetary restrictions, only priority roads and areas of Town were inventoried in 2021. State owned or maintained areas, such as the roundabout in the southern-central region of the Town, were not included in the inventory. Photograph 1 shows the location of all sites collected during the inventory as colored circles, with brown circles representing stump sites, blue circles representing vacant planting sites, and green circles representing tree sites. Due to ongoing road and sidewalk construction, East Main Street was not fully inventoried during the 2021 inventory.



Photograph 1. A screencap from the Ayer TreeKeeper® program showing the locations of all sites collected during the 2021 inventory.

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). This standard was developed partially in response to tragedies such as the demise of vast swaths of American elm (*Ulmus americana*) after the introduction of Dutch elm disease to the United States (see side panel, "Resilience Through Diversity"). It provides a valuable guideline to help protect urban forests from both pests and diseases as well as from the effects of extreme weather events and climate change.

Figures 3a–b show Ayer's distribution of the most abundant tree species inventoried compared to the 10% threshold. Among the inventoried street tree population, three species, including eastern white pine (*Pinus strobus*), red maple (*Acer rubrum*), and Norway maple (*A. platanoides*), meet or exceed the 10% single species threshold (Figure 3a). Red maple also exceed the 10% rule in parks, along with black oak (*Quercus velutina*) (Figure 3b).

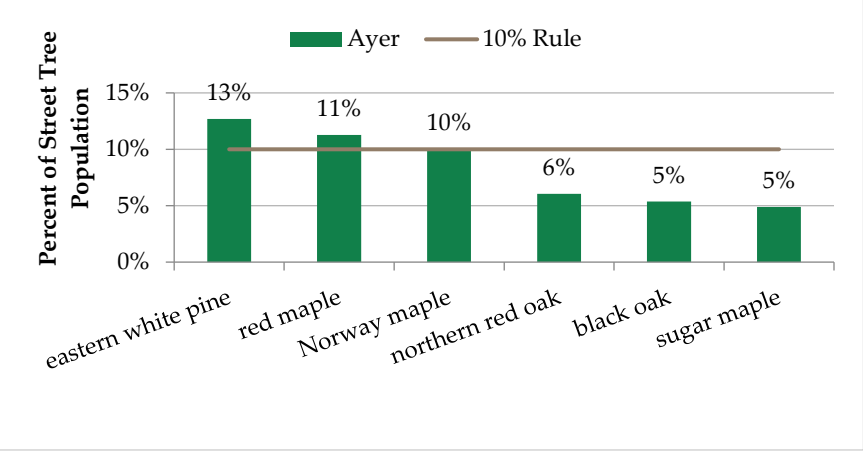


Figure 3a. Species distribution of inventoried street trees.

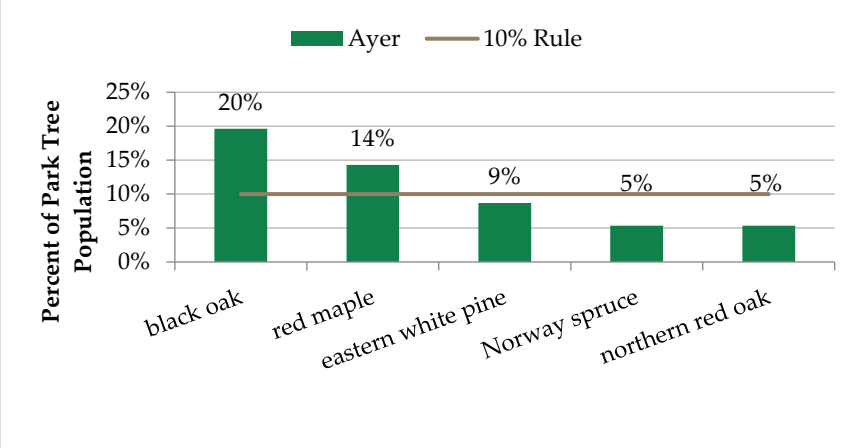


Figure 3b. Species distribution of inventoried park trees.

RESILIENCE THROUGH DIVERSITY

The Dutch elm disease epidemic of the 1930s provides a key historical lesson on the importance of diversity. 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's 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.

U.S. Forest Service (2017)

Figures 4a–b show the Town's distribution of the most abundant tree genera inventoried compared to the 20% single genus rule. Among the street trees, maple (*Acer*) is overabundant, and oak (*Quercus*) is approaching the 20% threshold (Figure 4a). Both genera are also overabundant in the inventoried parks and public properties (Figure 4b).

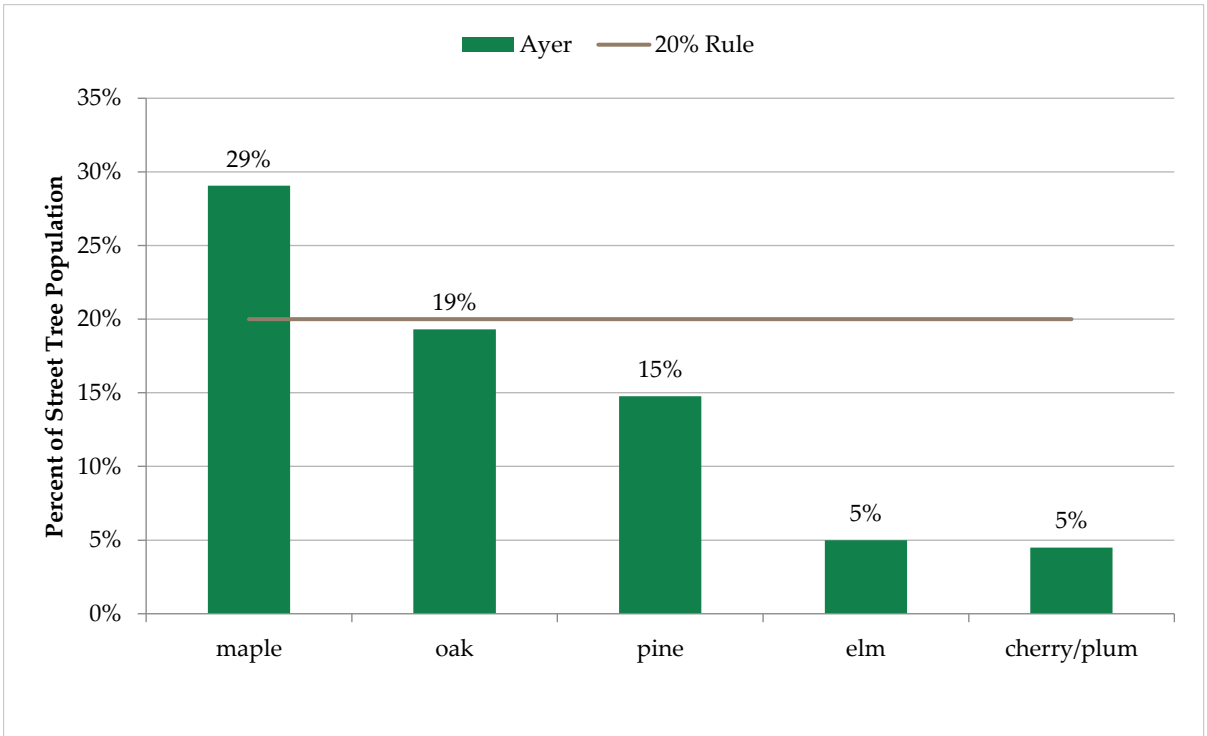


Figure 4a. Genus distribution of inventoried street trees.

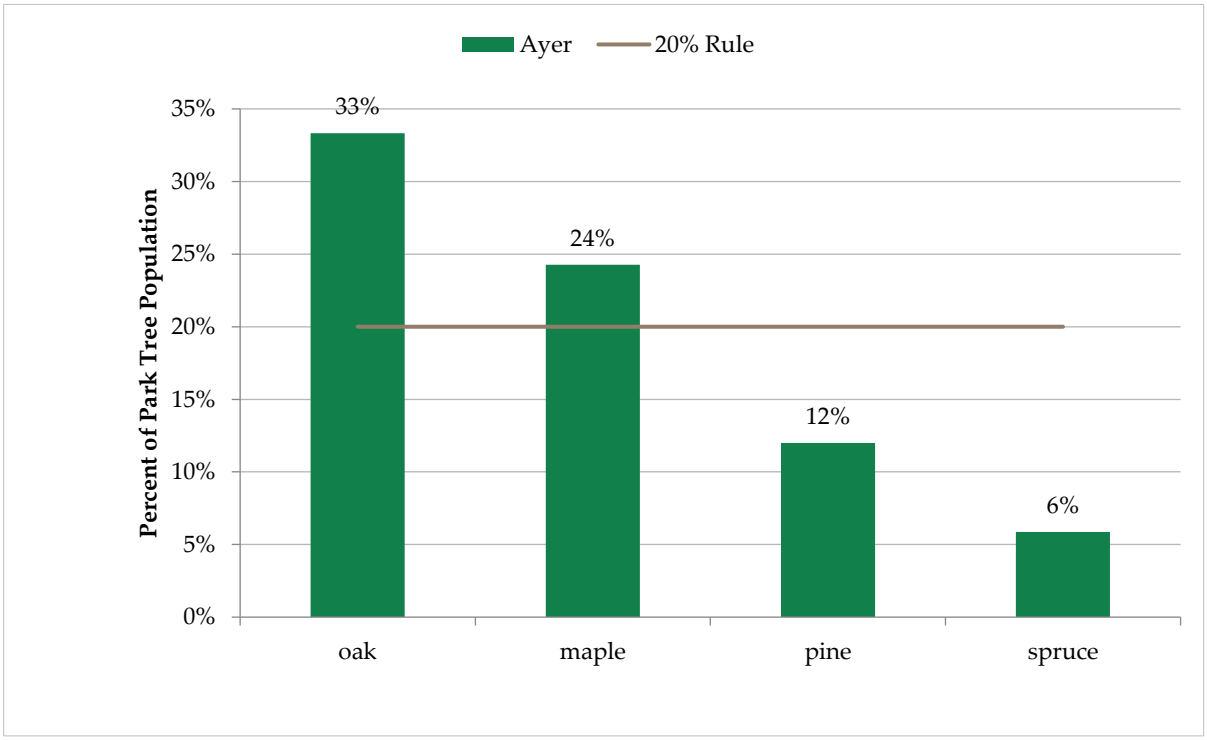


Figure 4b. Genus distribution of inventoried park trees.

Figures 5a-b show the Town's distribution of the most abundant tree families inventoried compared to the 30% threshold. While no single family comprises more than 26% of the inventoried street tree population (Figure 5a), Fagaceae, the family to which oak belong, comprises 34% of the inventoried park tree population, exceeding the 30% single family threshold (Figure 5b).

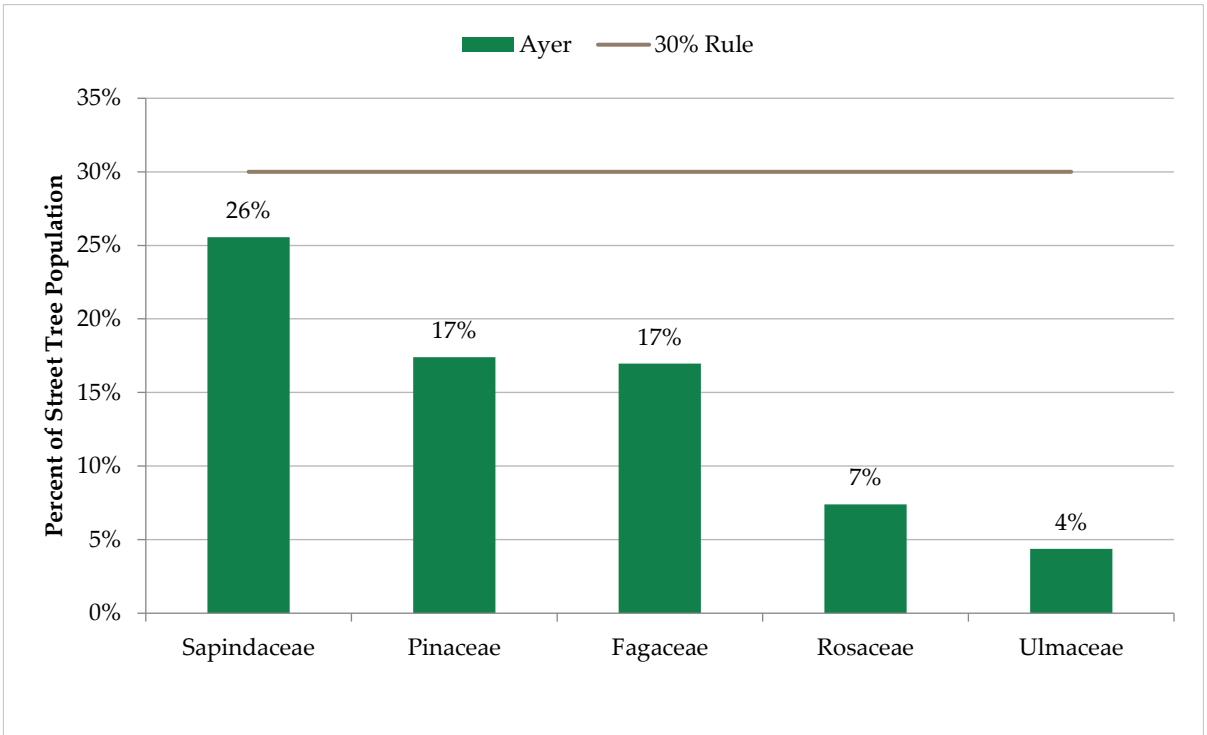


Figure 5a. Family distribution of inventoried street trees.

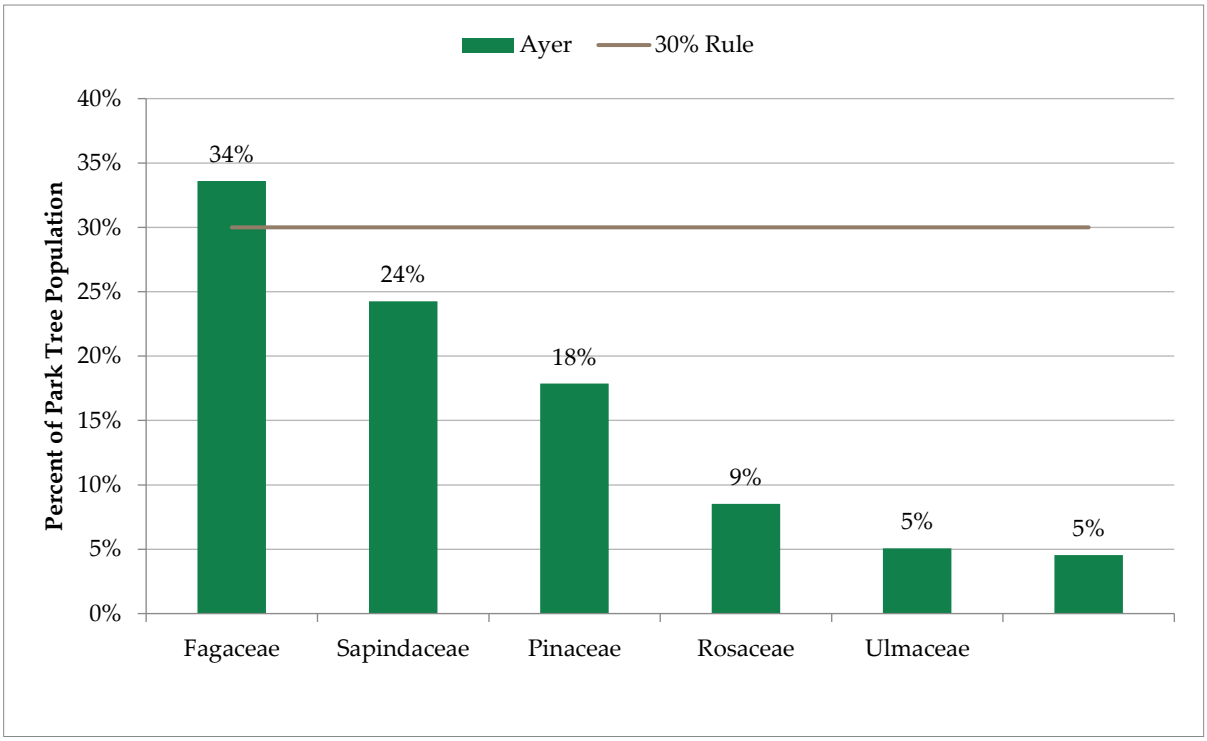


Figure 5b. Family distribution of inventoried park trees.

The species, genus, and family distribution of an urban tree population can be a useful metric for gauging the ability of the urban forest to both resist disruption by pests, diseases, extreme weather, and climate change, as well as the forest's resilience, or ability to recover from these disruptions (Ordóñez & Duinker 2014). For example, certain pests, like emerald ash borer (EAB, *Agrilus planipennis*), target a single genus (ash, *Fraxinus* spp.) as their host, and different species of tree have varying susceptibility to extreme weather events (Hauer et al. 2006, Duryea & Kampf 2007), which will become more common as the climate changes. Some pests also target a single family as their host, such as the bacterium *Erwinia amylovora*, commonly known as fireblight. Fireblight only affects plants in the rose family (*Rosaceae*), such as serviceberry (*Amelanchier* spp.), hawthorn (*Crataegus* spp.), apple/crabapple (*Malus* spp.), cherry/plum (*Prunus* spp.), and pear (*Pyrus* spp.). An urban forest with low species, genera, or family diversity is more likely to be damaged by pest, disease, weather, and climate disruptions due to the presence of large populations of susceptible trees. It is also likely to be less resilient, or less capable of recovering from such disturbances, since large portions of the urban forest may be eliminated or damaged by disturbances. Cultivating diversity on the species, genus, and family levels can help mitigate the effects of disturbances and ensure a thriving urban forest for generations to come.

PEST SUSCEPTIBILITY

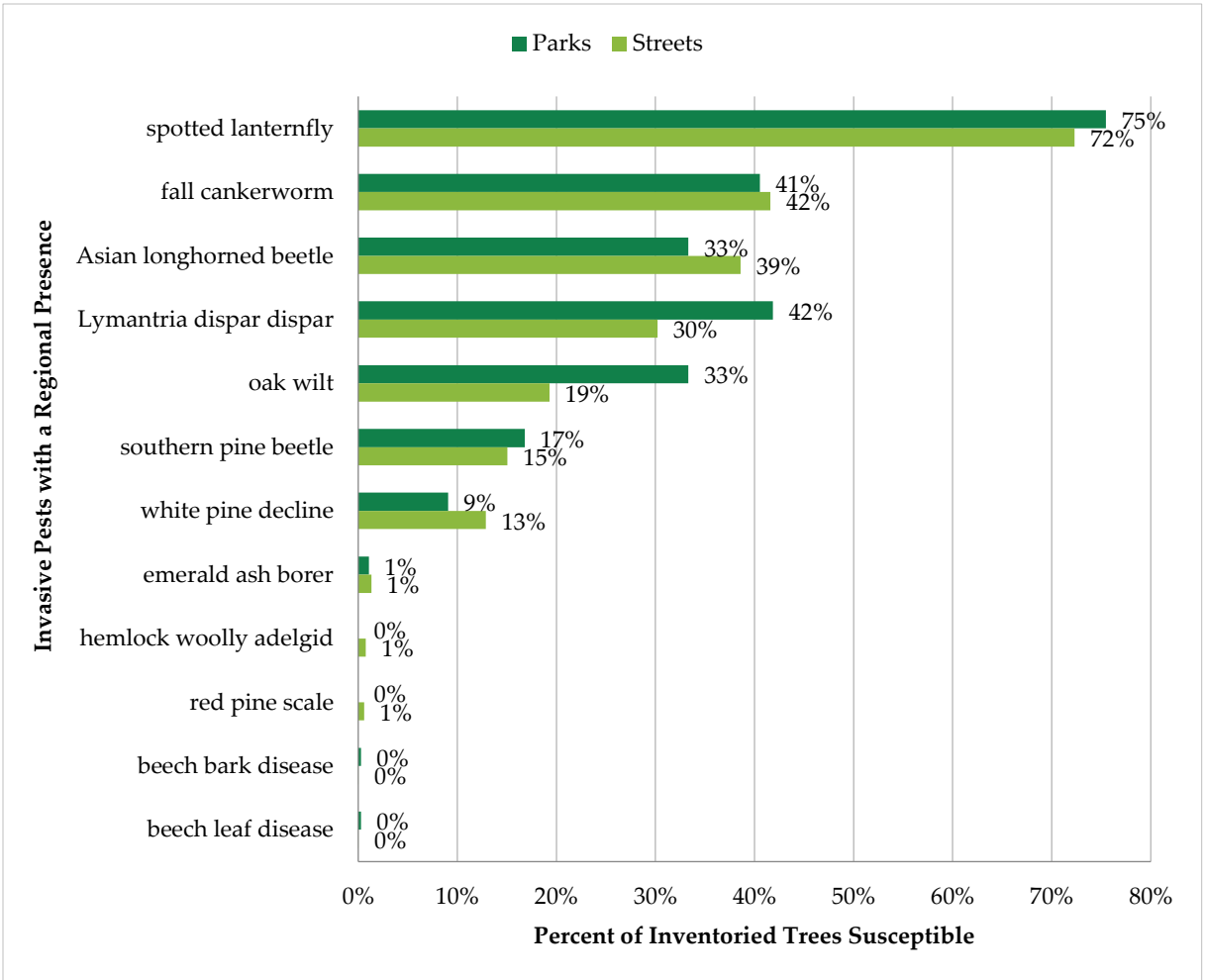


Figure 6. Tree resource susceptibility to invasive pests with a regional presence.

Figure 6 shows the percent of inventoried trees susceptible to some of the known pests and diseases in and around Massachusetts. Spotted lanternfly (SLF, *Lycorma delicatula*), an invasive pest with a wide host range, has the potential to impact more than 70% of both the park and street trees within Ayer. Fall cankerworm (*Alsophila pometaria*), Asian longhorned beetle (ALB, *Anoplophora glabripennis*), *Lymantria dispar* (LDD, formerly called European Gypsy moth), and oak wilt (*Bretziella fagacearum*) all could impact at least 30% of either the park or street trees as well.

It is important to remember that Figure 6 only represents data collected during the 2021 inventory. Many more trees throughout Ayer, including those on private property, may be susceptible to hosting these and other invasive pests and diseases. Therefore, early diagnosis of disease and pest infestation is essential to ensuring the health and continuity of the Town's public tree resource. See Appendix B for further information about the pests listed in Figure 6 and resources where additional information can be found.

Pest Susceptibility Recommendations

Overabundance of individual tree species, genera, and families can reduce an urban forest's resistance and resilience to disruptions caused by insect pests, diseases, extreme weather events, and climate change (Safford et al. 2013). Both parks and streets in Ayer would benefit from increased diversity at the species and genus level, and park trees would also benefit from increased diversity at the family level. Maple, particularly red maple, represent an excessively large proportion of the inventoried street and park tree populations, as do oak, particularly black oak. In more urban areas, diversity among these populations could be increased over time by limiting or avoiding the planting of maple and oak and increasing the overall diversity of new plantings. However, since much of Ayer's urban forest is comprised of volunteer stems of native trees rather than intentional plantings, planting programs are unlikely to significantly shift the species, genus, and family distribution of the Town. Instead, Town trees, particularly those susceptible to SLF, fall cankerworm, ALB, LDD, and oak wilt, should be routinely monitored for signs and symptoms of pests or diseases. Early detection of pests or diseases will allow for expedient management, reducing the overall costs of managing the pest/disease outbreak while minimizing damage to the urban forest.

DEFECT OBSERVATIONS

For each tree inventoried, DRG recorded the most significant defect. Defect observations were limited to the following categories:

- Dead and dying parts
- Broken and/or hanging branches
- Cracks
- Weakly attached branches and codominant stems
- Missing or decayed wood
- Tree architecture
- Root problems
- Other
- None

Table 1. Tree defect categories recorded during the inventory.

Defects	Street Trees	Percent of Street Trees	Park Trees	Percent of Park Trees
dead and dying parts	1,049	40%	233	62%
none	578	22%	46	12%
tree architecture	509	19%	19	5%
missed or decayed wood	201	8%	23	6%
weakly attached branches and codominant limbs	149	6%	26	7%
broken and/or hanging branches	82	3%	22	6%
other	41	2%	5	1%
root problems	8	0%	0	0%
cracks	5	0%	1	0%
Total	**2,622**	**100%**	**375**	**100%**

The most frequently recorded defect among both street and park trees was dead and dying parts (40% street and 62% park trees). The second most common defect was 'none', indicating that the tree had no major defect present at the time of the inventory. Tree architecture was also a common defect chosen for street trees (19% street trees), probably due to utility pruning along roadways.

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 parts' 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, inferences on overall tree condition or risk rating cannot be derived solely from the presence or absence of a defect recorded during the inventory. Second, an inventoried tree may have multiple defects; the 2021 Ayer inventory recorded only the most significant defect present at the time of the inventory.

Defect Observation Recommendations

The fact that dead and dying parts was the most recorded defect during the 2021 inventory indicates that many significant tree defects could be readily solved by either pruning or tree removal. It also indicates that risk associated with tree defects could be significantly reduced through the successful implementation of routine pruning cycles.

Trees recorded with a defect and recommended for priority pruning or removal should be pruned or removed as soon as possible to eliminate the risk associated with a tree with defective parts, or, in the case of trees with pests or diseases present, to reduce the chances of further spread of the pests or diseases. Trees recorded with a defect and recommended for further inspection should be assessed by qualified personnel equipped with suitable tools and knowledge to determine the next steps needed to mitigate risk or salvage the tree. Trees recorded with a defect but not recommended for further monitoring, priority pruning, or removal should be inspected as part of a routine assessment program designed to identify potentially hazardous trees and emerging disease or pest outbreaks. Routine assessments by qualified arborists or other qualified personnel can aid in identifying potentially hazardous tree defects before they become significant dangers to people or property.

CONDITION

Several factors affecting condition were considered for each tree, including root characteristics, branch structure, trunk, canopy, foliage condition, and the presence of pests. The condition of each inventoried tree was rated by an arborist as good, fair, poor, or dead. The general health of the inventoried tree population was characterized by the most prevalent condition assigned during the inventory.

Figure 7 shows that most of the inventoried trees in both parks and along the streets were recorded in fair condition, 66% and 59%, respectively. A further 25% of both park and street trees were rated in good condition. Based on these data, the general health of the inventoried tree population is rated as fair. Ayer has a low percentage of dead trees and trees in poor condition, so the general health of the Town's tree resource is approaching good.

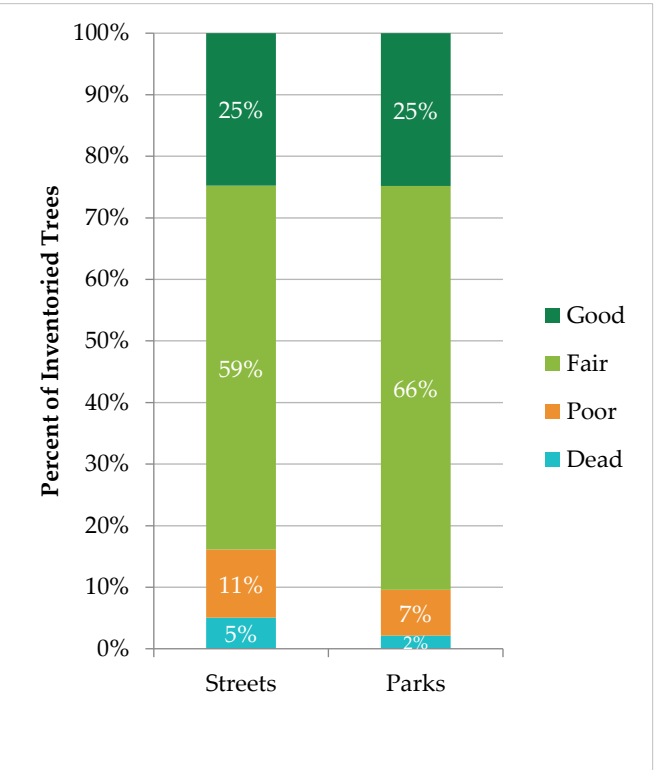


Figure 7. Condition of inventoried trees.

Condition Recommendations

Dead trees and many trees in poor condition should be removed as soon as possible because the health of these trees is unlikely to recover even with increased care, and these trees may present an elevated risk to people or property. Younger trees rated in fair or poor condition may benefit from structural pruning to improve their health over time. Pruning should follow *ANSI A300 (Part 1)* guidelines. Poor condition ratings among mature trees were generally due to visible signs of decline and stress, including decay, dead limbs, sparse branching, or poor structure. These trees will likely require corrective pruning and intensive plant health care to improve their vigor and should be monitored for worsening conditions. Trees in fair condition may benefit from pruning to remove dead or defective limbs and may return to good or better condition with time and care.

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. Size is used as a proxy for age because of the difficulty of accurately and rapidly measuring tree age in the field. Since tree species have different lifespans and mature at different diameters, actual tree age cannot be determined from diameter size class alone, but size classifications can be extrapolated into relative age classes which can offer insight into the maintenance needs of Ayer's tree resource. The inventoried trees were 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 holds 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).

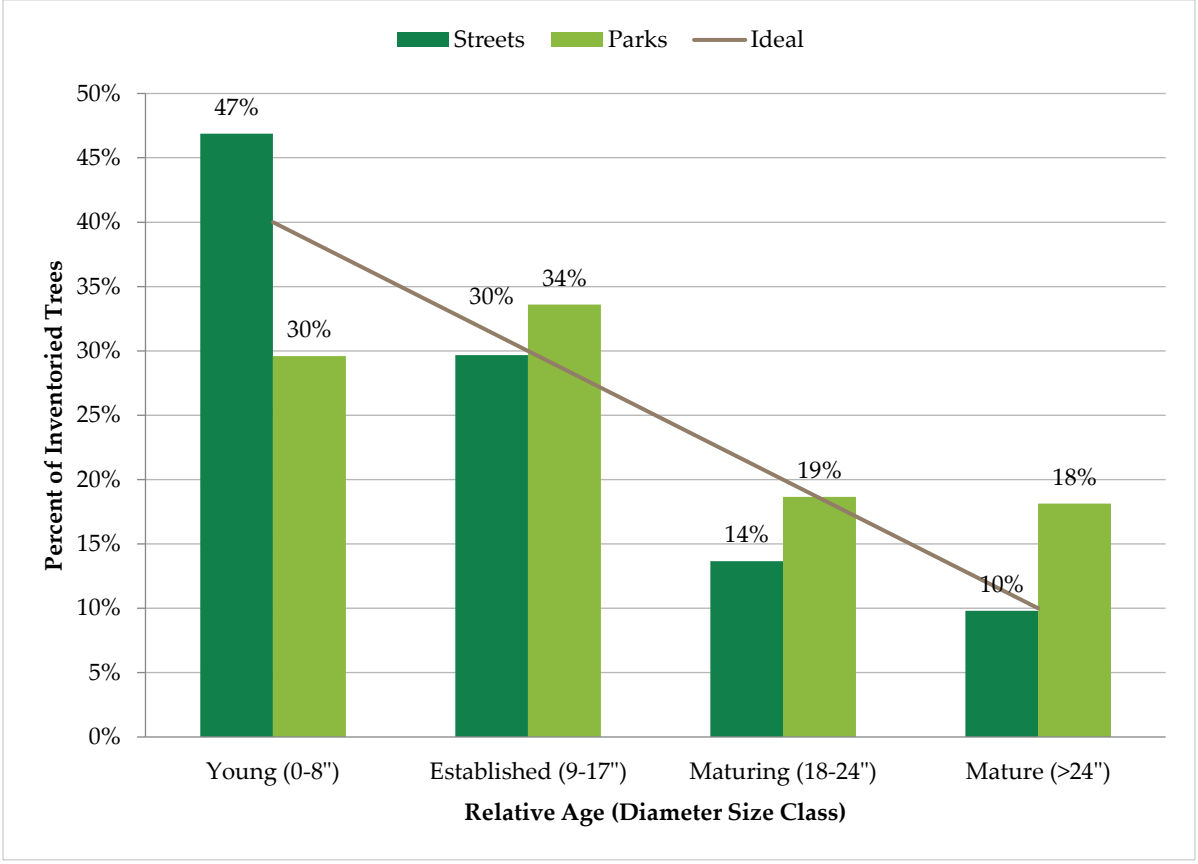


Figure 8. Relative age distribution of inventoried trees.

Figure 8 compares Ayer's relative age distribution of the inventoried tree population to the ideal. The Town's inventoried tree resource overall trends toward the ideal, particularly among the street tree population, which has only a slight overabundance of young trees (47%) and a slight underabundance of maturing trees (14%). The age distribution of the park tree population deviates more greatly from the ideal, with an underabundance of young trees (30%) and an overabundance of established and mature trees.

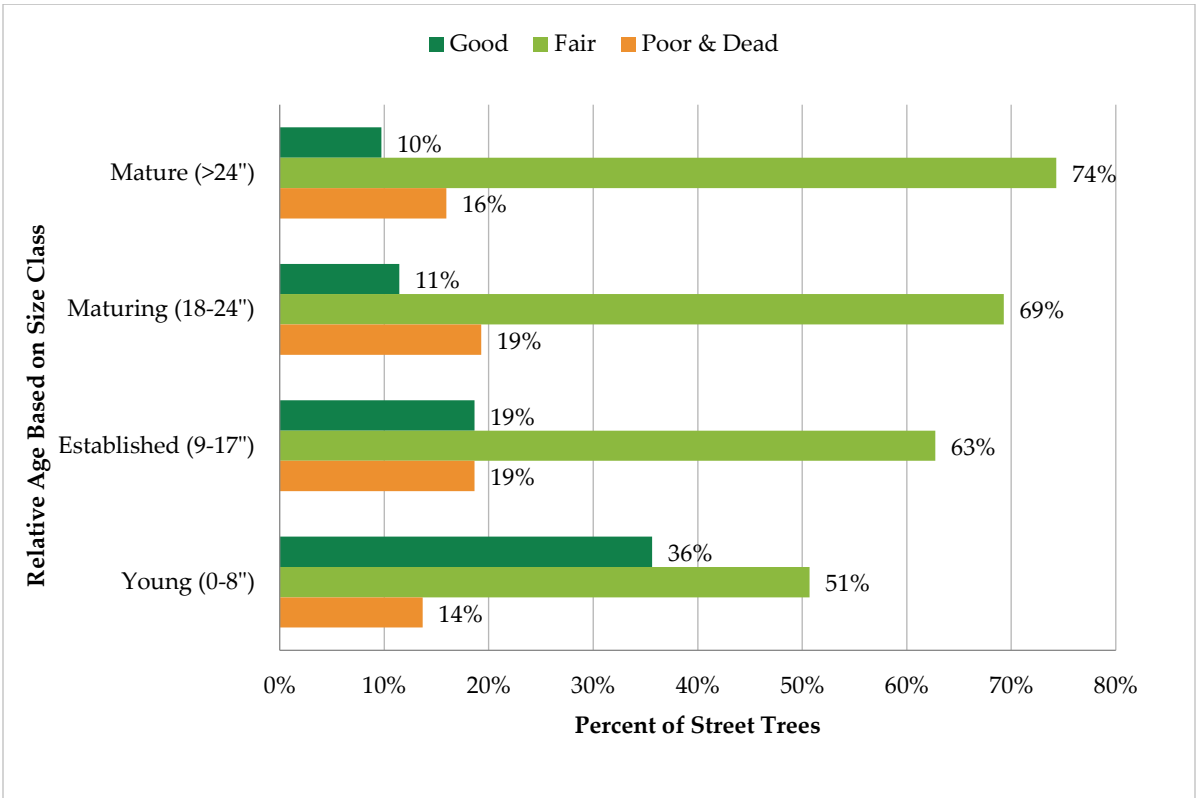


Figure 9a. Condition of inventoried street trees by relative age class.

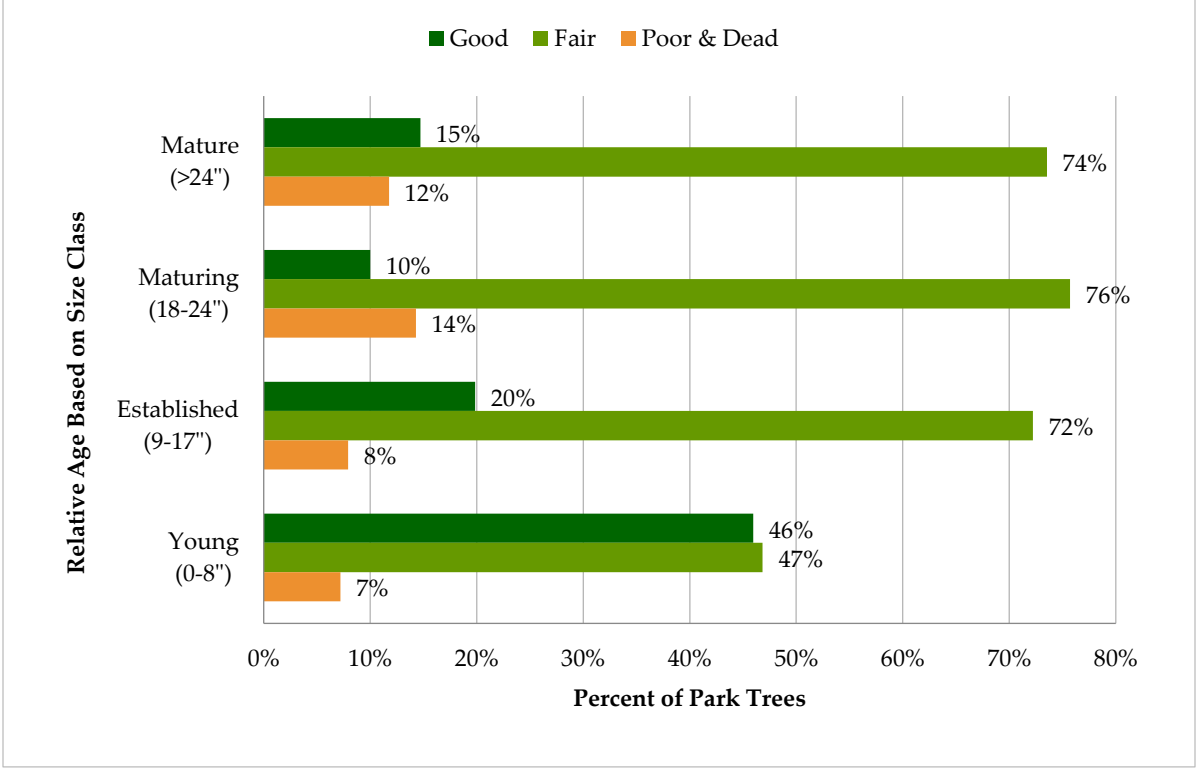


Figure 9b. Condition of inventoried park trees by relative age class.

Figures 9a–b cross analyze the condition of the inventoried tree resource with its relative age distribution, providing insight into the inventoried population's stability. Among the street and park tree populations, trees across all age categories were predominantly in Fair condition and young trees were more likely to be in Good condition than other age categories.

Relative Age Recommendations

Ayer has a shortage of young park trees, indicating that increased planting of young trees within parks and on public properties is necessary to ensure canopy continuity as mature and maturing trees age out of the useful urban tree population and are removed. The overall Fair or better condition rating of all age categories among both the street and park tree populations indicate that young trees have a good chance of reaching maturity if they are well maintained. Ideally, annual tree plantings should, at minimum, compensate for annual tree removals. Planting additional new trees beyond this benchmark should help shift the age distribution of Ayer's trees toward the ideal 40-30-20-10% age distribution over time. In addition, the Town should implement a robust proactive maintenance program to conserve the condition of young and established trees as they age and to protect mature and maturing trees from succumbing to treatable defects.

INFRASTRUCTURE CONFLICTS

In an urban setting, growing space for trees is limited both above and below ground. Trees in restricted growing spaces may conflict with infrastructure, such as buildings, sidewalks, utility wires, and pipes, which can pose risks to public safety and require significant investments of time and money to mitigate. Existing or possible conflicts between trees and infrastructure recorded during the 2021 inventory include:

- *Overhead Utilities*: Conflicts with or the presence of overhead utilities were recorded for all sites. All overhead utilities, including primary and secondary electrical lines, telecommunication lines, drops for homes and businesses, and fire alarm wires were considered for this field. Selections for this field included 'not present', indicating no overhead utilities over the site; 'present and not conflicting', indicating the presence of overhead utilities but no conflict with the site; or 'present and conflicting', indicating that overhead utilities were present and a tree was either touching them or would likely touch them within a year.
- *Hardscape Damage*: Damage to hardscape features such as sidewalks, curbs, and paved roads were noted. The minimum displacement of a hardscape feature required for it to count as damage was 1".
- *Clearance Required*: This field indicated whether a tree needed raising or reducing to provide clearance for non-utility line features or objects such as vehicles, pedestrians, or buildings.

Table 2. Tree conflicts with overhead infrastructure, hardscape, and required clearances recorded during the inventory.

Conflict	Street Trees	Percent of Street Trees	Park Trees	Percent of Park Trees
Overhead Utilities				
Present and Conflicting	321	12%	12	3%
Present and Not Conflicting	677	26%	20	5%
Not Present	1,624	62%	343	91%
Hardscape Damage				
Yes	19	1%	0	0%
No	2,603	99%	375	100%
Clearance Required				
Yes	675	26%	48	13%
No	1,947	74%	327	87%

Table 2 shows that most inventoried street and park trees in Ayer (62% and 91%, respectively) were not located near overhead utility lines. Another 26% of street trees and 5% of park trees were located near utility lines but were not conflicting with them, and only 12% of street trees and 3% of park trees were conflicting with overhead utility lines at the time of the inventory. Very few street trees (19, 1% of the inventoried street trees) and no park trees were causing hardscape damage, likely due to the relative scarcity of hardscape features throughout much of the Town and the abundant root space provided for most trees. About 26% of the street trees and 13% of the park trees required pruning to provide clearance for pedestrians, buildings, or vehicles.

Infrastructure Recommendations

Trees which contact overhead utilities may cause power outages and damage overhead lines, poles, transformers, and other overhead infrastructure. Mitigating these potential problems requires frequent utility pruning, which, in addition to requiring specially trained and certified arborists and specialized equipment, tends to reduce the aesthetic and functional value of trees located under or near overhead utilities. To reduce conflicts with overhead utilities, Ayer should consider the mature size of any future plantings located under or near overhead lines. The Town should endeavor to plant only small-stature trees within 20 feet of overhead utilities, medium-stature trees within 20–40 feet, and large-stature trees outside 40 feet. All plantings should be located at least 15 feet away from utility poles. This 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. This is particularly important in areas such as Ayer's downtown, where street trees provide necessary shade and improve the aesthetic qualities of the main street, but where below-ground root space is significantly constricted by hardscape features. If large stature trees are desired in these areas, planting sites should be expanded to allow sufficient space for the mature tree's root system.

Trees which require clearance pruning should be limbed up or reduced to provide at least 14 feet of clearance over roads, 8 feet of clearance over sidewalks, and 6 feet of clearance over and around buildings. This will improve traffic flow and safety, provide easier access to walking paths through the Town, and reduce damage to roofs and buildings.

STOCKING LEVEL

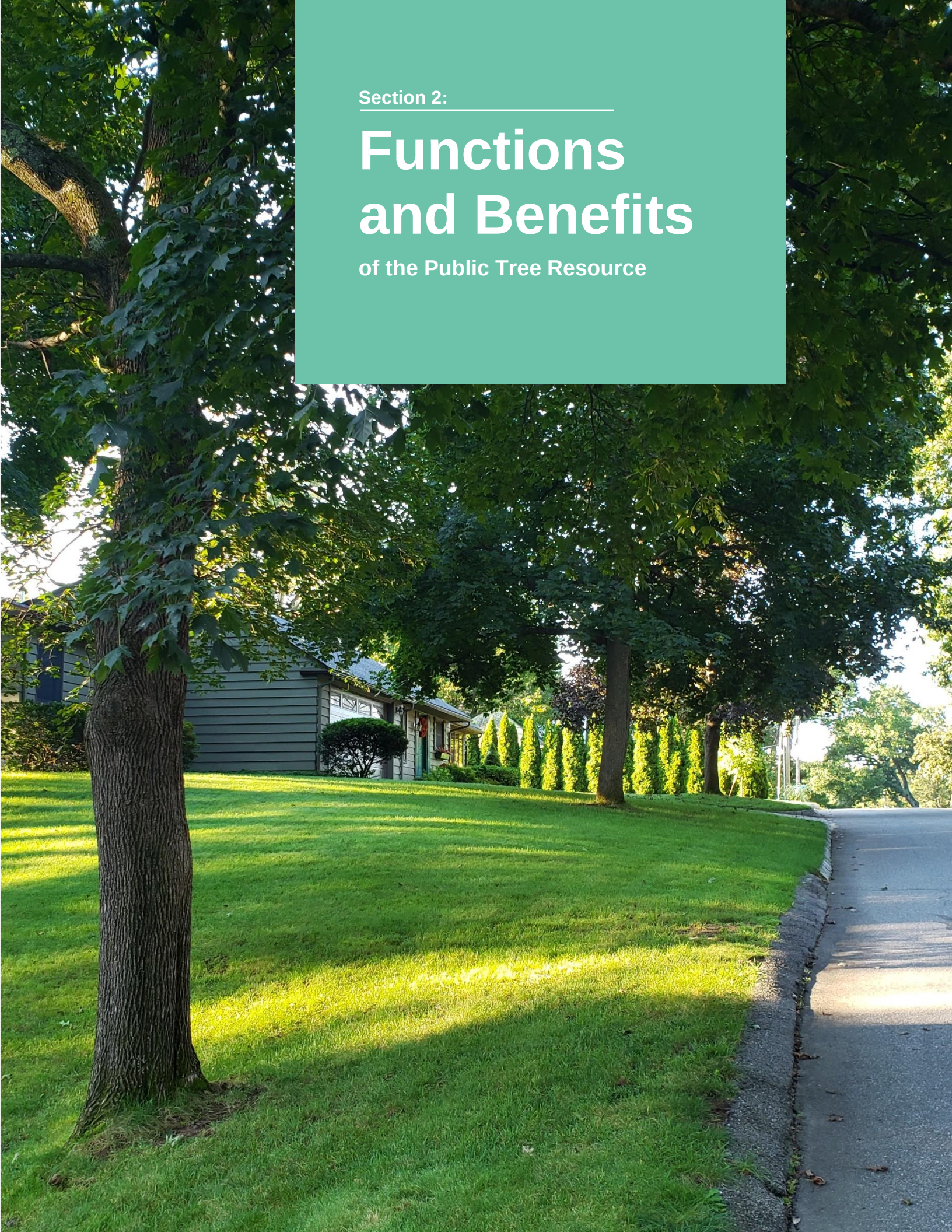
Stocking is a traditional forestry term used to measure the density and distribution of trees. For an urban/community forest, stocking level is used to estimate the total number of sites along the street ROW that could contain trees. Stocking level is the ratio of street ROW spaces occupied by trees to the total street ROW spaces suitable for trees. Park trees and other non-ROW public property trees are excluded from this measurement.

DRG found that the inventoried portions of Ayer contained 1,811 planting sites and 210 stumps, which can be considered potential planting sites because they will become vacant after stumps are removed. Based on the data collected during this inventory, the current street ROW tree stocking level for Ayer is 56%, meaning that only 56% of the available planting locations along the street ROW are occupied by a tree. However, this number may be somewhat deceptive, since there are many fully wooded areas in Ayer, and in such areas, only the largest trees or those which presented a hazard were collected, thus underrepresenting the total number of trees located within the street ROW.

Stocking Level Recommendations

At the current stocking level of 56%, the Town would need to plant an additional 2,021 trees to be fully stocked (stocking level of 100%), assuming Ayer's tree resource experiences zero loss, which is unlikely. Over the course of the ten-year program, a total of 327 existing street trees are recommended for removal. Additionally, the tree resource is susceptible to various threats, including storms, invasive pests, and disease. Typical annual mortality rates range from 1–3% of the population. Given the inventoried population's overall condition rating of Fair, Ayer's tree resource is likely to be on the lower end of the given annual mortality range. Using a 1% annual mortality rate of 30 trees per year, the Town can anticipate removing an additional 300 trees over a ten-year period. When accounting for recommended removals and annual mortality, Ayer would need to plant 2,648 trees over the course of ten years to have a fully stocked tree resource.

Fully stocking the ROW is an ambitious goal that may not be feasible or desirable for the Town. However, strategically increasing the number of street tree plantings in neighborhoods with low canopy cover may be an achievable goal which will help distribute the benefits trees provide more evenly over the Town, beautify currently barren areas, and raise the overall stocking level of the Town over time.



Section 2:

Functions and Benefits

of the Public Tree Resource

SECTION 2: FUNCTIONS AND BENEFITS OF THE PUBLIC TREE RESOURCE

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 outcomes, reduce stormwater runoff, sequester and store carbon, reduce energy use, and increase property value. A better understanding of the importance of trees to a community can be gained by using advanced analytics such as i-Tree Eco and other models in the i-Tree software suite which provide tools to estimate the monetary value of the various benefits provided by a public tree resource.

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).
- When surrounded by trees, physical signs of personal stress, such as muscle tension and pulse rate, were measurably reduced within three to four minutes (Ulrich 1991).

I-TREE ECO ANALYSIS

i-Tree Eco utilizes tree inventory data along with local air pollution and meteorological data to quantify the functional benefits of a community's tree resource. By framing trees and their benefits in a way that everyone can understand, dollars saved per year, i-Tree Eco helps a community to understand trees as both a natural resource and an economic investment. Knowledge of the composition, functions, and monetary value of trees helps to inform planning and management decisions, assists in understanding the impact of those decisions on human health and environmental quality, and aids communities in advocating for the necessary funding to manage their vested interest in the public tree resource appropriately.

ANNUAL RETURN ON INVESTMENT FROM THE PUBLIC TREE RESOURCE

The i-Tree Eco analysis of the Town of Ayer's inventoried trees quantified the functional benefits of three critical ecosystem services that they provide: air pollution removal, carbon sequestration, and avoided surface runoff. The Town's current annual tree maintenance budget is around $30,000, making Ayer's return on investment almost 23% annually.

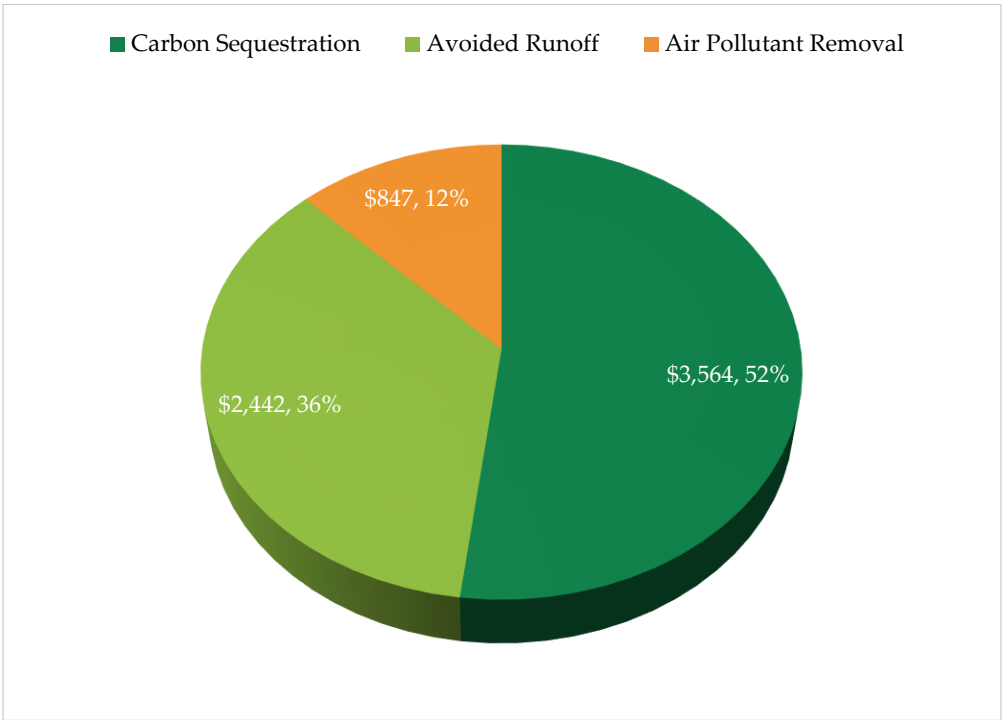


Figure 10. Estimated value of the benefits provided by inventoried trees.

Urban environments have unique challenges that make the estimated $6,853 of annual functional benefits provided by Ayer's inventoried tree population an essential asset to the Town (Figure 10). Compared to rural landscapes, urban landscapes are characterized by high pollutant emissions in a relatively small area. The inventoried trees in Ayer remove around 920 lbs. of airborne pollutants each year, a service that is valued at $847. Reducing stormwater runoff decreases the risk of flooding and combined sewer overflow, both of which impact people, property, and the environment. The Town's inventoried trees help to divert 273,320 gals. of runoff annually, a service valued at $2,442. Carbon dioxide ($CO_2$) also impacts people, property, and the environment as the primary greenhouse gas driving climate change. The inventoried trees sequester around 21 tons (42,000 lbs.) of carbon derived from airborne CO_2 every year; a service valued at $3,564.

The replacement value, or cost of replacing existing trees with trees of similar size, species, and condition, of the Town's inventoried tree population is estimated to be $4,687,489. In Ayer, six species account for about 51% of the inventoried tree resource and between 57% and 64% of the functional benefits it provides (see Table 3). If any of these species were lost to invasive pests, disease, or other threats, the loss would have significant costs. It is therefore critical to routinely inspect Town trees for signs of emergent disease, insect, or other problems and take steps to prevent wide-spread loss of valuable tree species. Promoting species diversity with future plantings will also help to increase the inventoried tree resource's resistance to and resilience after disturbances. Planting large-statured broadleaf tree species wherever possible will help to maximize potential environmental and economic benefits. See Appendix C for a tree species planting list recommended by DRG.

SEQUESTERING AND STORING CARBON

Trees are carbon sinks - the opposite of carbon sources. While carbon is emitted from cars and smokestacks, it is absorbed into trees during photosynthesis and stored in their tissues as they grow. The i-Tree Eco model estimates both the carbon sequestered each year and total carbon stored by the inventoried tree resource. Ayer's inventoried trees have stored 1,659 tons (3,298,000 lbs.) of carbon, which is all the carbon each tree has amassed throughout their lifetimes and is valued at $281,241. The populations of black oak (*Quercus velutina*) and red oak (*Quercus rubra*) store the most carbon; 260 tons and 206 tons, respectively. On a per-tree basis, the two European beech (*Fagus sylvatica*) in the inventory store the most carbon; 4.4 tons per tree, valued at nearly $750 per tree. When looking at the annual carbon sequestration of Ayer's trees, the populations of red maple (*Acer rubrum*) and black oak sequester the most carbon (3.1 tons per year and 2.9 tons per year, respectively). On a per-tree basis, eastern cottonwood (*Populus deltoides*) and Crimson King Norway maple (*Acer platanoides* 'Crimson King') sequester the most carbon annually (37 lbs. per tree per year and 33 lbs. per tree per year, respectively), a service valued at around $3 per tree per year.

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

Most Common Trees Inventoried		Count	Percent of Total	Benefits Provided by Street Trees				
				CO_2 Stored	CO_2 Sequestered	Avoided Runoff	Air Pollution Removed	Replacement Value
Common Name	Botanical Name		%	tons	tons/year	gal/year	lbs/year	Dollars
eastern white pine	*Pinus strobus*	372	12.5%	152.8	2.1	43,195	140	$813,538
red maple	*Acer rubrum*	356	12.0%	181.1	3.1	26,987	100	$470,170
Norway maple	*Acer platanoides*	237	8.0%	132.7	1.9	15,650	60	$320,546
black oak	*Quercus velutina*	220	7.4%	260.2	2.9	27,376	100	$453,159
northern red oak	*Quercus rubra*	182	6.1%	205.7	2.1	29,935	100	$591,666
sugar maple	*Acer saccharum*	147	5.0%	115.6	0.9	13,907	40	$283,255
scarlet oak	*Quercus coccinea*	122	4.1%	99.8	1.7	17,120	60	$286,856
American elm	*Ulmus americana*	115	3.9%	23.6	0.4	4,732	20	$65,668
apple species	*Malus*	83	2.8%	7.2	0.1	982	0	$27,004
white oak	*Quercus alba*	83	2.8%	124.3	0.9	18,064	60	$328,641
northern white cedar	*Thuja occidentalis*	71	2.4%	6.8	0.1	1,138	0	$31,346
black cherry	*Prunus serotina*	58	2.0%	14.2	0.3	1,955	0	$31,854
Norway spruce	*Picea abies*	53	1.8%	36.0	0.3	12,146	40	$154,147
cherry species	*Prunus*	45	1.5%	10.1	0.2	2,194	0	$25,424
northern catalpa	*Catalpa speciosa*	43	1.4%	10.1	0.2	3,452	20	$48,456
All Other Trees Inventoried		782	26.3%	269	3.7	54,486	100	$755,758
Total		**2,969**	**100%**	**1,649**	**20.9**	**273,320**	**920**	**$4,687,489**

CONTROLLING STORMWATER

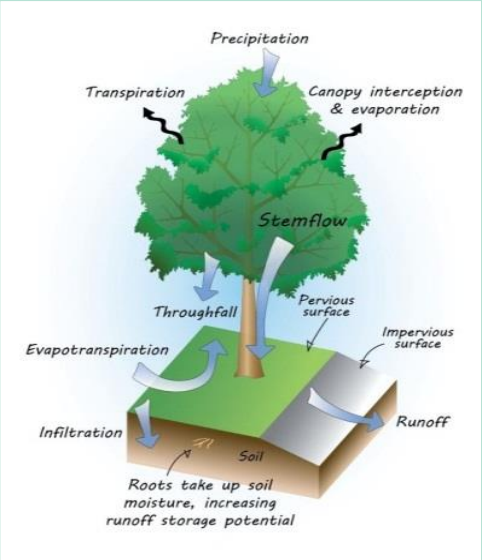
Trees intercept rainfall with their leaves and branches, helping lower stormwater management costs by avoiding runoff. The inventoried trees in the Town of Ayer help divert 273,320 gals. of runoff annually. Avoided runoff accounts for 36% of the annual functional benefits provided by Ayer's public tree resource.

The population of eastern white pine (*Pinus strobus*) diverted the most runoff annually, around 43,195 gals., valued at $2,442. On a per tree basis, the two European beech (*Fagus sylvatica*) again provided the greatest benefits; diverting nearly 490 gals. of runoff annually.

IMPROVING AIR QUALITY

The inventoried tree population annually removes 920 lbs. of air pollutants, including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter ($PM_{2.5}$). The i-Tree Eco model estimated the value of this benefit at $847, which is 12% of the value of all annual benefits. As shown in Figure 11, a small reduction of $PM_{2.5}$ is the most valuable contribution to pollutant removal. The species population that provided the highest annual air quality benefits was eastern white pine (*Pinus strobus*), which removed 140 lbs. of pollutants annually. On a per tree basis, pin oak (*Quercus palustris*) and thornless honeylocust (*Gleditsia triacanthos* v. *inermis*) removed the most pollutants; 1 lb. per tree per year and 0.9 lb. 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.

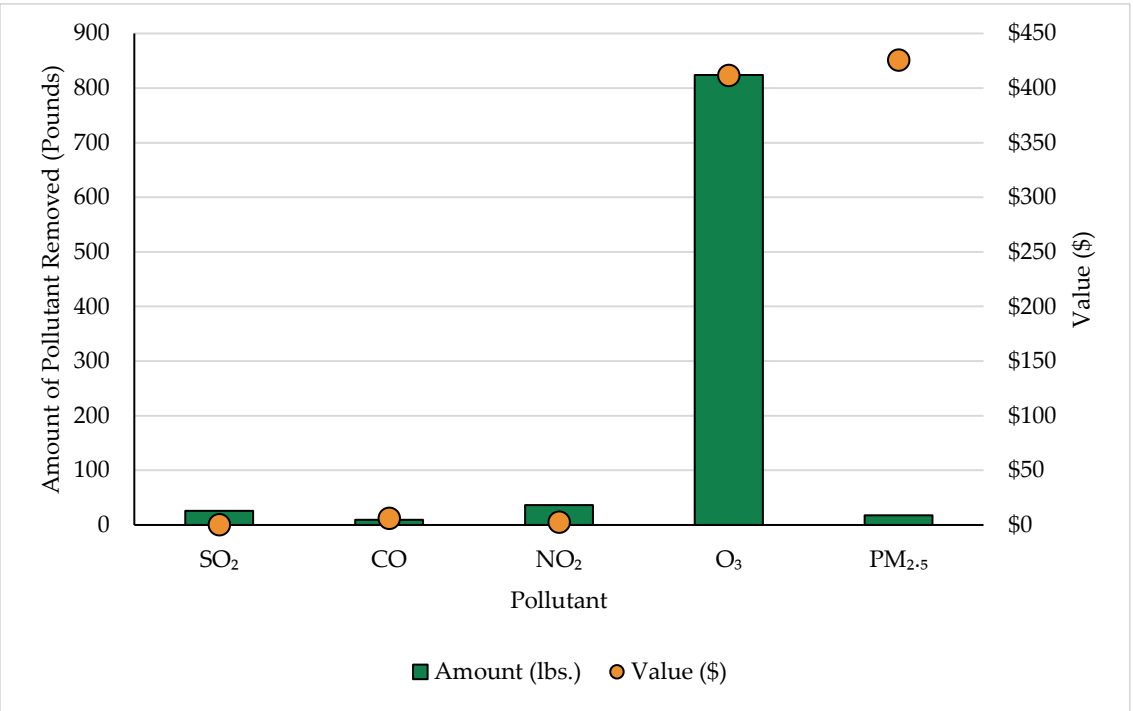


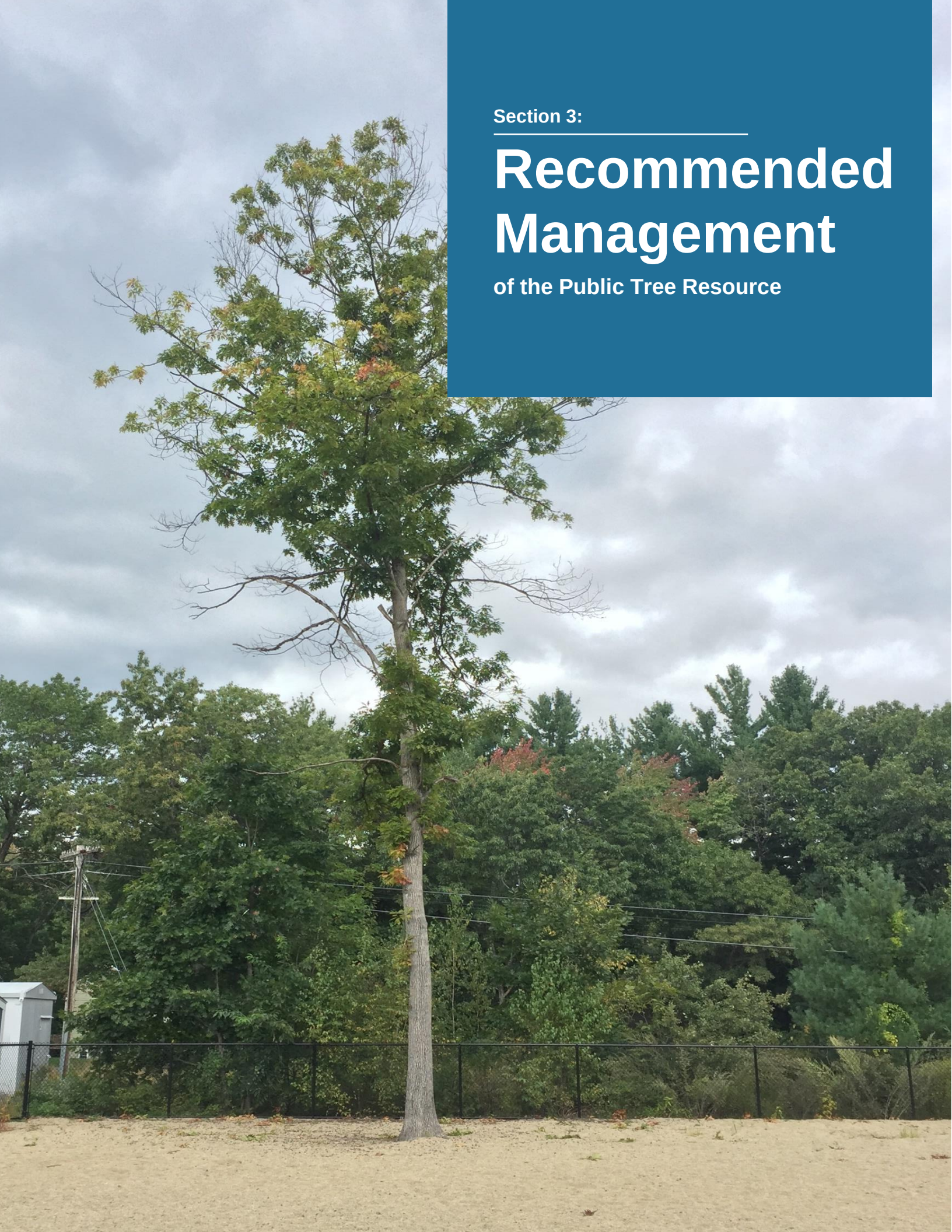
Figure 11. Annual removal of five common air pollutants by Ayer's inventoried trees.

REPLACEMENT VALUE

Replacement value is an estimate of the local cost of replacing an existing tree with a similar tree. It can help provide an estimate of the overall value of a tree population or individual tree. Collectively, Ayer's inventoried tree population has a replacement value of $4,687,489, which averages out to around $1,579 in replacement value per tree. The populations of eastern white pine (*Pinus strobus*) and red oak (*Quercus rubra*) were the most valuable ($813,538 and $591,666, respectively), which is at least partially due to the size of these two tree populations. On a per tree basis, the European beech (*Fagus sylvatica*) were the most valuable inventoried trees in Ayer, with a replacement value of $9,431 per tree.

CONCLUSIONS

Overall, Ayer's populations of black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), and eastern white pine (*Pinus strobus*) provide the largest share of the benefits enjoyed by the Town. This is due, at least in part, to the number of individuals of these species included in the 2021 inventory. Eastern white pine was the most common tree in the inventory (12.5% of the inventoried trees), followed by red maple (12.0%). Black oak (7.4%) and red oak (6.1%) made up smaller proportions of the inventoried population and were the fourth and fifth most common trees in the inventory. Interestingly, Norway maple, which accounted for 8.0% of the inventoried trees and was the third most common tree in the inventory, did not provide a proportional share of benefits. Ayer should make sure to check these high-value tree populations frequently for signs of pests or disease, and when it is necessary to remove individuals of these species, replace them with other large-stature, broadleaf trees, because large-stature, broadleaf trees tend to provide the most functional benefits to a community.



Section 3:

Recommended Management

of the Public Tree Resource

SECTION 3: RECOMMENDED MANAGEMENT OF THE PUBLIC TREE RESOURCE

During the inventory, both a risk rating and a recommended maintenance activity were assigned to each tree. DRG recommends prioritizing and completing each tree's recommended maintenance activity based on the assigned risk rating. This ten-year tree management program takes a multi-faceted and proactive approach to tree resource management.

RISK MANAGEMENT AND RECOMMENDED MAINTENANCE

Every tree, regardless of condition, has an inherent risk of whole or partial tree failure. During the inventory, DRG performed a Level 2 qualitative risk assessment for each tree and assigned a risk rating based on ANSI A300 (*Part 9*) and the companion publication *Best Management Practices: Tree Risk Assessment* (ISA 2011). Trees can have multiple potential modes of failure, each with its own risk rating. The potential mode of failure with the highest risk rating was recorded for each tree during the 2021 tree inventory. The specified time frame for the risk assessment was one year. See Appendix D for further information on the risk assessment and rating system.

DRG recommends that tree maintenance activities are prioritized and completed based on the risk rating that was assigned to each tree during the inventory. Trees with extreme or high risk ratings should be attended to first, followed by trees with a moderate risk rating, and trees with a low risk rating should be maintained once higher risk trees have been pruned or removed. The following sections describe the recommended maintenance activities for each risk rating category.

RECOMMENDED PRIORITY MAINTENANCE

Pruning or removing trees with an elevated level of risk (i.e., extreme, high, or moderate risk ratings) 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 these trees are addressed, recommended tree maintenance activities should be completed for smaller diameter trees that pose the greatest risk. Addressing elevated 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.

Priority Pruning Recommendations

Elevated risk trees recommended for pruning should be pruned immediately based on the assigned risk rating, which 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 the defective parts can correct the problem, risk associated with the tree is reduced while promoting healthy growth.

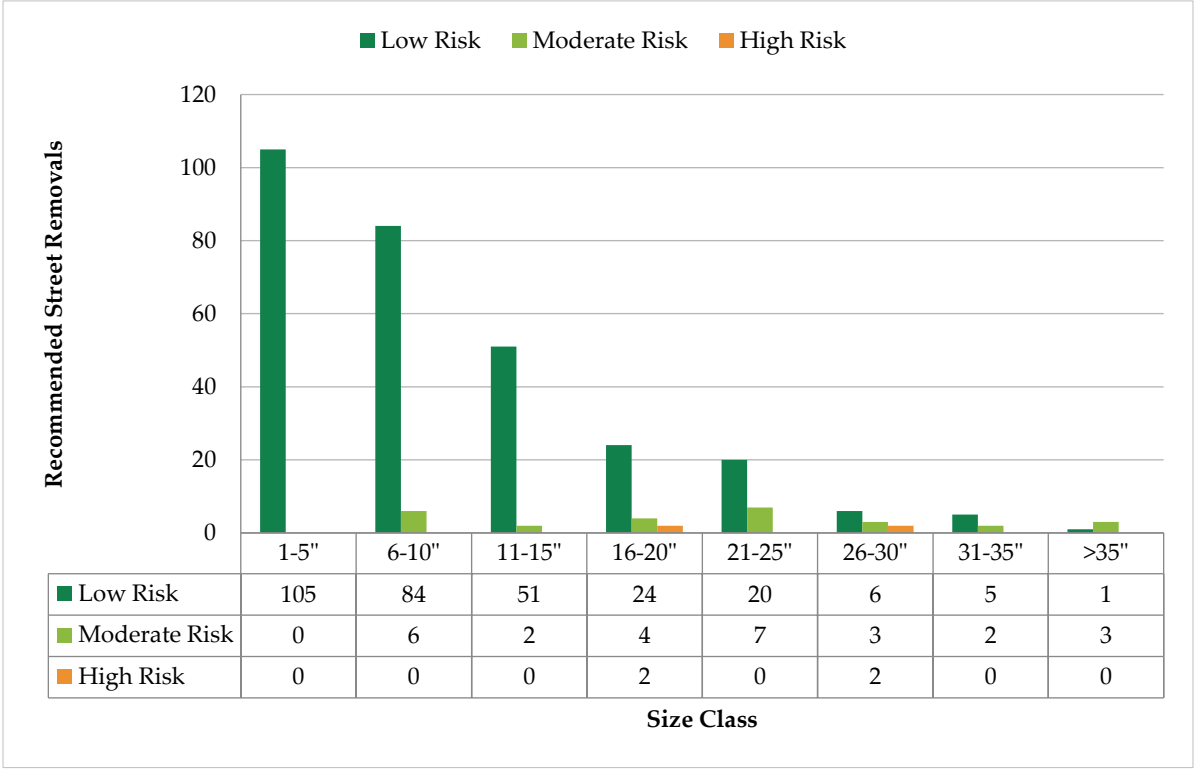
The inventory identified 37 moderate risk trees in the street ROW (Figure 12a) and a further 9 moderate risk trees in parks and on public properties (Figure 12b) which were recommended for pruning. No trees in either the ROW or parks which were recommended for pruning had a high or extreme risk rating. The diameter size classes for trees with recommended priority pruning ranged between 14 and 45 inches DBH. These trees should be pruned as soon as possible to reduce risk but may be a lower priority than completing higher risk tree removals.

Figure 12. Trees recommended for priority pruning. All trees recommended for priority pruning had a moderate risk rating.

Priority Removal Recommendations

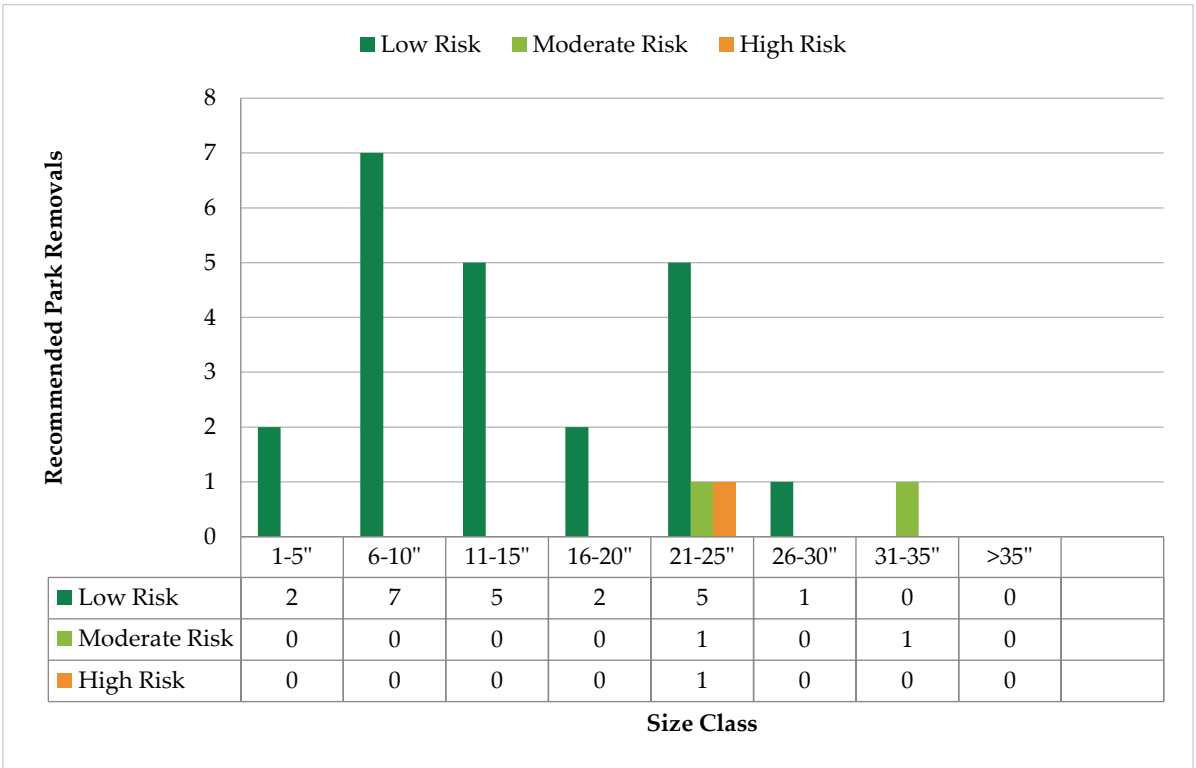
Trees with elevated risk ratings recommended for removal should be removed immediately. DRG recommends that trees be removed when pruning will not correct their defects, eliminate the risks that their defects cause, or when corrective pruning would be cost-prohibitive. These trees should be removed immediately and prioritized based on their risk rating and size class.

DRG identified 4 street trees and 1 park tree with a high risk rating recommended for removal. A further 27 street trees and 2 park trees with moderate risk ratings were recommended for removal. No trees in Ayer were assessed as presenting an extreme risk during the 2021 inventory. The diameter size classes for priority removal trees ranged between 6 and 49 inches DBH.



	1-5"	6-10"	11-15"	16-20"	21-25"	26-30"	31-35"	>35"
Low Risk	105	84	51	24	20	6	5	1
Moderate Risk	0	6	2	4	7	3	2	3
High Risk	0	0	0	2	0	2	0	0

Figure 13a. Street trees recommended for priority removal.



	1-5"	6-10"	11-15"	16-20"	21-25"	26-30"	31-35"	>35"	
Low Risk	2	7	5	2	5	1	0	0	
Moderate Risk	0	0	0	0	1	0	1	0	
High Risk	0	0	0	0	1	0	0	0	

Figure 13b. Park trees recommended for priority removal.

Low risk tree removals pose little threat; these trees are generally small, dead, invasive, or poorly formed trees that need to be 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. Low risk trees should be removed when convenient after all higher risk pruning and removals have been completed and may be performed concurrently with routine pruning. Due to the significant costs involved in mitigating moderate and high risk trees, low priority removals were included in years four through nine of the ten-year management plan (Table 4), after all high and moderate risk trees have been removed or pruned.

FURTHER INSPECTION

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 a risk to people, property, or other trees. Further inspections are beyond the scope of a standard tree inventory and can be one of the following:

a) Annual Inspection (e.g., a tree which has a defect that may require further monitoring to determine whether it is a hazard).

b) Recent Damage Inspection (e.g., a healthy tree that has been impacted by recent construction, weather, or other damage).

c) Advanced Risk Assessment (e.g., a tree with a defect requiring additional or specialized equipment for a Level 3 investigation).

d) Insect/Disease Monitoring (e.g., a tree that appears to have an emerging insect or disease problem).

e) No further inspection required.

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

a. **Level 1:** Level 1 inspection is defined as a limited visual assessment, which is often conducted as a walk-through or windshield survey designed to identify obvious defects or specified conditions.

b. **Level 2:** Level 2 inspection is defined as a basic assessment and is a detailed, 360-degree visual inspection of a tree and its surrounding site, and a synthesis of the information collected. All trees in the 2021 Ayer tree inventory were assessed to this level, provided that 360-degree access around the tree could be gained.

c. **Level 3:** Level 3 inspection is an advanced assessment and is performed to provide detailed information about specific tree parts, defects, targets, or site conditions. A Level 3 inspection may use specialized tools or require the input of an expert.

Further Inspection Recommendations

DRG arborists found 68 trees recommended for annual inspection, 2 trees recommended for a recent damage inspection, 17 trees recommended for a Level 3 assessment, and 25 recommended for insect and disease monitoring. The trees recommended for a Level 3 risk assessment should be assessed by a TRAQ arborist as soon as possible to determine whether these trees require removal, pruning, or other corrective action to reduce the risk associated with their observed defects. Level 3 assessments may require specialized or additional equipment, such as bucket trucks, to access and assess tree defects.

Trees recommended for annual inspection should be assessed routinely to monitor their condition and look for signs of worsening defects that may merit intervention. Some of these trees will likely recover given time and will no longer need additional monitoring, while others may require removal if their defects worsen. Trees recommended for recent damage inspections should be assessed to determine if the damage they have sustained is acceptable or if the tree needs to be pruned or removed because of the recent damage. Trees with recent damage may also need to have ongoing monitoring of their condition to determine if they are recovering from the damage or if they require intervention to prevent them from becoming hazardous.

More than half of the trees recommended for insect and disease monitoring were ash (*Fraxinus* spp.) which showed symptoms or signs of emerald ash borer (EAB, *Agrilus planipennis*). All trees recommended for insect/disease monitoring should be assessed to confirm the presence of damaging insects or diseases and should either be removed or treated, if necessary, to reduce the pest species load and improve the health of the public trees in Ayer.

ROUTINE INSPECTIONS

Inspections are essential to uncovering potential problems with trees. They should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees. Arborists are knowledgeable about the needs of trees and are trained and equipped to provide proper care. Ideally, the arborist conducting routine inspections will be ISA Certified and will also hold the ISA Tree Risk Assessment Qualification credential.

Routine Inspection Recommendations

All public trees along the street ROW and in parks should be regularly inspected and attended to as needed. When trees require additional or new work, they should be added to the maintenance schedule. The budget should also be updated to reflect the additional work. Utilize computer management software such as TreeKeeper® to make updates, edits, and keep a log of work records. In addition to locating trees with unidentified defects, inspections also present an opportunity to look for signs and symptoms of pests and diseases. Ayer has a large population of trees that are susceptible to pests and diseases, including ash (*Fraxinus* spp.), maple (*Acer* spp.), and oak (*Quercus* spp.). Routine inspections can also be used to update or add to the 2021 inventory. Keeping the inventory up to date is necessary to ensure that hazardous trees are handled in a timely fashion, to help predict adequate budgets, staff, and equipment for upcoming years, and to track progress toward Ayer's urban forestry goals.

DRG recommends that Ayer perform routine inspections of inventoried trees by windshield survey (inspections performed from a vehicle) in line with *ANSI A300 (Part 9)* annually and after all severe weather events to identify defects with heightened risk, signs of pest activity, and symptoms of disease. When trees need additional maintenance, they should be added to the work schedule immediately. Use asset management software such as TreeKeeper® to update inventory data and schedule work records. Level 2 assessments should be done routinely as well, ideally every 5 years or less, to identify defects and problems that are not readily noticeable during windshield (Level 1) surveys. Routine Level 2 inspections can be done as part of routine pruning, removal, and planting operations, or can be done as part of a contracted re-inventory of the Town.

ROUTINE PRUNING CYCLE

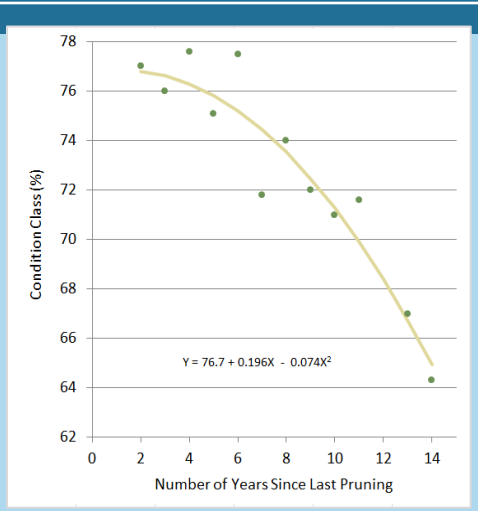
The routine pruning cycle includes all low risk trees that received maintenance recommendation of prune or routine prune. These trees pose some risk but have a smaller defect size and/or a lower probability of impacting a target. Over time, routine pruning can minimize reactive maintenance, limit instances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

Based on Miller and Sylvester's research (see side panel, "Proactive Pruning"), DRG recommends a five-year routine pruning cycle to maintain the condition of the inventoried tree resource. However, it is not always possible to remain proactive with a five-year cycle based on budgetary constraints, the size of the inventoried tree resource, or both. In these cases, extending the length of the routine pruning cycle is an option; however, best practice is to not exceed a 10-year pruning cycle. Tree condition has been shown to deteriorate significantly after 10 years without regular pruning as once-minor defects worsen, reducing tree health and potentially increasing risk (Miller and Sylvester 1981).

Routine Pruning Cycle Recommendations

DRG identified 1,990 trees that should be included in a routine pruning cycle as of the 2021 inventory. Due to budgetary constraints, DRG recommends that the Town establish an eight-year routine pruning cycle with approximately 250 trees pruned each year, starting in year 3 of the management plan. As Ayer's urban forestry program grows, the Town may want to shorten the length of the routine pruning cycle to improve overall tree condition and reduce tree-related risk in the Town.

PROACTIVE PRUNING



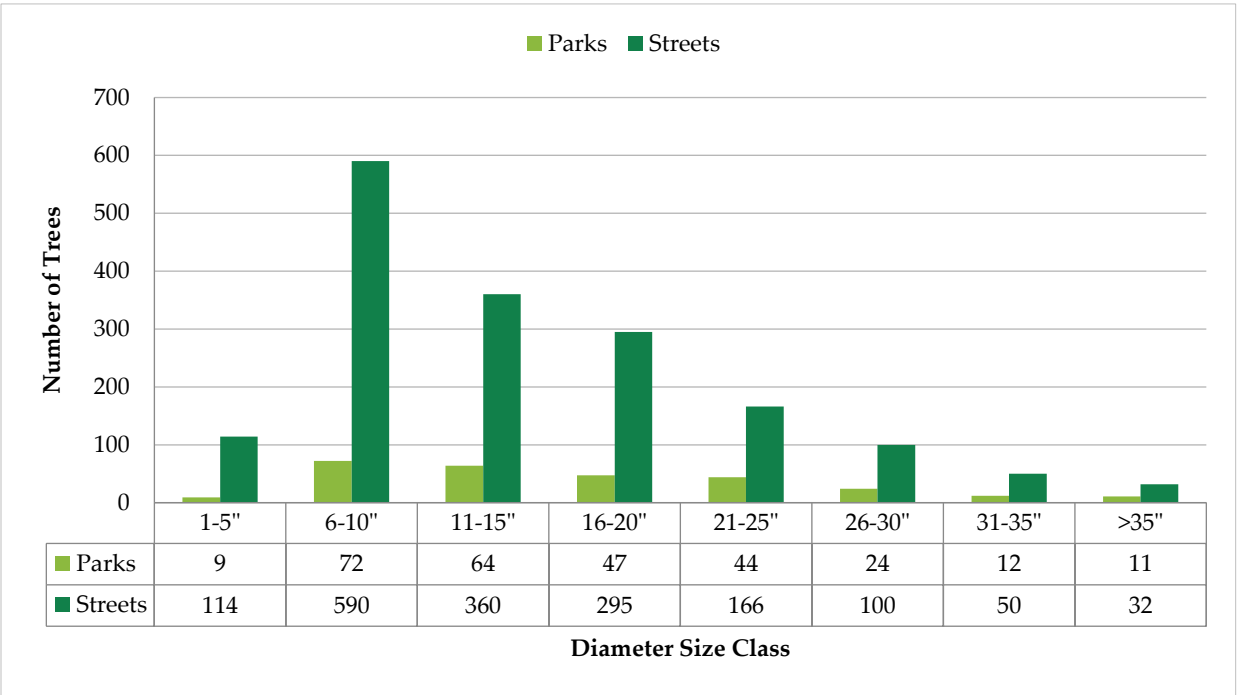
Relationship between tree condition and years since previous pruning.

(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. DRG recommends that pruning cycles begin after all Extreme and High Risk tree maintenance has been 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.



	1-5"	6-10"	11-15"	16-20"	21-25"	26-30"	31-35"	>35"
Parks	9	72	64	47	44	24	12	11
Streets	114	590	360	295	166	100	50	32

Figure 14. Street and park trees recommended for routine pruning.

YOUNG TREE TRAINING CYCLE

Trees included in the young tree training cycle are generally less than 8 inches DBH. These younger trees may 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 these problems are not corrected, 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 includes trees that can be pruned from the ground with a pole pruner or pruning shear.

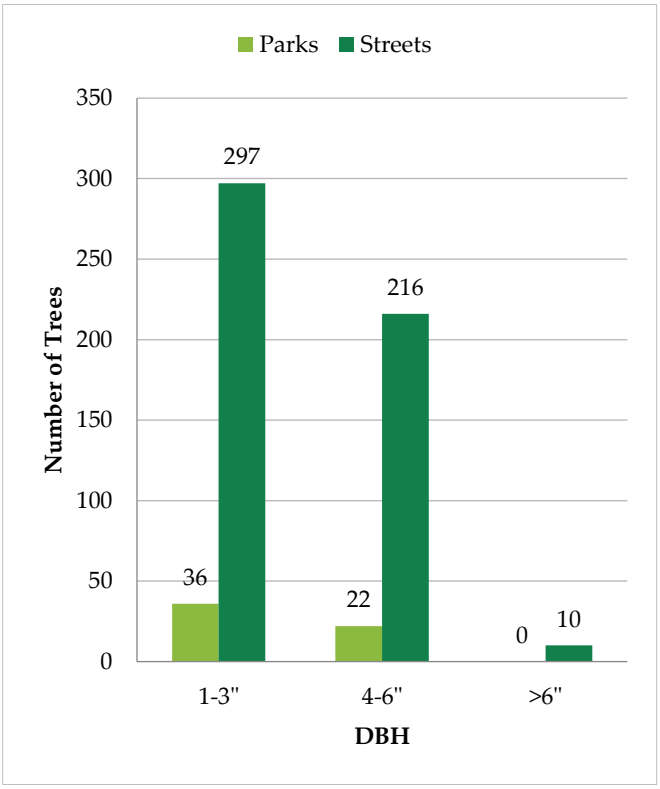


Figure 15. Trees recommended for young tree training cycle by size class.

Young Tree Training Cycle Recommendations

DRG recommends that Ayer implement a three-year young tree training cycle beginning after the completion of all elevated risk recommended maintenance activities. During the inventory, 581 trees inventoried and recommended for young tree training. Since Ayer has so many young trees, the young tree training cycle is vital for the future condition of the inventoried tree population. DRG recommends that an average of 194 trees be trained with structural pruning each year beginning in year two of the management program. Due to the costs involved in mitigating elevated risk trees in year one of the management program, only 75 trees are recommended for young tree training in the first year.

When new trees are planted, they should enter the young tree training cycle after establishment, typically within 2–3 years after planting. In future years, the number of trees in the young tree training cycle will be based 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

Planting new trees in areas where there is sparse canopy, poor canopy continuity, or gaps in existing canopy should be a priority when considering new tree planting. While the Town of Ayer as a whole receives value from the ecosystem services provided by the public tree resource, those benefits are unlikely to be distributed evenly across the Town.

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, make sure 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 shade may be a priority, but it is important to consider how a tree may impact 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

Creating larger growing sites for trees in the municipal ROW can be the single most beneficial management practice to improve the survival rate of planted and developing trees. Increasing planting space can also reduce the amount of tree-related infrastructure conflicts, as the trees will be planted 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 Ayer has sidewalks of a sufficient width and length, the city could install tree pits with enough space remaining for the sidewalk to still comply 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 also be applied to existing large tree sites, 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 spaces can be used quite effectively by municipalities to beautify a streetscape, provide greater storm water retention, along with the added benefit of slowing car speeds at the bump-out location.

The inventory identified 227 stumps recommended for removal, with a wide range of sizes from 3 to 48 inches in diameter. Stump removals should occur when convenient and be included in regular planting plans if the site would be feasible for planting after the stump is removed. For this reason, it is most convenient to remove all stumps in areas with scheduled tree planting work, so all feasible sites in an area are stocked at once. The inventory also identified 1,811 vacant planting sites, including 840 sites suitable for a large tree, 133 sites suitable for a medium-sized tree, and 838 sites suitable for a small tree. Many of these vacant sites were concentrated in newer developments, where either construction was ongoing and thus trees had not yet been installed, or where the development predated current subdevelopment regulations which dictate that the developer must install trees at regular intervals along both sides of the street. These sparsely treed neighborhoods would benefit most from new plantings.

A list of suggested tree species is provided in Appendix C. These tree species are specifically selected for the current climate of Ayer, which lies in USDA Hardiness Zones 5b (minimum temperature of -15 to -10 degrees Fahrenheit) and 6a (minimum temperature of -10 to -5 degrees Fahrenheit). This list is not exhaustive but can be used as a guideline for species that meet community objectives and to enhance any existing list of approved species.

MAINTENANCE SCHEDULE AND BUDGET

Utilizing the 2021 Town of Ayer tree inventory data, an annual maintenance schedule was developed detailing the recommended tasks to complete each year over a ten-year period. DRG made budget projections using industry knowledge and public bid tabulations. A complete table of estimated costs for Ayer's ten-year tree management program follows (Table 4). Since the pricing estimates used in Table 4 were compiled using the estimated pricing of contractor services, they will be higher than the actual cost of doing the recommended maintenance work in-house. As Ayer's urban forest management program grows, it may be more cost-effective to work toward doing most tree care activities in-house. However, at the time of the 2021 inventory, most work on street trees was being contracted out due to staff and equipment limitations.

Following the recommended maintenance schedule outlined in Table 4 can help shift tree maintenance activities from being reactive to a more proactive and cost-effective tree care program over time. Annual budget funds are needed to ensure that elevated risk trees are expediently managed and that the vital young tree training and routine pruning cycles can begin as soon as possible. If routing efficiencies and/or contract specifications allow more tree work to be completed each year than expected, or if this maintenance schedule requires adjustment to meet budgetary or other needs, then it should be modified accordingly. Unforeseen situations such as severe weather events may arise and change the maintenance needs of trees. If maintenance needs change, then budgets, staffing, and equipment should be adjusted to meet the new demand.

This management plan is ambitious and may be a challenge to complete during a ten-year timeframe, especially since Ayer is in the process of growing their urban forestry program. Keep in mind that, although all inventoried trees not recommended for removal or priority pruning are included in the young tree training and routine pruning cycles, not all these trees will need to be pruned every cycle, likely resulting in lower actual costs than those estimated in the following budget table. Even if annual budgets do not allow for all the work recommended in this plan to be completed, the budget suggestions put forth here can still help to guide decisions about how to prioritize maintenance tasks and allocate limited funds to best maintain, preserve, and grow the city's public tree resource. They can also serve as a useful tool when advocating for increased funding for public tree management, both from the city itself and from state government programs.

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

- No less than $60,375 for the first year of implementation.
- No less than $91,906 for the second year.
- No less than $125,412 for the third year.
- No less than $153,976 for the fourth year.
- No less than $168,843 for the fifth year.
- No less than $168,495 for the sixth year.
- No less than $170,192 for the seventh year.
- No less than $171,038 for the eighth year.
- No less than $157,608 for the ninth year.
- No less than $141,380 for the tenth and final year of the maintenance schedule.

Since Ayer is in the process of growing its urban forestry program, the budget is intentionally designed to increase in cost progressively for the first eight years of the management plan, as progress can be demonstrated and additional funding advocated for and secured. Once all priority pruning, tree removals, and stump removals recommended during the 2021 inventory are complete, around year 8, the annual budget is predicted to drop and eventually stabilize around $135,850 per year (see Figure 1). This estimate was made based on the year 10 cost of new and replacement tree plantings, young tree training, routine pruning, and routine inspections. Again, it is important to remember that the actual costs of the routine pruning cycle and young tree training cycle will depend on how many trees need maintenance in any given year – while all trees should be assessed at least once during each cycle, not every tree will need significant maintenance every cycle.

Table 4. Estimated budget for recommended ten-year tree resource management program

Activity Cost			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Ten-Year Cost
Activity	Diameter	Cost/Tree	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	
High Priority Removals	1-5"	$90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	6-10"	$225	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	11-15"	$575	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	16-20"	$1,080	2	$2,160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$2,160
	21-25"	$1,820	1	$1,820	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,820
	26-30"	$2,430	2	$4,860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$4,860
	31-35"	$2,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	>35"	$3,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
Activity Total(s)			**5**	**$8,840**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$8,840**
Moderate Priority Removals	1-5"	$90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	6-10"	$225	-	-	6	$1,350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,350
	11-15"	$575	-	-	2	$1,150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,150
	16-20"	$1,080	-	-	4	$4,320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$4,320
	21-25"	$1,820	-	-	8	$14,560	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$14,560
	26-30"	$2,430	-	-	3	$7,290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$7,290
	31-35"	$2,900	3	$8,700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$8,700
	>35"	$3,900	3	$11,700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$11,700
Activity Total(s)			**6**	**$20,400**	**23**	**$28,670**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$49,070**
Low Priority Removals	1-5"	$90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	107	$9,630	-	-	$9,630
	6-10"	$225	-	-	-	-	-	-	-	-	-	-	20	$4,500	15	$3,375	30	$6,750	26	$5,850	-	-	$20,475
	11-15"	$575	-	-	-	-	-	-	-	-	-	-	10	$5,750	16	$9,200	30	$17,250	-	-	-	-	$32,200
	16-20"	$1,080	-	-	-	-	-	-	-	-	-	-	13	$14,040	13	$14,040	-	-	-	-	-	-	$28,080
	21-25"	$1,820	-	-	-	-	-	-	5	$9,100	15	$27,300	5	$9,100	-	-	-	-	-	-	-	-	$45,500
	26-30"	$2,430	-	-	-	-	-	-	7	$17,010	-	-	-	-	-	-	-	-	-	-	-	-	$17,010
	31-35"	$2,900	-	-	-	-	5	$14,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$14,500
	>35"	$3,900	-	-	-	-	1	$3,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$3,900
Activity Total(s)			**0**	**$0**	**0**	**$0**	**6**	**$18,400**	**12**	**$26,110**	**15**	**$27,300**	**48**	**$33,390**	**44**	**$26,615**	**60**	**$24,000**	**133**	**$15,480**	**0**	**$0**	**$171,295**
Stump Removals	1-5"	$50	-	-	-	-	3	$150	4	$200	4	$200	4	$200	4	$200	4	$200	4	$200	4	$200	$1,550
	6-10"	$100	-	-	-	-	6	$600	6	$600	6	$600	6	$600	5	$500	5	$500	5	$500	5	$500	$4,400
	11-15"	$125	-	-	-	-	6	$750	6	$750	6	$750	6	$750	6	$750	6	$750	6	$750	6	$750	$6,000
	16-20"	$195	-	-	-	-	4	$780	4	$780	4	$780	5	$975	5	$975	5	$975	5	$975	5	$975	$7,215
	21-25"	$250	-	-	-	-	3	$750	3	$750	3	$750	3	$750	4	$1,000	4	$1,000	4	$1,000	4	$1,000	$7,000
	26-30"	$310	-	-	-	-	2	$620	2	$620	2	$620	2	$620	2	$620	3	$930	3	$930	3	$930	$5,890
	31-35"	$375	-	-	-	-	1	$375	2	$750	2	$750	2	$750	2	$750	2	$750	2	$750	2	$750	$5,625
	>35"	$425	-	-	-	-	-	-	-	-	-	-	1	$425	1	$425	1	$425	1	$425	1	$425	$2,125
Activity Total(s)			**0**	**$0**	**0**	**$0**	**25**	**$4,025**	**27**	**$4,450**	**27**	**$4,450**	**29**	**$5,070**	**29**	**$5,220**	**30**	**$5,530**	**30**	**$5,530**	**30**	**$5,530**	**$39,805**
Moderate Priority Pruning	1-5"	$62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	6-10"	$126	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
	11-15"	$183	-	-	3	$549	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$549

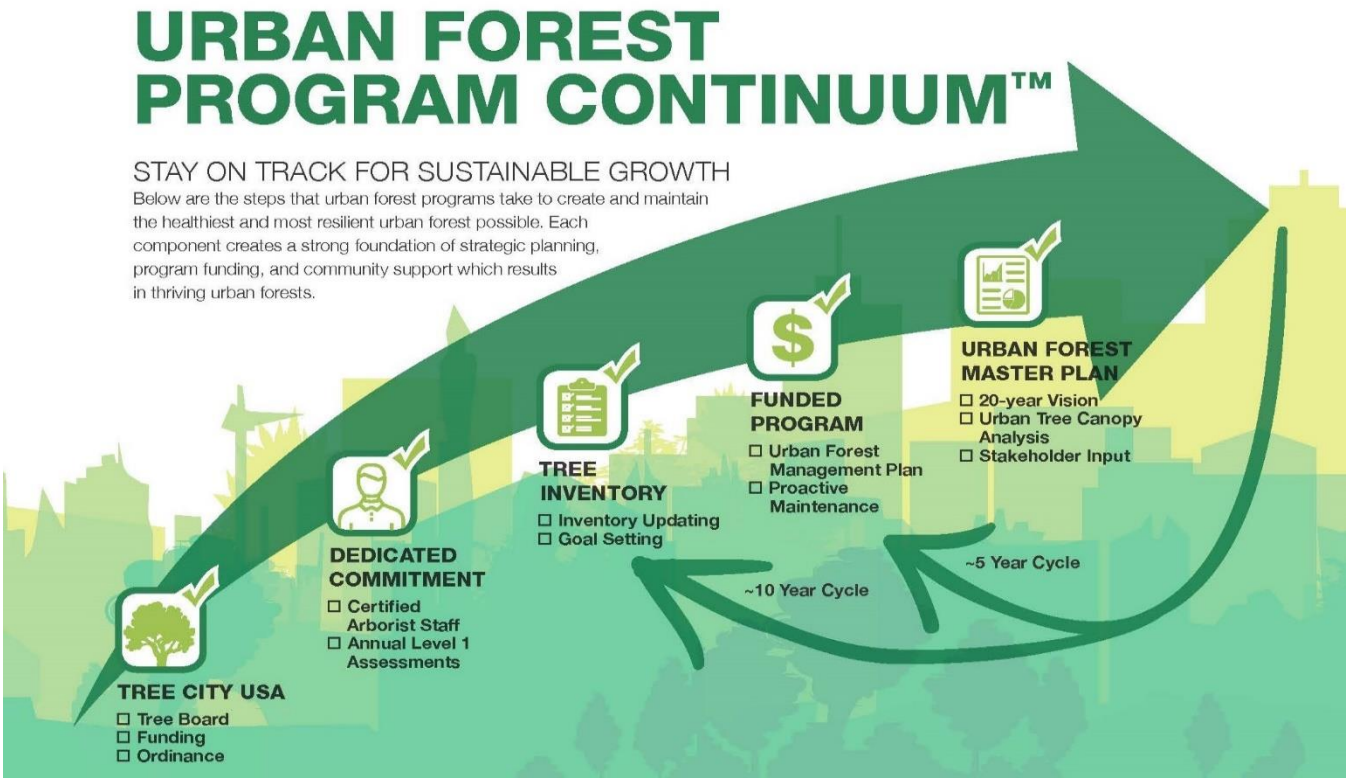
	16-20"	$223	-	-	10	$2,230	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$2,230
	21-25"	$275	-	-	10	$2,750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$2,750
	26-30"	$312	-	-	11	$3,432	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$3,432
	31-35"	$415	8	$3,320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$3,320
	>35"	$450	4	$1,800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,800
Activity Total(s)			**12**	**$5,120**	**34**	**$8,961**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$14,081**
Routine Inspection	Drive-by Assessment	$1	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	2,645	$2,645	$26,450
	Walk-by Assessment	$5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0
Activity Total(s)			**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**2,645**	**$2,645**	**$0**
Young Tree Training (3-year Cycle)	all sizes	$45	75	$3,375	194	$8,730	194	$8,730	193	$8,685	194	$8,730	194	$8,730	193	$8,685	193	$8,685	193	$8,685	193	$8,685	$81,720
Activity Total(s)			**75**	**$3,375**	**194**	**$8,730**	**194**	**$8,730**	**193**	**$8,685**	**194**	**$8,730**	**194**	**$8,730**	**193**	**$8,685**	**193**	**$8,685**	**193**	**$8,685**	**193**	**$8,685**	**$81,720**
Routine Pruning (8-year Cycle)	1-5"	$62	-	-	-	-	15	$930	15	$930	15	$930	16	$992	15	$930	16	$992	15	$930	16	$992	$7,626
	6-10"	$126	-	-	-	-	82	$10,332	83	$10,458	83	$10,458	83	$10,458	82	$10,332	83	$10,458	83	$10,458	83	$10,458	$83,412
	11-15"	$183	-	-	-	-	53	$9,699	53	$9,699	53	$9,699	53	$9,699	53	$9,699	53	$9,699	53	$9,699	53	$9,699	$77,592
	16-20"	$223	-	-	-	-	43	$9,589	43	$9,589	43	$9,589	42	$9,366	43	$9,589	43	$9,589	43	$9,589	42	$9,366	$76,266
	21-25"	$275	-	-	-	-	26	$7,150	26	$7,150	27	$7,425	26	$7,150	26	$7,150	26	$7,150	27	$7,425	26	$7,150	$57,750
	26-30"	$312	-	-	-	-	16	$4,992	15	$4,680	16	$4,992	15	$4,680	16	$4,992	15	$4,680	16	$4,992	15	$4,680	$38,688
	31-35"	$415	-	-	-	-	8	$3,320	7	$2,905	8	$3,320	8	$3,320	8	$3,320	7	$2,905	8	$3,320	8	$3,320	$25,730
	>35"	$450	-	-	-	-	6	$2,700	5	$2,250	6	$2,700	5	$2,250	5	$2,250	6	$2,700	5	$2,250	5	$2,250	$19,350
Activity Total(s)			**0**	**$0**	**0**	**$0**	**249**	**$48,712**	**247**	**$47,661**	**251**	**$49,113**	**248**	**$47,915**	**248**	**$48,262**	**249**	**$48,173**	**250**	**$48,663**	**248**	**$47,915**	**$386,414**
Replacement Tree Planting and Maintenance	Purchasing & Planting	$550	17	$9,350	25	$13,750	25	$13,750	50	$27,500	71	$39,050	71	$39,050	71	$39,050	71	$39,050	71	$39,050	71	$39,050	$298,650
	Watering	$30	17	$510	25	$750	25	$750	50	$1,500	71	$2,130	71	$2,130	71	$2,130	71	$2,130	71	$2,130	71	$2,130	$16,290
Activity Total(s)			**34**	**$9,860**	**50**	**$14,500**	**50**	**$14,500**	**100**	**$29,000**	**142**	**$41,180**	**142**	**$41,180**	**142**	**$41,180**	**142**	**$41,180**	**142**	**$41,180**	**142**	**$41,180**	**$314,940**
New Tree Planting and Maintenance	Purchasing & Planting	$550	10	-	10	-	10	-	10	-	10	-	10	-	10	-	10	-	10	-	10	-	$0
	Watering	$30	10	$300	10	$300	10	$300	10	$300	10	$300	10	$300	10	$300	10	$300	10	$300	10	$300	$3,000
Activity Total(s)			**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**20**	**$300**	**$3,000**
Natural Mortality (1%)	Tree Removal	$650	7	$4,550	20	$13,000	20	$13,000	25	$16,250	25	$16,250	25	$16,250	25	$16,250	25	$16,250	25	$16,250	25	$16,250	$144,300
	Stump Removal	$175	7	$1,225	20	$3,500	20	$3,500	25	$4,375	25	$4,375	25	$4,375	25	$4,375	25	$4,375	25	$4,375	25	$4,375	$38,850
	Replacement Tree	$580	7	$4,060	20	$11,600	20	$11,600	25	$14,500	25	$14,500	25	$14,500	25	$14,500	25	$14,500	25	$14,500	25	$14,500	$128,760
Activity Total(s)			**21**	**$9,835**	**60**	**$28,100**	**60**	**$28,100**	**75**	**$35,125**	**75**	**$35,125**	**75**	**$35,125**	**75**	**$35,125**	**75**	**$35,125**	**75**	**$35,125**	**75**	**$35,125**	**$311,910**
Activity Grand Total			**2,818**		**3,026**		**3,249**		**3,319**		**3,369**		**3,401**		**3,396**		**3,414**		**3,488**		**3,353**		**32,833**
Cost Grand Total				**$60,375**		**$91,906**		**$125,412**		**$153,976**		**$168,843**		**$174,355**		**$168,032**		**$165,638**		**$157,608**		**$141,380**	**$1,407,525**

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 2,997 public trees inventoried provide $6,853 in estimated annual economic value, which is almost 23% of the city's current annual tree maintenance budget of $30,000. Successfully implementing the ten-year management program may increase Ayer's ROI over time, or at least maintain it over the years.

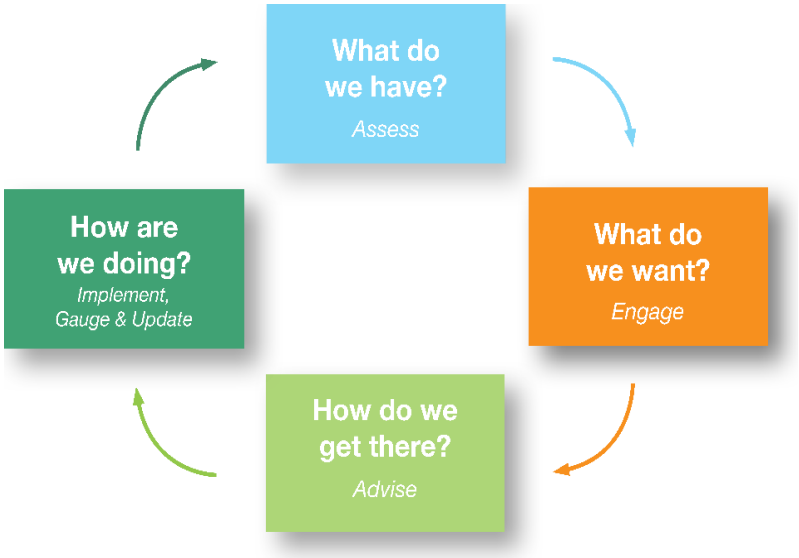
The maintenance program laid out in this report is ambitious and is a challenge to complete in ten years but becomes easier after all priority tree maintenance is completed. This *Standard Inventory Analysis and Management Plan* could potentially help the Town advocate for an increased urban forestry budget to fund the recommended maintenance activities. Getting started is the most difficult part because of the expensive maintenance in the first several years, 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 Ayer and its residents will increase as well. Inventoried trees are only a fraction of the total trees in Ayer when including private property, which is why it is important to also incentivize private landowners to care for their trees and to plant new ones. The Town's urban forestry program is 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 ambitious goals once they are reached.



EVALUATING AND UPDATING THIS PLAN

This *Standard Inventory Analysis and Management Plan* provides management priorities for the next ten years, and it is important to update the tree inventory using TreeKeeper® as work is completed, so the software can provide updated species distribution and benefit estimates. This empowers Ayer to self-assess the Town's progress over time and set goals to strive toward by following the adaptive management cycle (depicted to the right). Below are some ways of implementing the steps of this cycle:



- Prepare planting plans well enough in advance to schedule and complete stump removal in the designated area, and to select species best suited to the available sites.
- Annually compare the number of trees planted to the number of trees removed and the number of vacant planting sites remaining, then adjusting future planting plans accordingly.
- Annually compare the species distribution of the inventoried tree resource with the previous year after completing planting plans to monitor recommended changes in abundance.
- Schedule and assign high-priority tree work so it can be completed as soon as possible instead of reactively addressing new lower priority work requests as they are received.
- Include data collection such as measuring DBH and assessing condition into standard procedure for tree work and routine inspections, so changes over time can be monitored.

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GLOSSARY

address (data field): The address number was recorded based on parcel data within the GIS data collection program and confirmed with visual observation of the actual address number posted on a building at the inventoried site. In instances where there was no posted address number on a building or sites were located by vacant lots with no GIS parcel addressing data available, the address number assigned was matched as closely as possible to opposite or adjacent addresses by the arborist(s) and the suffix field (assigned address field) was set to "X".

air pollution removal: In i-Tree Eco, air pollution removal refers to the removal of ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter less than 2.5 microns ($PM_{2.5}$).

American National Standards Institute (ANSI): ANSI is a private, nonprofit organization that facilitates the standardization work of its members in the United States. ANSI's goals are to promote and facilitate voluntary consensus standards and conformity assessment systems, and to maintain their integrity.

***ANSI A300*:** Tree care performance parameters established by ANSI that can be used to develop specifications for tree maintenance.

arboriculture: The art, science, technology, and business of commercial, public, and utility tree care.

assigned address (data field): see **suffix**

avoided runoff: In i-Tree Eco, avoided runoff measures the amount of surface runoff avoided when trees intercept rainfall during precipitation events.

canopy: Branches and foliage that make up a tree's crown.

canopy cover: As seen from above, it is the area of land surface that is covered by tree canopy.

Carbon Monoxide (CO): A colorless, odorless, highly toxic gas formed as a result of the incomplete combustion of a carbon or carbon compound.

carbon sequestration: The capture and storage of carbon from the Earth's atmosphere. In i-Tree Eco, carbon sequestration is calculated as an annual functional benefit of trees.

carbon storage: Storage of carbon in plant tissue. In i-Tree Eco, carbon storage is calculated as a structural benefit over the lifetime of the tree.

clearance required (data field): Indicates whether a tree requires clearance pruning to provide clearance for roads, sidewalks, or structures.

comments (data field): Additional comments on the state of the inventoried site. Comments may include additional defects that were significant but not the primary defect, explanations for why further inspection is needed, and other general information considered important by the inventory arborist.

community forest: see **urban forest**.

condition (data field): The general condition of each tree rated during the inventory according to categories adapted from the International Society of Arboriculture's rating system.

cycle: Planned length of time between vegetation maintenance activities.

dead (condition rating): A dead tree shows no signs of life.

defect: See **structural defect**.

defect (data field): The primary defect noted by the inventory arborist. Defects include missing or decayed wood, dead or dying parts, broken or hanging branches, weakly attached branches and codominant stems, cracks, root problem, tree architecture, other, and none.

diameter: See **tree size**.

diameter at breast height (DBH): See **tree size**.

extreme risk tree: Applies in situations where tree failure is imminent, 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 in order to prevent injury.

failure: In terms of tree management, failure is the breakage of stem or branches, or loss of mechanical support of the tree's root system.

fair (condition rating): A fair tree has minor problems that may be corrected with time or corrective action.

functional benefit: In i-Tree Eco, a benefit which is due to the physiological processes carried out by trees, calculated on an annual basis.

further inspection (data field): Notes that a specific tree may require an annual inspection for several years to make certain of its maintenance needs. A healthy tree obviously impacted by recent construction serves as a prime example. This tree will need annual evaluations to assess the impact of construction on its root system. Another example would be a tree with a defect requiring additional equipment for investigation.

genus: A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature, the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.

geographic information system (GIS): A technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework. GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to provide a better understanding of how it all interrelates.

global positioning system (GPS): GPS is a system of earth-orbiting satellites that make it possible for people with ground receivers to pinpoint their geographic location.

good (condition rating): A tree in good condition shows no major problems.

hardscape damage (data field): Indicates whether hardscape surrounding a site was displaced by 1" or more.

high risk tree: 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.

insect/disease monitoring (further inspection): A tree which requires additional inspection by an entomologist or tree disease specialist to determine whether or not there is an emergent pest or disease present.

invasive tree: A tree species that is out of its original biological community. Its introduction into an area causes or is likely to cause economic or environmental harm, or harm to human health. An invasive, exotic tree has the ability to thrive and spread aggressively outside its natural range. An invasive species that colonizes a new area may gain an ecological edge since the insects, diseases, and foraging animals that naturally keep its growth in check in its native range are not present in its new habitat.

inventory: See **tree inventory**.

inventory date (data field): Date a site was collected.

i-Tree Eco: i-Tree Eco is a street tree management and analysis tool that uses tree inventory data to quantify the dollar value of annual environmental benefits, including runoff reduction, air pollution reduction, and carbon sequestration, as well as life-long structural benefits trees provide, including carbons storage and structural value.

i-Tree Streets: i-Tree Streets is a street tree management and analysis tool that uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits: energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase. While i-Tree Streets was not used for the tree benefits analysis in this management plan, it is still used as the basis for the tree benefits tab in TreeKeeper®.

i-Tree Tools: State-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

level 3 assessment (further inspection): A more in-depth assessment than the level 2 assessment conducted during the inventory which requires specialized equipment or training to complete.

low-risk tree: 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.

mapping coordinates (data field): Helps to locate a tree; X and Y coordinates were generated for each tree using GPS.

moderate risk tree: 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.

monoculture: A population dominated by one single species or very few species.

multi-stem (data field): Indicates whether a tree has multiple trunks splitting less than 1 foot above ground level. For this inventory, multi-stem trees were measured below the trunk split or at ground level in cases where multiple stems originated from a branching point below grade.

multi-year annual (further inspection): Designates a tree which should be inspected annually or biannually to monitor a defect for improvement or degradation.

Nitrogen Dioxide (NO_2): Nitrogen dioxide is a compound typically created during the combustion processes and is a major contributor to smog formation and acid deposition.

none (risk rating): Equal to zero. It is used only for planting sites and stumps, or as a residual risk rating when a tree is recommended for removal.

ordinance: See **tree ordinance**.

overhead utilities (data field): Designates the presence of any overhead utility lines including primary and secondary electrical distribution lines, telecommunication lines, service drops, streetlight supply lines, etc. within the airspace around or in a tree's crown.

Ozone (O_3): A strong-smelling, pale blue, reactive toxic chemical gas with molecules of three oxygen atoms. It is a product of the photochemical process involving the Sun's energy. Ozone exists in the upper layer of the atmosphere as well as at the Earth's surface. Ozone at the Earth's surface can cause numerous adverse human health effects. It is a major component of smog.

park name (data field): The park or public grounds on which a site was located. If a site was within the street ROW, the park name field was set to N/A.

Particulate Matter ($PM_{2.5}$): A major class of air pollutants consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists.

plant tree (primary maintenance need): Used only for sites which do not currently host a tree, but which could be viable planting sites. Indicates the need to plant a tree.

poor (condition rating): A tree in poor condition has major problems that are irrecoverable.

primary maintenance need (data field): The type of tree work recommended to reduce immediate risk or fulfill other goals.

prune (primary maintenance need): The tree needs priority pruning to remove dead limbs, provide clearance, remove an obstruction, or thin or restore the canopy.

pruning: The selective removal of plant parts to meet specific goals and objectives.

remove (primary maintenance need): Data field collected during the inventory identifying the need to remove a tree. Trees designated for removal have defects that cannot be cost-effectively or practically treated. Most of the trees in this category have a large percentage of dead crown.

replacement value: In i-Tree Eco, the compensatory value calculated based on the local cost of having to replace a tree with a similar tree.

residual risk (data field): The risk rating of a tree after the recommended primary maintenance has been carried out. Residual risk may be equal to but never greater than the original risk rating.

resilience: The ability of a community to absorb disturbance and reorganize while undergoing change to retain essentially the same function, structure, identity, and feedbacks as prior to the disturbance.

resistance: The ability of a community to remain unchanged when challenged by a disturbance such as pests, severe weather, or climate change.

right-of-way (ROW): See **street right-of-way**.

risk: Combination of the probability of an event occurring and its consequence.

risk assessment complete (data field): Indicates whether the arborist was able to complete a Level 2 qualitative risk assessment. Arborists may not be able to fully assess tree risk due to embankments, homeowner conflicts, fences, or other obstacles to getting a 360 degree view of the tree.

risk rating (data fields): Level 2 qualitative risk assessment will be performed on the ANSI A300 (Part 9) and the companion publication *Best Management Practices: Tree Risk Assessment*, published by International Society of Arboriculture (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.

routine prune (primary maintenance need): The tree requires no immediate pruning but should be included in a routine pruning cycle to maintain condition over time.

side (data field): Each site is assigned a side value to aid in locating the site. Side values include: *front*, *side*, *median* (includes islands), and *rear* based on the site's location in relation to the assigned address.

site: Any point for which data was recorded during the inventory, including trees, vacant sites, and stumps.

species (data field): Fundamental category of taxonomic classification, ranking below a genus or subgenus, and consisting of related organisms capable of interbreeding.

stem: A woody structure bearing buds and foliage and giving rise to other stems.

structural benefit: In i-Tree Eco, a benefit which is produced by the physical arrangement and composition of trees and tree parts and which is calculated as an aggregate over the lifetime of a tree.

structural defect: A feature, condition, or deformity of a tree or tree part that indicates weak structure and contributes to the likelihood of failure.

structural value: See **replacement value**.

stump removal (Primary Maintenance Need): Indicates a stump that should be removed.

suffix (data field): Data field indicating whether the address was assigned by the arborist.

Sulfur Dioxide (SO_2): A strong-smelling, colorless gas that is formed by the combustion of fossil fuels. Sulfur oxides contribute to the problem of acid rain.

topping: Characterized by reducing tree size using internodal cuts without regard to tree health or structural integrity; this is not an acceptable pruning practice.

train (primary maintenance need): A young or small size tree that requires routine structural pruning to ensure good form as it grows.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall. Characteristically, it has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefits the community and results mainly from the presence of a tree. The benefit received has real or intrinsic value associated with it.

tree inventory: Comprehensive database containing information or records about individual trees typically collected by an arborist.

tree lawn: see **planting strip**.

tree ordinance: Tree ordinances are policy tools used by communities striving to attain a healthy, vigorous, and well-managed urban forest. Tree ordinances simply provide the authorization and standards for management activities.

tree pit: see **well/pit**.

tree size (data field): A tree's diameter measured to the nearest inch in 1-inch size classes at 4.5 feet above ground, also known as diameter at breast height (DBH) or diameter.

tree well: see **well/pit**.

urban forest: All the trees within a municipality or a community. This can include the trees along streets or rights-of-way, in parks and greenspaces, in forests, and on private property.

volunteer: A tree that was not intentionally planted, but rather grew naturally in a location and has been allowed to remain as part of the maintained landscaping.

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
- Clearance Required
- Comments
- Condition
- Defect
- Further Inspection Required
- Hardscape Damage
- Inventory Date
- Multi-Stem
- Park Name
- Primary Maintenance
- Residual Risk
- Risk Assessment Complete
- Risk Rating
- Size*
- Species
- Suffix (Assigned Address)
- X & Y Coordinates

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

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.

Layer	Source	Date	Projection
Buildings	Mass GIS	2021	NAD 1983 StatePlane Massachusetts Mainland FIPS 2001
Centerlines	Mass GIS	2021	NAD 1983 StatePlane Massachusetts Mainland FIPS 2001
City Limits	Mass GIS	2020	NAD 1983 StatePlane Massachusetts Mainland FIPS 2001
Parcels	Mass GIS	2020	NAD 1983 StatePlane Massachusetts Mainland FIPS 2001

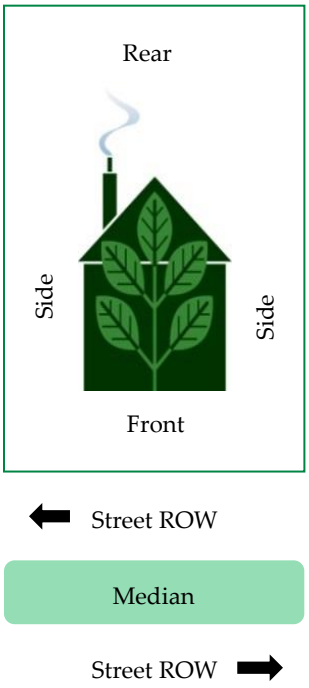
STREET ROW SITE LOCATION

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

Address, Number, and Street Name

Where there was no GIS parcel addressing data available for sites located adjacent to a vacant lot, or adjacent to an occupied lot without a posted address number, the arborist used their best judgment to assign an address number based on nearby addresses. An "X" was then added to the number in the database to indicate that it was assigned, for example, "37X Choice Avenue."

Sites in medians were assigned an address number by the arborist in Rover using parcel and streets geographical data. Each segment was numbered with an assigned address that was interpolated from addresses facing that median and addressed on that same street as the median. If there were multiple medians between cross streets, each segment was assigned its own address. The *street name* assigned to a site was determined by street centerline information.



Side Value

Each site was assigned a *side*, including *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 nearly all of them have the "Assigned Address" field set to 'X' and have the "Park Name" data field filled. All sites within a park were assigned the *side* value of *front.*

Site Location Example

Corner Lot A

Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
Side:	Front
On Street:	Hoover St.

Corner Lot B

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

I-TREE ECO METHODOLOGY

Replacement value (also called structural value) is a compensatory value calculated based on the local cost of having to replace a tree with a similar tree. In other words, it is a measurement of the value of the resource itself. The structural value of an urban forest is the sum of the structural values of all the individual trees contained within. Monetary values are assigned based on valuation procedures of the Council of Tree and Landscape Appraisers using information on species, diameter, condition, and location (McPherson 2007) and (Nowak et al. 2008).

Carbon sequestration refers to the capture and storage of carbon from the earth's atmosphere. i-Tree Eco analysis reports on the gross annual amount of carbon sequestered as well as the total amount of carbon stored over the lifetime of the tree. For this analysis, carbon storage and sequestration values are calculated at a rate of $170.55 per ton.

Air pollution removal refers to the removal of ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter less than 2.5 microns ($PM_{2.5}$). For this analysis, the pollution removal value is calculated based on the prices of $0.50 per pound of ozone, $0.02 per pound of sulfur dioxide, $0.07 per pound of nitrogen dioxide, $0.66 per pound carbon monoxide, and $23.91 per pound of particulate matter less than 2.5 microns.

Avoided runoff measures the amount of surface runoff avoided when trees intercept rainfall during precipitation events. Surface runoff from rainfall contributes to the contamination of streams, rivers, lakes, and wetlands by washing oils, pesticides, and other pollutants, either directly into waterways or into drainage infrastructure that ultimately empties into waterways. For this analysis, annual avoided runoff is calculated based on the estimated amount of intercepted rainfall and the local weather station at the Fitchburg Municipal Airport, where annual precipitation in 2016 equaled 29.3 inches. The monetary value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series at a rate of $0.067 per cubic foot.

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).

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 may 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 native species to extinction. The following appendix includes key pests and diseases that adversely affect trees in Massachusetts, or which are emergent threats for Massachusetts 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 public trees to routinely check APHIS, USDA Forest Service, and other websites for updates about invasive species and diseases in your area so that you can be prepared to combat their attack. 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.

APHIS, Plant Health, Plant Pest Program Information
- www.aphis.usda.gov/plant_health/plant_pest_info

The University of Georgia, Center for Invasive Species and Ecosystem Health
- www.bugwood.org

USDA National Agricultural Library
- www.invasivespeciesinfo.gov/microbes

USDA Northeastern Areas Forest Service, Forest Health Protection
- www.na.fs.fed.us/fhp

ASIAN LONGHORNED BEETLE

Adult Asian longhorned beetle.

Photograph courtesy of New Bedford Guide (2011)

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 arrived in the United States in wood pallets and other wood-packing material accompanying cargo shipments from Asia. ALB is a serious threat to America's hardwood tree species.

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 elder (*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*).

BEECH BARK DISEASE

Perennial nectria cankers caused by beech bark disease on an American beech.

Photograph courtesy of Linda Haugen, USDA Forest Service, Bugwood.org

Beech bark disease is the result of an insect-fugus complex which begins when a non-native beech scale insect, *Cryptococcus fagisuga*, feeds on the bark of beech trees, creating lesions through which a native canker fungi, *Neonectria* spp., can enter the tree. The scale insect, which is native to Europe, was first introduced to Nova Scotia in the 1890s and has since spread west and south across Canada and the United States.

Cryptococcus fagisuga is a soft-bodied scale insect which secretes a white wooly wax during the nymph stage which can make infested trees appear to be covered in wool. The insects feed on the bark, leaving punctures through which the nectria canker fungi can enter. 50–85% of infect beech trees will die within 10 years of infestation. Even trees that do not succumb to the disease may be significantly structurally weakened by the nectria cankers and are prone to "beech snap", or trunk failure. Such trees pose a safety hazard within the urban environment.

The beech scale and resulting beech bark disease is found on both American beech (*Fagus grandifolia*) and on European beech (*Fagus sylvatica*).

BEECH LEAF DISEASE

Beech leaf disease (BLD) was first identified in Ohio in 2012. Since then, it has been found in Pennsylvania, New York, Rhode Island, Connecticut, and Massachusetts.

Dark stripes between leaf veins are an early symptom of BLD.

Photograph courtesy of Tom Macy, Ohio DNR Division of Forestry (2019)

The disease complex is associated with a nematode, *Litylenchas crenatae*, and impacts American beech (*Fagus grandifolia*), European beech (*F. sylvatica*), and Oriental beech (*F. orientalis*). Early signs of the disease include dark stripes between the veins of leaves, most noticeable when looking up through the canopy on sunny days. As the disease progresses, leaves become withered, curled, or develop a leathery texture and sections of canopy may die back. Infected trees often appear to have a thin canopy, and the disease can lead to tree mortality. Research into this disease is ongoing, and the method of spread and infection, as well as potential treatments, are not yet known.

DUTCH ELM DISEASE

Considered by many to be one of the most destructive invasive diseases of shade trees in the United States, Dutch elm disease (DED) was first found in Ohio in 1930. By 1933 the disease was present in several east coast cities and by 1959 it had killed thousands of elms. Today, DED is present in about two-thirds of the eastern United States and kills many of the remaining and newly planted elms annually. The disease is caused by a fungus that attacks the vascular system of elm trees, blocking the flow of water and nutrients and resulting in rapid leaf yellowing, tree decline, and death. The species most affected by DED is *Ulmus americana* (American elm).

Branch death, or flagging, at multiple locations in the crown of a diseased elm.

Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwod.org (2011)

There are two closely related fungi that are collectively referred to as DED. The most common is *Ophiostoma novo-ulmi*, which is thought to be responsible for most of the elm deaths since the 1970s. The fungus is transmitted to healthy elm by elm bark beetles. Two species of beetle carry the fungus: native elm bark beetle (*Hylurgopinus rufipes*) and European elm bark beetle (*Scolytus multistriatus)*.

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 an 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 *Fraxinus* (ash). Common signs and symptoms of EAB infestation include excessive woodpecker activity, branch dieback, and characteristic D-shaped exit holes.

FALL CANKERWORM

Fall cankerworm (*Alsophila pometaria*) is a native pest of North American hardwood trees. While it generally causes minimal damage to forests, occasional population booms may cause greater damage. Larvae are present and feeding starting in May and will eat entire leaves, often completely defoliating trees and leaving them weakened and susceptible to secondary pests and infections. Larvae are either light green with white longitudinal stripes or dark greenish-brown with a black stripe down the length of their back.

Fall cankerworm larvae.

Photograph courtesy of John Ghent, bugwood.org

Preferred hosts of fall cankerworm include ash (*Fraxinus* spp.), basswood (*Tilia* spp.), beech (*Fagus* spp.), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), red oak (*Quercus rubra*), and white oak (*Q. alba*). However, this pest species will feed on a wide variety of hardwood tree species.

HEMLOCK WOOLY ADELGID

The hemlock woolly adelgid (HWA, *Adelges tsugae*) was first described in western North America in 1924 and first reported in the eastern United States in 1951 near Richmond, Virginia.

In their native range, populations of HWA cause little damage to hemlock trees, as they are preyed on by on natural enemies and possible tree resistance has evolved with this insect. In eastern North America and in the absence of natural control elements, HWA attacks both eastern or Canadian hemlock (*Tsuga canadensis*) and Carolina hemlock (*T. caroliniana*), often damaging and killing them within a few years of becoming infested.

HWA is now established from northeastern Georgia to southeastern Maine and as far west as eastern Kentucky and Tennessee.

Hemlock woolly adelgids on a branch.

Photograph courtesy of Connecticut Agricultural Experiment Station, Bugwood.org (2011)

LYMANTRIA DISPAR

Lymantria dispar dispar (LDD, formerly called European gypsy moth) 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. LDD caterpillars defoliate trees, which makes the host trees vulnerable to diseases and other pests that can eventually kill the tree.

Male LDD 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 of the species cannot fly.

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

Photograph courtesy of USDA APHIS (2019)

LDD prefers approximately 150 primary hosts but feeds on more than 300 species of trees and shrubs. Many preferred hosts are found in these common genera: birch (*Betula* spp.); cedar (*Juniperus* spp.); larch (*Larix* spp.); poplar (*Populus* spp.); oak (*Quercus* spp.); and willow (*Salix* spp.).

OAK WILT

Oak wilt symptoms on red and white oak leaves.

Photograph courtesy of USDA Forest Service (2011a)

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.

Just as with DED, oak wilt disease is caused by a fungus that clogs the vascular system of oak and results in decline and death of the tree. The fungus is carried from tree to tree by several borers common to oak, 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.

RED PINE SCALE

Cottony white masses wedged into the bark are a sign of red pine scale infestation.

Photo courtesy of budgwood.org

Red pine scale (*Matsucoccus matsumarae*) is a non-native pest species of red pine (*Pinus resinosa*) which was likely introduced to the US on exotic pines brought in for the 1939 New York World's Fair. Today it is distributed throughout southern New England, New York, New Jersey, and eastern Pennsylvania.

The scale insect feeds through the bark, leeching nutrients and water from the tree and leading to foliage changing slowly from light green to yellow to red. Symptoms generally appear on individual branches first and gradually spread to the entire crown. Cottony white filaments may be easily visible on branches when infestations are heavy. The feeding of the insects weakens host trees, predisposing them to attack by bark beetles and other pests which, in conjunction with red pine scale, may kill the tree.

SOUTHERN PINE BEETLE

The southern pine beetle (SPB, *Dendroctonus frontalis*) is the most destructive insect pest of pine in the southern United States. It attacks and kills all species of southern white pine including eastern white pine (*Pinus strobus*). Trees are killed when beetles construct winding, S-shaped egg galleries underneath the bark. These galleries effectively girdle the tree and destroy the conductive tissues that transport food throughout the tree. Furthermore, the beetles carry blue staining fungi on their bodies that clog the water conductive tissues which transport water within the tree. Signs of attack on the outside of the tree are pitch tubes and boring dust, known as frass, caused by beetles entering the tree.

Adult southern pine beetles.

Photograph courtesy of Forest Encyclopedia Network (2012)

Adult SPBs reach an ultimate length of only 1/8 inch, similar in size to a grain of rice. They are short-legged, cylindrical, and brown to black in color. Eggs are small, oval-shaped, shiny, opaque, and pearly white.

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 (*Ailanthus altissima*) 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.

Pinned spotted lanternfly nymph.

Photograph courtesy of PA Dept of Agriculture

Symptoms of SLF include 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: almond, apricot, cherry, nectarine, peach, plum (*Prunus* spp.), apple (*Malus* spp.), maple (*Acer* spp.), oak (*Quercus* spp.), pine (*Pinus* spp.), poplar (*Populus* spp.), sycamore (*Platanus* spp.), walnut (*Juglans* spp.), and willow (*Salix* spp.), as well as grape vines and hop plants.

WHITE PINE DECLINE

White pine decline is believed to have developed around 2009 and is affecting eastern white pine (*Pinus strobus*) throughout the east coast of the US. White pine decline is characterized by yellowing or browning needles, premature needle drop, thinning canopies, undersized shoots and needles, resinosis, branch dieback, and whole tree death. However, white pine decline is not the result of a single pest or disease, but rather, a complex of multiple native pests and diseases, spurred on by changing climate.

Eastern white pine exhibiting signs of white pine decline.

Photograph courtesy of UMass Amerherst.

White pine needle disease is the primary cause of many of the observed symptoms of white pine decline and is caused by several different fungal pathogens, including *Lecanostica acicula*, *Septorioides strobi*, *Bifusella linearis*, and *Lophophacidium dooksii*. Caliciopsis canker, another component of white pine decline, is facilitated by white pine bast scale. It is believed that increased temperatures and precipitation from May through July, caused by climate change, are boosting the concentration of these pests and contributing to white pine decline. Currently, the best management method for combating this disease complex is to improve white pine vigor through stand thinning, fertilization, and generally reducing stressors on white pine.

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APPENDIX C

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 Zones 5 and 6 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 saccharum	sugar maple	'Legacy'
Acer nigrum	black maple	
*Betula alleghaniensis**	yellow birch	
*Betula lenta**	sweet birch	
Betula nigra	river birch	Heritage®
Carpinus betulus	European hornbeam	'Franz Fontaine'
*Carya illinoensis**	pecan	
*Carya lacinata**	shellbark hickory	
*Carya ovata**	shagbark hickory	
*Castanea mollissima**	Chinese chestnut	
Celtis laevigata	sugarberry	
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	(Choose male trees only)
Gleditsia triacanthos inermis	thornless honeylocust	'Shademaster'
Gymnocladus dioica	Kentucky coffeetree	Prairie Titan®
*Juglans nigra**	black walnut	
*Larix decidua**	European larch	
Liquidambar styraciflua	American sweetgum	'Rotundiloba'
*Liriodendron tulipifera**	tuliptree	'Fastigiatum'
*Magnolia acuminata**	cucumbertree magnolia	(Numerous exist)
*Magnolia macrophylla**	bigleaf magnolia	
Metasequoia glyptostroboides	dawn redwood	'Emerald Feathers'
Nyssa sylvatica	blackgum	
*Platanus occidentalis**	American sycamore	
Platanus × acerifolia	London planetree	'Yarwood'
Quercus alba	white oak	

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

Scientific Name	Common Name	Cultivar
Quercus bicolor	swamp white oak	
Quercus coccinea	scarlet oak	
Quercus lyrata	overcup oak	
Quercus macrocarpa	bur oak	
Quercus montana	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus palustris	pin oak	
Quercus imbricaria	shingle oak	
Quercus phellos	willow oak	
Quercus robur	English oak	Heritage®
Quercus rubra	northern red oak	'Splendens'
Quercus shumardii	Shumard oak	
Styphnolobium japonicum	Japanese pagodatree	'Regent'
Taxodium distichum	common baldcypress	'Shawnee Brave'
Tilia americana	American linden	'Redmond'
Tilia cordata	littleleaf linden	'Greenspire'
Tilia × euchlora	Crimean linden	
Tilia tomentosa	silver linden	'Sterling'
Ulmus parvifolia	Chinese elm	Allée®
Zelkova serrata	Japanese zelkova	'Green Vase'

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Aesculus × carnea	red horsechestnut	
Alnus cordata	Italian alder	
*Asimina triloba**	pawpaw	
Cladrastis kentukea	American yellowwood	'Rosea'
Corylus colurna	Turkish filbert	
Eucommia ulmoides	hardy rubber tree	
Koelreuteria paniculata	goldenraintree	
Ostrya virginiana	American hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Phellodendron amurense	Amur corktree	'Macho'
Pistacia chinensis	Chinese pistache	
Prunus maackii	Amur chokecherry	'Amber Beauty'
Prunus sargentii	Sargent cherry	
*Pterocarya fraxinifolia**	Caucasian wingnut	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
*Sassafras albidum**	sassafras	

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 oliverianum	Chinese maple	
*Acer pensylvanicum**	striped maple	
Acer triflorum	three-flower maple	
*Aesculus pavia**	red buckeye	
Amelanchier arborea	downy 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'
*Franklinia alatamaha**	Franklinia	
*Halesia tetraptera**	Carolina silverbell	'Arnold Pink'
Laburnum × watereri	goldenchain tree	
Maackia amurensis	Amur maackia	
*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 subhirtella	Higan cherry	'Pendula'
Prunus virginiana	common chokecherry	'Schubert'
*Staphylea trifolia**	American bladdernut	
Stewartia ovata	mountain stewartia	
*Styrax japonicus**	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'

Note: * denotes species that are **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'
Cedrus libani	cedar-of-Lebanon	
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica	Japanese cryptomeria	'Sekkan-sugi'
× *Cupressocyparis leylandii*	Leyland cypress	
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	
Pinus taeda	loblolly pine	
Pinus virginiana	Virginia pine	
Psedotsuga menziesii	Douglas-fir	
Thuja plicata	western arborvitae	(Numerous exist)
Tsuga canadensis	eastern hemlock	

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	
Pinus parviflora	Japanese white pine	
Thuja occidentalis	eastern arborvitae	(Numerous exist)

Small Trees: 15 to 30 Feet in Height at Maturity

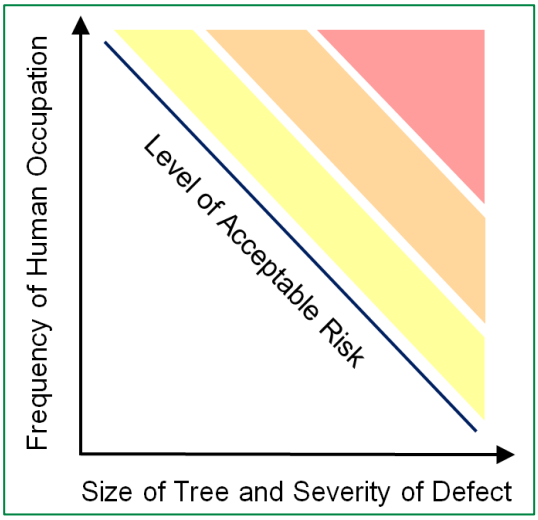
Scientific Name	Common Name	Cultivar
Ilex × *attenuata*	Foster's holly	
Pinus aristata	bristlecone pine	
Pinus mugo	mugo pine	

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 D
RISK ASSESSMENT & PRIORITY AND PROACTIVE MAINTENANCE

RISK ASSESSMENT

Every tree has an inherent risk of whole or partial tree failure. During the 2021 Glens Falls 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 potential modes of failure, each with its own risk rating. However, only one risk rating per tree was assigned during the inventory - the mode of failure with the greatest associated risk. The specified time period for the risk assessment was one year.



- **Likelihood of Failure**—Identifies a mode of 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 may occur at any moment under normal weather conditions.
- **Likelihood of Impacting a Target**—Considers the rate of occupancy of targets within the target zone and any factors that could affect the failed tree or tree part as it falls towards the target.
  - Very low—The chance of the failed tree or branch impacting the target is remote.
    - Common on rarely used sites, including rarely used trails or trailheads
    - May occur in instances where target areas provide protection
  - Low—It is not likely that the failed tree or branch will impact the target.
    - Occasional use areas fully exposed to the tree
    - Frequently used areas partially exposed to the tree
    - Constant use areas that are well protected from the tree

- 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 areas 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 the target and the 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
    - 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 to traffic or utilities, 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 identified the tree failure mode having the greatest risk and reported that as the tree risk rating. Generally, trees with the highest qualitative risk ratings should receive corrective treatment first. The following risk ratings were 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. DRG recommends only removal or pruning to alleviate risk. In special situations, such as a memorial tree or a tree in a historic area, the Town of Ayer 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, longer-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 become significant hazards.