TREE MANAGEMENT PLAN

City of Baltimore, Maryland

October 2019

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ACKNOWLEDGMENTS

The City of Baltimore's vision to promote and preserve the urban forest and improve the management of public trees was a fundamental inspiration for this project. This vision will ensure canopy growth and continuity, which will reduce stormwater runoff and improve aesthetic value, air quality, and public health.

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The Baltimore City Recreation and Parks' (BCRP) Urban Forestry Division and its *TreeBaltimore* Program also recognizes the support of its Mayor and city council, the Department of Planning and its Office of Sustainability, and the following individuals:

Mayor - Bernard (Jack) Young

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Chief of Urban Forestry - Erik Dihle

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Director

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EXECUTIVE SUMMARY

This plan was developed for The City of Baltimore by Davey Resource Group (DRG) with a focus on addressing short-term and long-term maintenance needs for inventoried public trees. DRG completed a tree inventory to gain an understanding of the needs of the existing urban forest and to project a recommended maintenance schedule for tree care. Analysis of inventory data and information about the city's existing program and vision for the urban forest were utilized to develop this *Tree Management Plan*. Also included in this plan are economic, environmental, and social benefits provided by the trees in The City of Baltimore.

State of the Existing Urban Forest

Baltimore's citywide inventory took place over two growing seasons starting in April 2017 and concluding in August 2018. Collection included trees, stumps, and planting sites along public street rights-of-way (ROW) and in city-maintained parks.

In total, 190,941 sites were collected during the inventory. That included 120,283 trees, 5,108 stumps, and 65,550 vacant sites; 163,546 of those total sites were collected in the right-of-way and 27,395 were collected in parks. The vacant sites contained 40,068 existing vacant sites, 21,678 potential sites, and 3,804 sites which were vacant, but not suitable for planting.

The data were delivered to the city as a geodatabase on a monthly basis. A copy of the delivered data remained in DRG's TreeKeeper® 8 inventory management software. The data analyzed in this report are from the Baltimore TreeKeeper® 8 system and accessed on January 31, 2019.

Analysis of the inventory data found the following:

- Of the 334 species identified, *Acer rubrum* (red maple) comprised the largest percentage of the inventoried population (11%). Similarly, at the genus level, *Acer* (maple) dominate, representing 22% of the total population. Both these statistics indicate potential threats to biodiversity in the city.
- The diameter size class distribution of the inventoried tree population trends toward the ideal, with a greater number of young trees than established, maturing, or mature trees.
- The overall condition of the inventoried tree population is rated Good, with 64% of the population recorded.
- Approximately 8% of the inventoried trees were recorded as having temporary staking present.
- Approximately 4% of the inventoried trees was recorded as showing signs of mechanical damage.
- Overhead utilities were found to be present at approximately 8% of the inventoried sites.
- Hardscape was found to be covering the roots up to the trunk on approximately 3% of the inventoried sites.
- Granulate ambrosia beetle (*Xylosandrus crassiusculus*), spotted lanternfly (*SLF or Lycorma delicatula*), and Asian longhorned beetle (*ALB or Anoplophora glabripennis*) pose the biggest threats to the health of the inventoried population.
- On average, Baltimore's city owned trees each provide $77.57 in annual benefits.

- In total, inventoried tree canopy provides over $9.3 million in the following annual benefits:
  - *Aesthetic and other benefits*: valued at $4.9 million per year.
  - *Air quality*: 78,419 pounds of pollutants removed valued at over $360,000 per year.
  - *Net total carbon sequestered and avoided*: 19,059 tons valued at over $270,000 per year.
  - *Energy*: Over 9,000 megawatt-hours (MWh) and 323,831 therms (thm) valued at over $1 million per year.
  - *Stormwater flow reductions:* Approximately 275 million gallons valued at $2.7 million per year.

Tree Maintenance Needs

Trees provide many environmental and economic benefits justifying the time and money invested in planting and maintenance. The breakdown of tree maintenance are as follows: tree removal (8%); priority prune (22%); maintenance prune (25%); and none/no work needed (46%).

Maintenance should be prioritized based on the recommendation of removals and priority pruning and diameter size class. In general, trees with these recommendations had larger defects or other considerations and should be removed or pruned to promote public safety. Trees with a maintenance prune recommendation should be addressed after all priority tree maintenance has been completed. Lastly, trees with no work identified could still need pruning as time progresses and future defects develop.

Further maintenance tasks include removing existing stumps identified during the inventory. Three percent of the total inventory, 5,108 stumps, were collected along the ROW and in city-maintained parks. As these stumps present lower risk than those associated with standing trees, this task can be included in maintenance years after priority, high-diameter and pruning and removal tasks are complete.

Planting Needs

Planting trees is necessary to maintain and increase canopy cover, and to replace trees that have been removed or lost to natural mortality (expected to be 1–3% per year) or other threats (for example, construction, invasive pests, or impacts from weather events such as drought, flooding, ice, snow, storms, and wind). A total of 65,550 sites, 34% of the total inventory, were identified as vacant sites. Baltimore already has a strong planting schedule in place. Prioritization and budget suggestions are provided to help guide planting decisions regarding existing vacant sites and potential areas suitable for constructing new tree pits. Further prioritization and planning are needed to target these plantings in areas of the community that have the highest need for canopy expansion.

Citywide tree planting should focus on replacing tree canopy recommended for removal and establishing new canopy in areas that promote economic growth, such as business districts, recreational areas, trails, parking lots, areas near buildings with insufficient shade, and areas where there are gaps in the existing canopy. Various tree species should be planted; however, the planting of *Acer rubrum* (red maple) should be limited until the species distribution normalizes. The city's existing planting list offers informed choices for species selection. Due to the species distribution and threats from Emerald ash borer (EAB, *Agrilus planipennis*), all *Fraxinus* spp. (ash) trees

should be temporarily removed from the planting list or planted only when a landscape plan is in place.

Proactive pruning cycles improve the overall health of the tree population and may eventually reduce program costs. In most cases, pruning cycles will correct defects in trees before they worsen, which will avoid costly problems.

The City of Baltimore has over 250 neighborhoods and over 93,000 trees along its streets, and the city's goal is to perform proactive maintenance in every neighborhood. This program addresses trees greater than 4.5 inches in diameter by either pruning or removing the trees depending on their condition. This approach addresses multiple goals through structural pruning, removal of dead or decaying limbs, and the removal of trees when needed. Neighborhoods have been ranked based on a citywide inventory that identifies maintenance and condition of the trees. The higher the combined score for maintenance and condition, as well as the total number of trees in the neighborhood, the higher the ranking of pruning need in the neighborhood.

Urban Forest Program Needs

Adequate funding will be needed for the city to implement an effective management program that will provide short-term and long-term public benefits, ensure that priority maintenance is performed expediently, and establish proactive maintenance cycles. A proposed budget was calculated using costs for services, existing budget information, and the inventory data. The budget reflects continuous maintenance pruning, as well as the existing backlog of priority pruning according to risk. The estimated total cost for the first year of this ten-year program is approximately $4.3 million. This total will decrease by an average of nearly $108,000 per year over ten years. By Year 10, the estimated costs will have fallen to under $3.3 million. This decrease in budget is due to clearing the backlog of priority work in the first 3 years, then leveling off into a typical urban forestry maintenance pruning program. High-priority removal and pruning is costly; most of this work is scheduled during the first few years of the program, resulting in the budget being higher for those years. After high-priority work has been completed, the urban forestry program will mostly involve proactive maintenance, which is generally less costly. Budgets for later years are thus projected to be lower.

Over the long-term, supporting proactive management of trees through funding will reduce municipal tree care management costs and potentially minimize the costs to build, manage, and support certain city infrastructure. Keeping the inventory up to date in the TreeKeeper® software is crucial for making informed management decisions and projecting accurate maintenance budgets.

The City of Baltimore has many opportunities to improve its urban forest. Planned tree planting and a systematic approach to tree maintenance will help ensure a cost-effective, proactive program. Investing in this tree management program will promote public safety, improve tree care efficiency, and increase the economic and environmental benefits the community receives from its trees.

The ten-year budget recommendations noted below signify an increase in initial funding due to the backlog of maintenance concerns. In later years, the budget is reduced to nearly existing budget amounts (depending on future money costs/inflation) over the ten-year span. The first bullet point includes tree removal cost, along with associated new stump removal costs. Priority pruning are those prunes which were designated during the inspection as currently requiring maintenance. After the inventoried priority pruning is completed regular cyclical maintenance will take its place. Proactive pruning is the concurrent neighborhood-based tree maintenance program. Existing stump removal follows. The new tree and establishment line items include costs for planting 2,000 trees annually and their respective 2-year establishment costs. Support costs are grouped residual line items including associated tree pit maintenance, administration and outreach costs, litter and storm debris cleanup, integrated vegetation management, and treatment for tree pests and diseases.

FY 2020 – Year 1	**$4,256,835**	FY 2025 -Year 6	**$3,531,860**
• $608,230 - Tree removal + stump removal • $1,224,255 - Priority pruning by DBH • $450,000 - Proactive pruning • $125,550 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs		• $499,150 - Tree removal + stump removal • $610,035 - Maintenance pruning • $450,000 - Proactive pruning • $123,875 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs	
FY 2021 – Year 2	**$4,238,350**	FY 2026 – Year 7	**$3,510,455**
• $599,400 - Tree removal + stump removal • $1,212,450 - Priority pruning by DBH • $450,000 - Proactive pruning • $127,700 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs		• $478,500 - Tree removal + stump removal • $609,280 - Maintenance pruning • $450,000 - Proactive pruning • $123,875 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs	
FY 2022 – Year 3	**$4,201,275**	FY 2027 – Year 8	**$3,408,005**
• $599,400 - Tree removal + stump removal • $1,179,200 - Priority pruning by DBH • $450,000 - Proactive pruning • $123,875 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs		• $394,500 - Tree removal + stump removal • $608,500 - Maintenance pruning • $450,000 - Proactive pruning • $106,205 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs	
FY 2023 – Year 4	**$3,632,500**	FY 2028 – Year 9	**$3,346,000**
• $599,400 - Tree removal + stump removal • $610,425 - Maintenance pruning • $450,000 - Proactive pruning • $123,875 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs		• $338,500 - Tree removal + stump removal • $608,175 - Maintenance pruning • $450,000 - Proactive pruning • $100,525 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs	
FY 2024 – Year 5	**$3,541,100**	FY 2029 – Year 10	**$3,277,695**
• $508,000 - Tree removal + stump removal • $610,425 - Maintenance pruning • $450,000 - Proactive pruning • $123,875 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs		• $276,580 - Tree removal + stump removal • $607,910 - Maintenance pruning • $450,000 - Proactive pruning • $94,505 - Existing stump removal • $820,000 - New trees + establishment • $1,028,800 - Support costs	

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INTRODUCTION

The City of Baltimore is home to more than 611,000 residents who enjoy the beauty and benefits of their urban forest. The city's forestry program manages and maintains trees on public property, including trees, stumps, and planting sites in specified parks, public facilities, and along the street rights-of-way. The Baltimore City Recreation and Parks' Forestry Division has staff committed to developing a strong urban forest and partners with organizations and volunteers to plant over 3,000 new trees every year.

Funding for Baltimore's urban forestry program comes from the general fund. The City of Baltimore conducted an inventory of public trees during the growing seasons of 2017 and 2018. The city has a tree ordinance, celebrates Arbor Day, and has been a Tree City USA community for 34 years. Through the *TreeBaltimore* initiative, led by Recreation and Parks, the city strives to care for existing trees, promote natural regeneration of forests, and foster a sense of stewardship in volunteers and citizens alike.

Approach to Tree Management

The best approach to managing an urban forest is to develop an organized, proactive program using tools (such as a tree inventory and a Tree Management Plan) to set goals and measure progress. These tools can be utilized to establish tree care priorities, build strategic planting plans, draft cost-effective budgets based on projected needs, and ultimately minimize the need for costly, reactive solutions to crises or urgent hazards.

Over two growing seasons during 2017 and 2018, The City of Baltimore worked with DRG to inventory trees and develop a management plan. This plan considers the diversity, distribution, and general condition of the inventoried trees, but also provides a prioritized system for managing public trees. The following tasks were completed:

- Inventory of trees, stumps, and planting sites along the street ROW and within public parks.
- Analysis of tree inventory data.
- Development of a plan that prioritizes the recommended tree maintenance.

This plan is divided into three sections:

- *Section 1: Tree Inventory Analysis* summarizes the tree inventory data and presents trends, results, and observations.
- *Section 2: Benefits of the Urban Forest* summarizes the economic, environmental, and social benefits that trees provide to the community. This section presents statistics of an i-Tree Streets benefits analysis conducted for The City of Baltimore.
- *Section 3: Tree Management Program* utilizes the inventory data to develop a prioritized maintenance schedule and projected budget for the recommended tree maintenance over a ten-year period.

SECTION 1: TREE INVENTORY ANALYSIS

Over two inventory phases during the summers of 2017 and 2018, DRG's ISA certified arborist assessed and inventoried trees, stumps, and planting sites along the street ROW, city owned parks, and public facilities. This included approximately 1,350 public street miles (excluding alleys, private roads, and major limited access highways) and 1,784 acres of developed parkland.

A total of 190,941 sites were collected during the inventory: 120,283 trees, 5,108 stumps, and 65,550 planting sites. Of the 190,941 sites collected, 163,546 (86%) were collected along the street ROW, and the remaining 27,395 (14%) were collected in parks. Figure 1 provides a breakdown of the number and type of sites in the inventory. Figure 2 shows the sites by location type. Appendices A and B, as well as the glossary, provide detailed descriptions of data collection, site location methods, and assessment criteria.

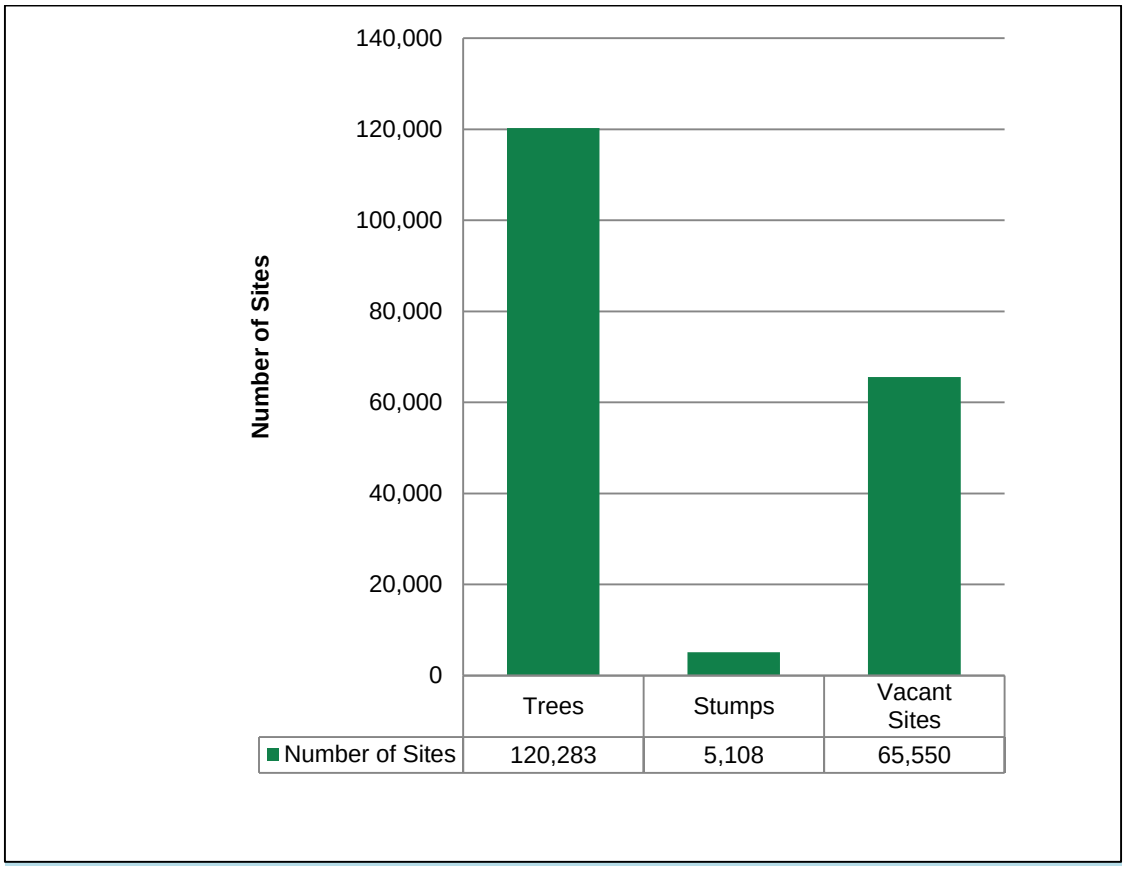


Figure 1. Sites collected during the 2017–2018 inventory by site type.

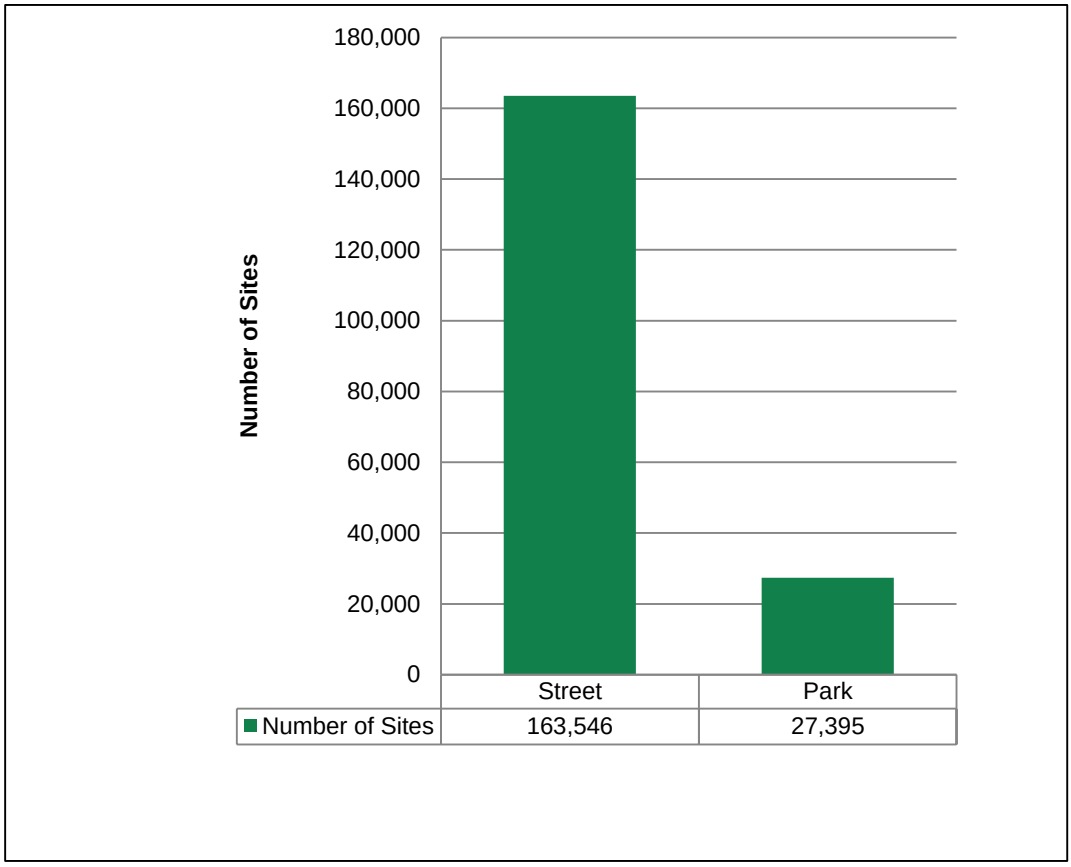


Figure 2. Sites collected during the 2017-2018 inventory by location type.

Assessment of Tree Inventory Data

Data analysis and professional judgment are used to draw general conclusions about the state of the inventoried tree population. Recognizing trends in the data can help guide short-term and long-term management planning. In this plan, the following criteria and indicators of the inventoried tree population were assessed:

Photograph 1. *Davey's ISA Certified Arborists inventoried trees along street ROW and in community parks to collect information about trees that could be used to assess the state of the urban forest.*

- *Species Diversity*, the variety of species in a specific population, affects the population's ability to withstand threats from invasive pests and diseases. Species diversity also impacts tree maintenance needs and costs, tree planting goals, and canopy continuity.
- *Diameter Size Class Distribution Data*, the statistical distribution of a given tree population's trunk-size class, is used to indicate the relative age of a tree population. The diameter size class distribution affects the valuation of tree-related benefits as well as the projection of maintenance needs and costs, planting goals, and canopy continuity.

- *Condition*, the general health of a tree population, indicates how well trees are performing given their site-specific conditions. General health affects both short-term and long-term maintenance needs and costs as well as canopy continuity.
- *Stocking Level* is the proportion of existing street trees compared to the total number of potential street trees (number of inventoried trees plus the number of planting spaces); stocking level can help determine tree planting needs and budgets.
- *Other Observations* include inventory data analysis that provides insight into past maintenance practices and growing conditions; such observations may affect future management decisions.

Species Diversity

Species diversity affects maintenance costs, planting goals, canopy continuity, and the forestry program's ability to respond to threats from invasive pests or diseases. Monocultures or low species diversity (large number of trees of the same species) can lead to severe losses in the event of species-specific epidemics such as the devastating results of Dutch elm disease (*Ophiostoma novo-ulmi*) throughout New England and the Midwest. Due to the spread of Dutch elm disease in the 1930s, combined with the disease's prevalence today, massive numbers of *Ulmus americana* (American elm), a popular street tree in many eastern American cities and towns, have perished (Karnosky 1979).

Several communities were stripped of most of their mature shade trees, creating a drastic void in canopy cover. Many of these communities have replanted to replace the lost elm trees. Ash and maple trees were popular replacements for American elm in the wake of Dutch elm disease. Unfortunately, some of the replacement species for American elm trees are now overabundant, which is a biodiversity concern. Emerald ash borer (EAB, *Agrilus planipennis*) and Asian longhorned beetle (ALB, *Anoplophora glabripennis*) are non-native insect pests that attack some of the most prevalent urban shade trees and certain agricultural trees throughout the country. Their devastating effects are due to their attack of not only weaker trees but also the ability to kill healthy, thriving trees.

The composition of a tree population should follow the 10-20-30 Rule for species diversity: a single species should represent no more than 10% of the urban forest, a single genus no more than 20%, and a single family no more than 30%. A recent discussion among emerging arbor-professionals is the theory of investing in monotypic species if all other site parameters are even. A monotypic species has a single representative of a single genus – an example would be the ginko tree. The theory is they are less susceptible or prone to another invasive species or blight coming to North America in the future. Evaluating future tree selections through the lens of emerging theory could be beneficial to the future of Baltimore's urban forest.

Findings

Analysis of The City of Baltimore's tree inventory data indicated that the park tree population had relatively good diversity, with 115 genera and 334 species represented. Along the street ROW, diversity was lower and contained 66 fewer species than that of the overall inventoried population.

Figure 3 uses the 10% Rule to compare the percentages of the most common species identified during the inventory. *Acer rubrum* (red maple) exceed the recommended 10% maximum for a single species in a population, comprising 11% of the inventoried tree population.

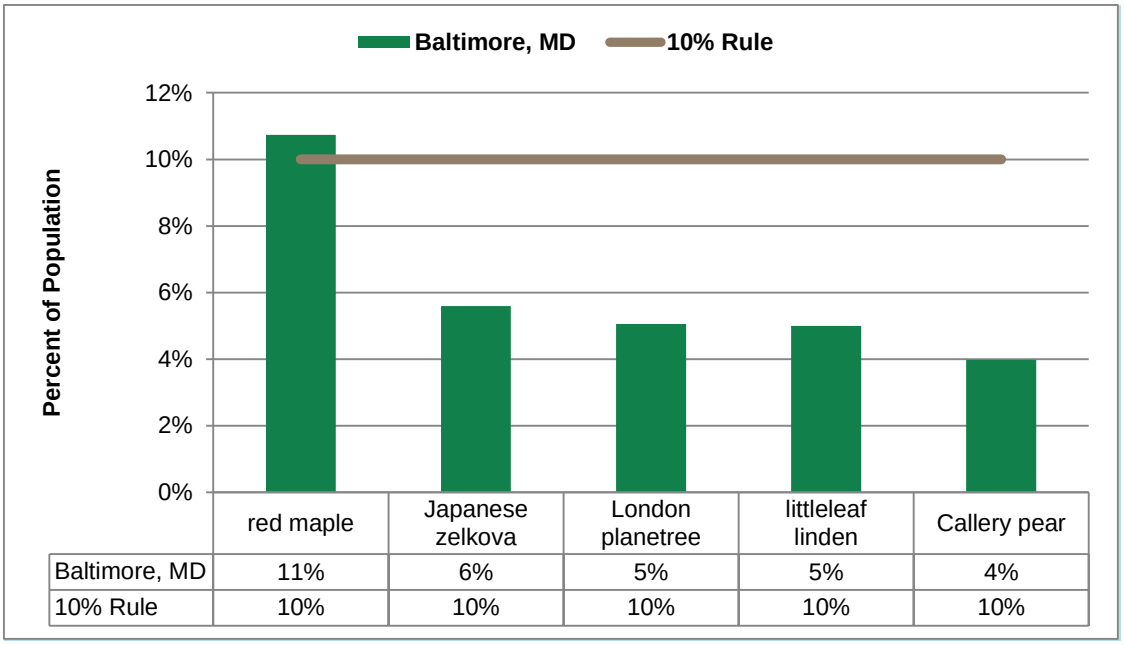


Figure 3. Five most abundant species of the inventoried population compared to the 10% Rule.

Figure 4 uses the 20% Rule to compare the percentages of the most common genera identified during the inventory. *Acer* (maple) exceed the recommended 20% maximum for a single genus in a population, comprising 22% of the inventoried tree population.

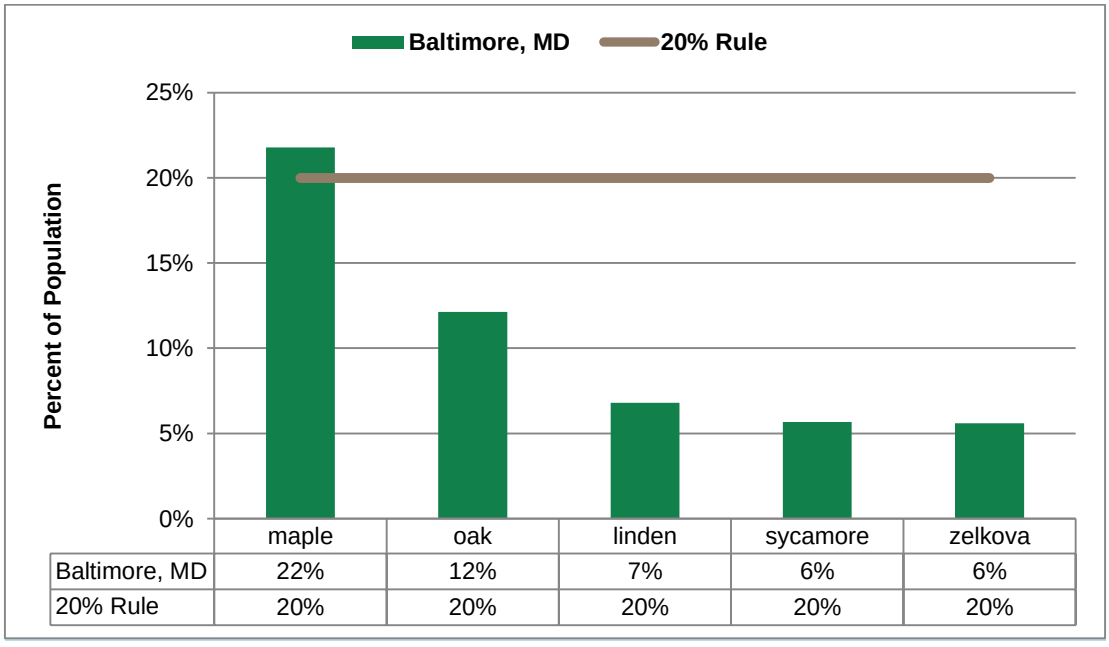


Figure 4. Five most abundant genera of the inventoried population compared to the 20% Rule.

Discussion

Acer (maple) only slightly exceeds the threshold of concern, but nearly doubles the percentage of *Quercus* (oak), the next highest-ranking genus. This, along with its susceptibility to Asian longhorned beetle, the planting of *Acer* (maple) should be limited to minimize the potential for loss. Continued diversity of tree species is a fundamental objective that will ensure the urban forest is sustainable and resilient to future invasive pest infestations. Please review Appendix C for a recommended tree species list for planting.

Diameter Size Class Distribution

Analyzing the diameter size class distribution provides an estimate of the relative age of a tree population and offers insight into maintenance practices and needs. Diameter at breast height is known as DBH and was measured for each tree during the inventory process.

The inventoried trees were categorized into the following diameter size classes: young trees (0–8 inches DBH), established (9–17 inches DBH), maturing (18–24 inches DBH), and mature trees (greater than 24 inches DBH). These categories reflect Richards' ideal distribution (1983). Richards proposed an ideal diameter size class distribution for street trees based on observations of well-adapted trees in Syracuse, New York. His ideal distribution suggests the largest fraction of trees (approximately 40% of the population) should be young (less than 8 inches DBH), while a smaller fraction (approximately 10%) should be in the large-diameter size class (greater than 24 inches DBH). A tree population with an ideal distribution would have an abundance of newly planted and young trees, and lower numbers of established, maturing, and mature trees.

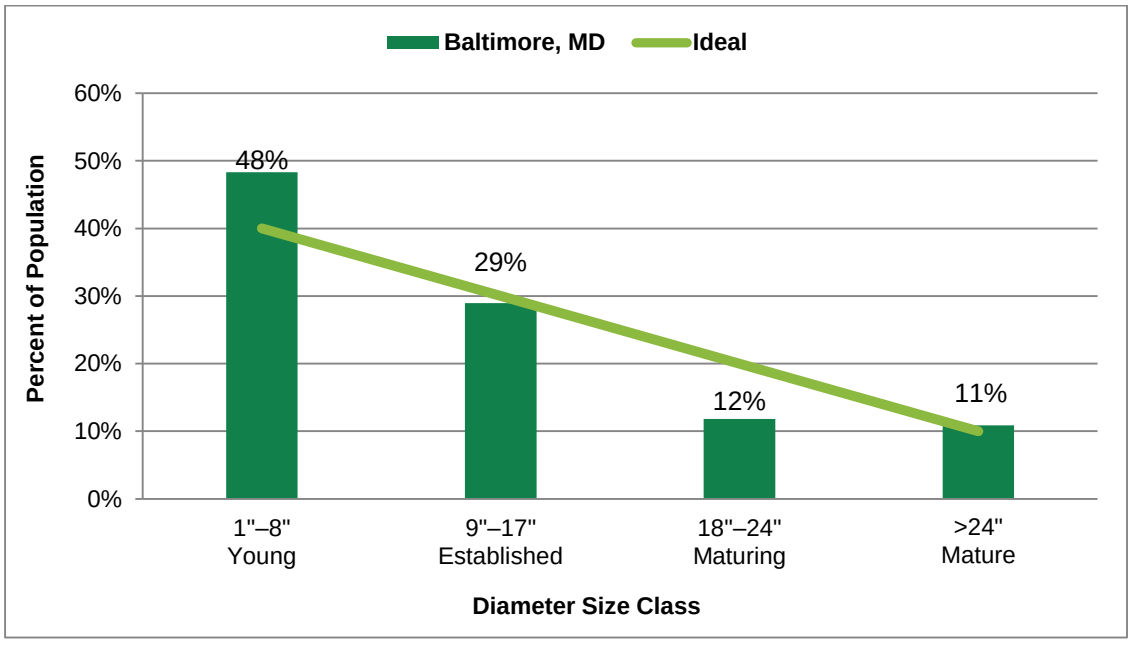


Figure 5. Comparison of diameter size class distribution for inventoried trees to the ideal distribution.

Findings

Figure 5 compares Baltimore's diameter size class distribution of the inventoried tree population to the ideal proposed by Richards (1983). The City of Baltimore's distribution trends toward the ideal; young trees exceed the ideal by 8%, while maturing trees fall short by 8%.

Discussion

Even though it may appear that Baltimore may have too many young trees, this may not necessarily be the case. Another contributing factor to the skewed distribution is a lower than ideal percentage of established and maturing trees. One of the city's objectives is to have an uneven-aged distribution of trees at the street, park, and citywide levels. DRG recommends the city have a strong planting and maintenance program to ensure that young, healthy trees are in place to fill in tree canopy gaps and replace older declining trees. The city must promote tree preservation and proactive tree care to ensure the long-term survival of older trees.

Additionally, tree planting and tree care will allow the distribution to normalize over time. See Appendix C for a recommended tree species list for planting. See Appendix D for planting suggestions and information on species selection.

Planting trees is necessary to increase canopy cover and replace trees lost to natural mortality (expected to be 1%–3% per year) and other threats (for example, invasive pests or impacts from weather events such as storms, wind, ice, snow, flooding, and drought). Planning for the replacement of existing trees and identifying the best places to create new canopy is critical.

Condition

DRG assessed the condition of individual trees based on methods defined by the International Society of Arboriculture (ISA). Several factors 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 Good, Fair, Poor, or Dead.

In this plan, the general health of the inventoried tree population was characterized by the most prevalent condition assigned during the inventory.

Comparing the condition of the inventoried tree population with relative tree age (or size class distribution) can provide insight into the stability of the population. Since tree species have different lifespans and mature at different diameters, variables such as heights, crown spreads, and actual tree age cannot be determined from diameter size class alone. Nonetheless, general classifications of size can be extrapolated into relative age classes. The following categories are used to describe the relative age of a tree: young (0–8 inches DBH), established (9–17 inches DBH), maturing (18–24 inches DBH), and mature (greater than 24 inches DBH).

Figures 6 and 7 illustrate the general health and distribution of young, established, mature, and maturing trees relative to their condition.

Findings

Most of the inventoried trees were recorded to be in Good condition, 64% (Figure 6). Based on these data, the general health of the overall inventoried tree population is rated Good. Figure 7 illustrates that most trees across all age classes were rated to be in Good condition. The percentage of trees in Good condition decreases in the older age sectors.

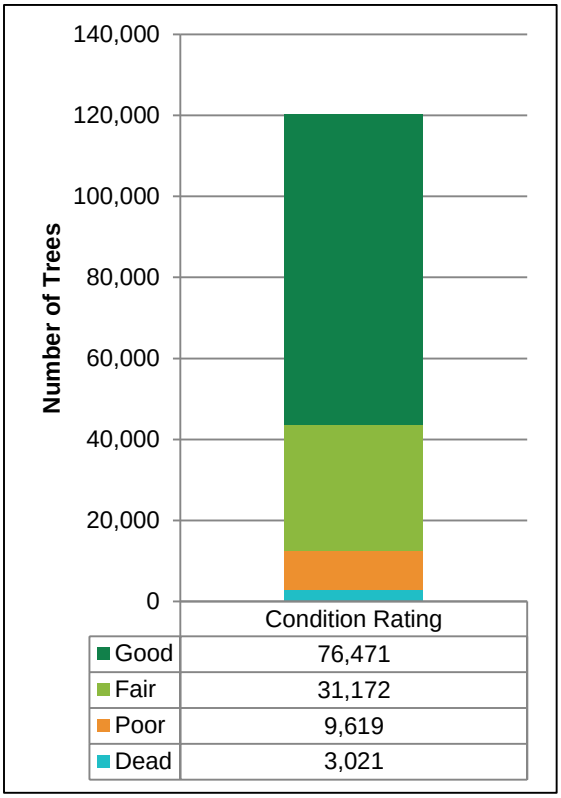


Figure 6. Conditions of inventoried trees.

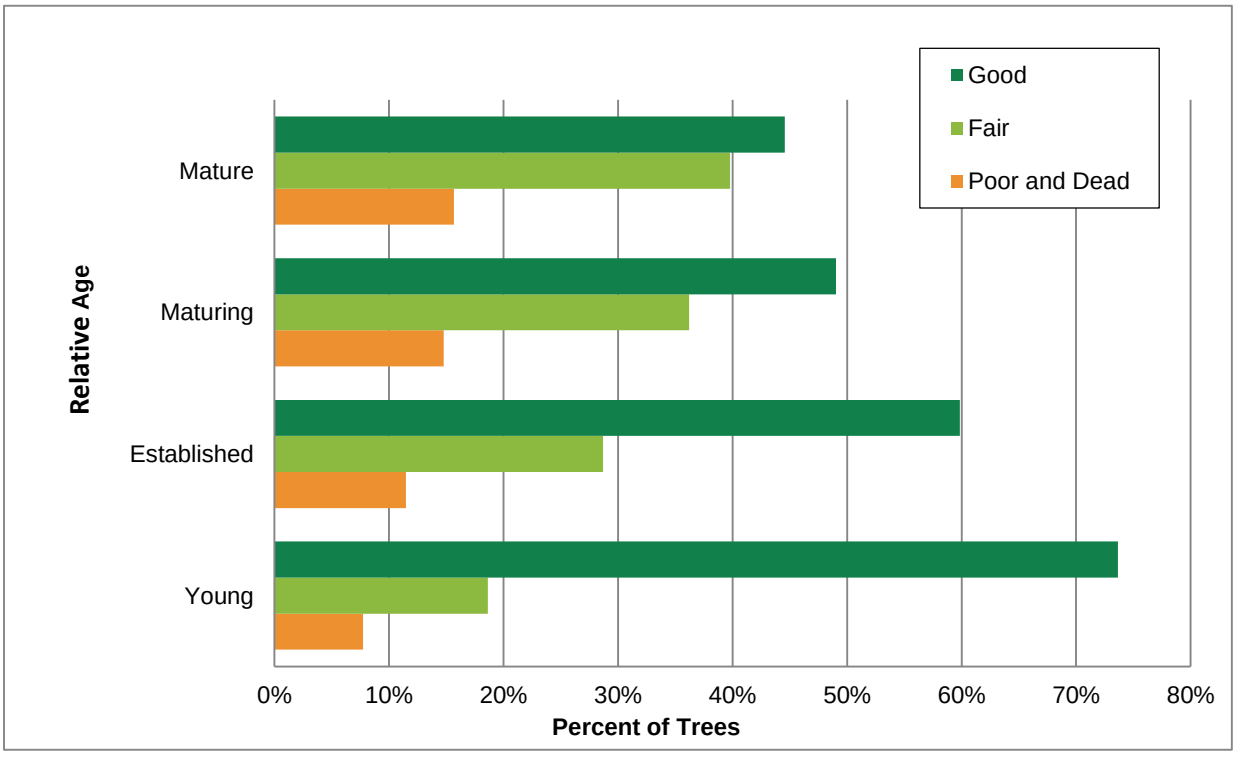


Figure 7. Tree condition by relative age during the 2017–2018 inventory.

Discussion

Even though the condition of Baltimore's inventoried tree population is rated Good, data analysis has provided the following insight into maintenance needs and historical maintenance practices:

- Dead or dying trees should be removed because of their potential public risk, whereas these trees will likely not recover, even with increased care. It is more financially feasible to pursue maintenance of healthy trees and remove those beyond their economic life.
- Younger trees rated in Fair or Poor condition may benefit from improvements in structure that may improve their health over time. Pruning should follow *ANSI A300 (Part 1)* standards (ANSI 2008).
- 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 require corrective pruning, regular inspections, and possible intensive plant health care to improve their vigor. The cost to cure the tree may outweigh the benefits, some poor trees may not recover even with intensive tree care.
- Proper tree care practices are needed for the long-term general health of the urban forest. Many of the newly planted trees were improperly mulched or had staking hardware in place long after it should have been removed. The following guidelines developed by ISA and those recommended by *ANSI A300 (Part 6)* (ANSI 2012) will ensure that proper tree maintenance practices ultimately improve the health of the urban forest.

Street ROW Stocking Level

Stocking is a traditional forestry term used to measure the density and distribution of trees. For an urban/community forest such as Baltimore's, stocking level is used to estimate the total number of sites along the street ROW that could contain trees. Park trees and public property trees are excluded from this measurement.

Stocking level is the ratio of street ROW spaces occupied by trees to the total street ROW spaces suitable for trees. For example, a street ROW tree inventory of 1,000 total sites with 750 existing trees and 250 planting sites would have a stocking level of 75%.

For an urban area, DRG recommends that the street ROW stocking level be at least 90% so that no more than 10% of the suitable potential planting sites along the street ROW are vacant.

Calculations of trees per capita are important in determining the density of a city's urban forest. Areas with more residents and greater housing density call for a greater need for trees to provide benefits.

The inventory indicates 93,675 trees present in the city's ROW. The City of Baltimore's ratio of street trees per capita, based on census data, is approximately 0.15, which falls below the mean ratio of 0.37 reported for 22 U.S. cities (McPherson and Rowntree 1989).

Findings

Figure 8 shows the amount of each type of vacant site collected. The inventory found a total of 65,550 planting sites. Of the inventoried sites, 40,068 were vacant sites suitable for immediate planting (Vacant Site); 21,678 were locations suitable for vacant sites, but were still paved or had yet to have a well or pit cut (Vacant Potential); and 3,804 were vacant sites not suitable for immediate planting (Vacant Site Not Suitable).

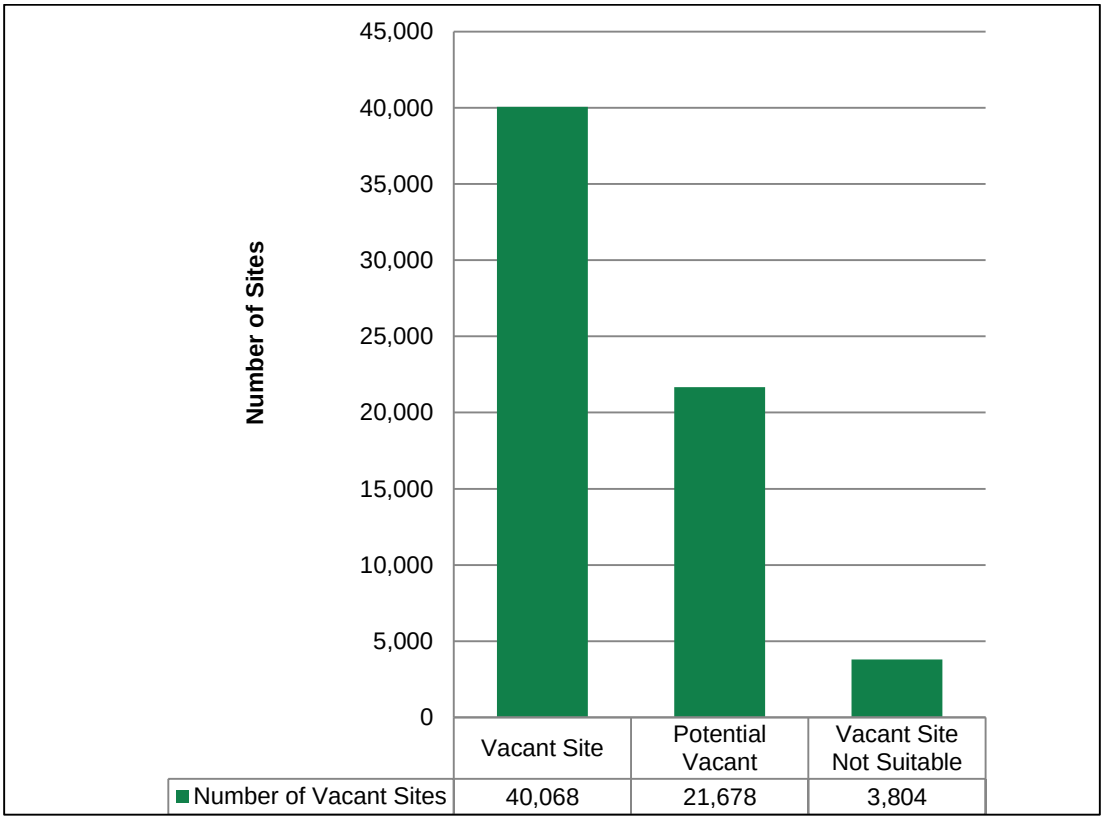


Figure 8. Vacant sites collected during the 2017-2018 inventory by site type.

Comparing the total number of planting sites (65,550) to the total number of sites along the city ROW (163,546), Baltimore's current street ROW tree stocking level is 57%.

Discussion

Less than ideal ROW stocking levels can be attributed to a combination of urban tree mortality, inadequate maintenance funding, and low actual tree plantings. Urban trees are outside of the their typical in situ environment and struggle with atypical anthropogenic stressors. Soil productivity, pollution, limited growing space, and physical damage are common mortality contributors. Inadequate tree planting and maintenance budgets, along with urban tree mortality, will result in lower stocking levels.

Fully stocking the street ROW with trees is an excellent planting goal. Working to attain a fully stocked street ROW is important to promote canopy continuity and environmental sustainability. The city should consider improving its street ROW population's stocking level by 35%, working toward achieving the ideal of 90%. These vacant site locations provide a bulk view of where to continue street tree plantings. Refining this data by overlaying other mappings would facilitate a hierarchy of planting sites, based on community input. Generally, this entails a planned program of planting, care, and maintenance for the city's street trees.

The City of Baltimore estimates it plants 2,000 trees per year internally, with an additional 1,000 planted by city and project partners. With 65,550 planting sites along the street ROW, it would take approximately 8 years for the city to reach the recommended stocking level of 90%. If possible, exceeding this recommendation can better prepare for impending threats to the urban canopy.

Other Observations

Observations were recorded during the inventory to further describe a tree's health, structure, or location when more detail was needed. The observations analyzed here were from a predetermined and prioritized list (Table 1). Secondary, custom notes and comments were also collected but vary on their usage.

Findings

Temporary staking and mechanical damage were most frequently observed and recorded (7.81% and 3.85% of inventoried trees, respectively).

Table 1. Observations Recorded During the 2017–2018 Tree Inventory

Observation	Number of Trees	Percent
Temporary Staking	9,389	7.81%
Mechanical Damage	4,630	3.85%
Temporary Trunk Protection	4,093	3.40%
Broken Branch in Tree	1,975	1.64%
Improperly Mulched	776	0.65%
Nutrient Deficiency	623	0.52%
Improperly Planted	276	0.23%
Permanent Trunk Protection	147	0.12%
Protective Hardware Present	66	0.05%
Trees in Population	**120,283**	**100%**

Discussion

Trees noted as with temporary staking present (9,389 trees) should be regularly inspected for potential constriction. In fact, some may already be impacted by the staking hardware and removal may be required to mitigate future hazards. Future planting efforts should emphasize proper staking—it should only be installed when necessary to keep trees from leaning (windy sites) or to prevent damage from pedestrians and/or vandals. Stakes should only be attached to trees with a loose, flexible material.

Installed hardware that has been attached to any tree for more than one year, and hardware that may no longer be needed for its intended purposes, should be inspected and removed as appropriate.

Trees with observable mechanical damage (4,630 trees) could indicate inadequate protection from mowers, string-trimmers, or other lawn care equipment or pedestrians and vehicles. Education of maintenance staff and outreach to citizens along with proper mulching and guards could help lower this percentage.

Photograph 2. *Temporary staking and fencing can guide young tree development and provide trunk protection. However, to remain effective, these safeguards must be properly maintained.*

Infrastructure Conflicts

In an urban setting, space is limited both above and below ground. Trees in this environment may conflict with infrastructure, such as buildings, sidewalks, and utility wires and pipes, which may pose risks to public health and safety. The inventory examined the following potential conflicts with infrastructure:

- *Overhead Utilities*—The presence of overhead, pole to pole utility lines above a tree, stump, or planting site was noted; it is important to consider these data when planning pruning activities and selecting tree species for planting.
- *Hardscape Damage*—Trees can adversely impact hardscape, which affects tree root and trunk systems. The inventory recorded whether there was a hardened surface placed over the root surface up to the trunk. These data should be used to schedule hardscape alterations, tree pruning, and plan repairs to damaged infrastructure. To limit hardscape damage caused by trees, trees should only be planted in growing spaces where adequate above ground and below ground space is provided.

Findings

There were 15,646 (8.2%) sites recorded with some type of overhead utility. Most of those sites, 5.8% of the total sites, had both electric and communication utilities.

Hardscape damage was minimal: only 1.8% of the total sites were noted to have a hardened surface present over the root surface up to the trunk.

Table 2 shows the number of trees affected by the different types of overhead utilities and the different types of hardscape.

Table 2. Trees Noted to be Conflicting with Infrastructure

Conflict	Infrastructure Present	Number of Trees	Percent
Overhead Utilities	Electric	3,652	1.9%
	Communication	943	0.5%
	Both	11,051	5.8%
	None	175,295	91.8%
Hardscape	Steel Grate	1,283	0.7%
	Pavers/Bricks	918	0.5%
	Stone	768	0.4%
	Concrete	349	0.2%
	Other	93	0.0%
	None	187,530	98.2%
Total Sites		**190,941**	**100%**

Discussion

Tree canopy should not interfere with vehicular or pedestrian traffic, nor should it rest on buildings or block signs, signals, or lights. Pruning to avoid clearance issues and raise tree crowns should be completed in accordance with *ANSI A300 (Part 9)* (2011). DRG's clearance distance guidelines are as follows: 14 feet over streets; 8 feet over sidewalks; and 5 feet from buildings, signs, signals, or lights.

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

Trees currently conflicting with overhead utilities can be difficult to manage. Ensure that staff have adequate training and certification for utility line clearance work. Proper pruning cuts should be made to allow trees and utilities to co-exist where possible. Where this is not possible, tree removal should be considered.

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.

Hardscape conflicts present in the inventory should be managed primarily by removing the offending hardscape. Root pruning can be difficult and cause permanent damage to trees. As with overhead utilities, if the level interference with hardscape is too high, tree removal should be considered.

Growing Space

Information about the type and size of the growing space was recorded. Growing space size was recorded as length and width, up to 20 feet. Growing space types are categorized as follows:

- Tree Lawn/Grass Strip—The strip of land between a sidewalk and a road.
- Well/Pit—A square, rectangular, or round hole cut in a paved surface for the purpose of planting a tree.
- Open/Unrestricted—Includes areas such as open park space, or a street tree that is not confined by a Tree Lawn/Grass Strip, Planter/Raised Bed, or Well/Pit.
- Median/Island—A median is the strip of land between the lanes of opposing traffic and a divided highway. An island is a piece of land surrounded by road.
- Planter/Raised Bed—A planting space similar to or built on a tree pit which raises the soil surface above the sidewalk or street surface.
- Natural Area—An area that is not maintained but includes a tree that would be considered part of a park feature.
- Bump Out—An area created in a paved surface for planting trees or herbaceous plants.

Photograph 3. *A well/pit in the sidewalk to grow trees is common on the City of Baltimore's streets.*

- Other—An area that does not otherwise fit into the above categories.
- Potential Well/Pit—Used exclusively for potential vacant sites. A site where a well or pit could be dug to house a tree in the future.

Findings

Much of the tree population is in open or otherwise unrestricted areas (37%), wells or pits (31%), or in tree lawns (25%). Vacant sites on the other hand were overwhelmingly located in tree lawns (84%). This difference is largely due to the fact that vacant sites were not collected in parks, on open lawns, or behind sidewalks—the most common locations identified as open/unrestricted.

Discussion

To prolong the useful life of street trees**,** small-growing tree species should be planted in tree lawns 4–5 feet wide, medium-size tree species in tree lawns 6–7 feet wide, and large-growing tree species in tree lawns at least 8 feet wide. The useful life of a public tree ends when the cost of maintenance exceeds the value contributed by the tree. This can be due to increased maintenance required by a tree in decline, or it can be due to the costs of repairing damage caused by the tree's presence in a restricted site.

Potential Threats from Pests

Insects and diseases pose serious threats to tree health. Awareness and early diagnosis are essential to ensuring the health and continuity of street and park trees. Appendix E provides information about some of the current potential threats to Baltimore's trees and includes websites where more detailed information can be found.

Pests target a single species or an entire genus. The inventory data were analyzed to provide a general estimate of the percentage of trees susceptible to some of the known pests in Maryland (Figure 9). It is important to note that the figure only presents data collected from the inventory. Many more trees throughout Baltimore, including those on public and private property, may be susceptible to these invasive pests.

Findings

Granulate ambrosia beetle (*Xylosandrus crassiusculus*), spotted lanternfly (SLF or *Lycorma delicatula*), and Asian longhorned beetle (ALB or *Anoplophora glabripennis*) are known threats to a large percentage of the inventoried street trees (58.4%, 48.3%, and 29.8%, respectively). These pests were not detected during the inventory, but due to the large percentages of host trees identified, the city could see severe losses in canopy should an infestation occur.

Although no special information was collected regarding Baltimore's ash trees, 3,644 ash trees were inventoried along the street ROW and in the parks. Of these, 27% were in Good condition, 35% Fair, 29%, Poor, and 10% were already dead.

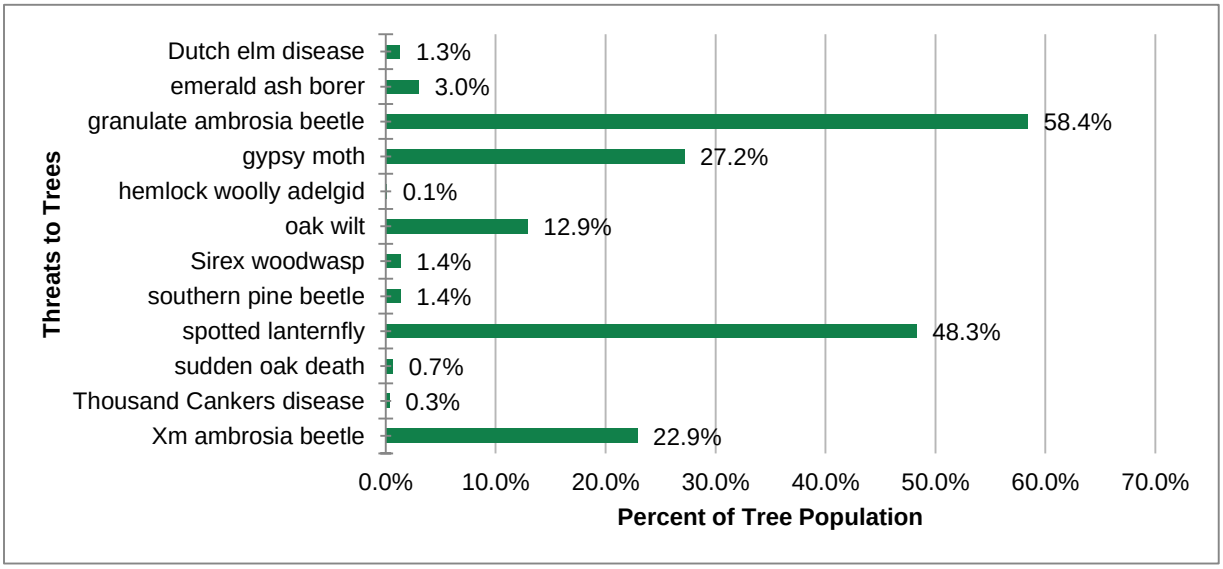


Figure 9. Potential impact of insect and disease threats noted during the 2017-2018 inventory.

Discussion

The City of Baltimore should be aware of the signs and symptoms of potential infestations and should be prepared to act if a significant threat is observed in its tree population or a nearby community (such as spotted lanternfly in Philadelphia).

The city should establish an integrated pest management plan to focus on identifying and monitoring threats. Additional support and guidance can be provided by understanding the economic threshold of each pest, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating results.

SECTION 2: BENEFITS OF THE URBAN FOREST

The urban forest plays an important role in supporting and improving the quality of life in urban areas. Tree shade and beauty contribute to community quality of life by softening the often-hard appearance of urban landscapes and streetscapes. When properly maintained, trees provide communities abundant environmental, economic, and social benefits far exceeding the time and money invested in planting, pruning, protection, and removal.

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).

The trees growing along the public streets constitute a valuable community resource. They provide numerous tangible and intangible benefits, such as pollution control, energy reduction, stormwater management, property value increases, wildlife habitat, natural resource education, and civic aesthetics.

The services and benefits of trees in the urban and suburban setting were once considered to be unquantifiable. Today, by using extensive scientific studies and practical research, these benefits can now be confidently calculated using tree inventory information.

The results of applying a proven, defensible model and method that determines tree benefit values for Baltimore's tree inventory data are summarized in this report using the i-Tree's Streets application. The results of the tree inventory provide insight into the overall health of the city's public trees and the management activities needed to maintain and increase the benefits of trees into the future.

Photograph 4. *Trees provide significant aesthetic value to the community. Additionally, the tangible services of trees provide quantifiable benefits that justify the time and money invested in planting and maintenance.*

Tree Benefit Analysis

i-Tree Streets

In order to quantify the dollar value provided and returned to the community, the city's tree inventory data were formatted for use in the i-Tree Streets benefit-cost assessment tool. i-Tree Streets, a component of i-Tree Tools, analyzes an inventoried tree population's structure to estimate the costs and benefits of that tree population.

i-Tree Tools

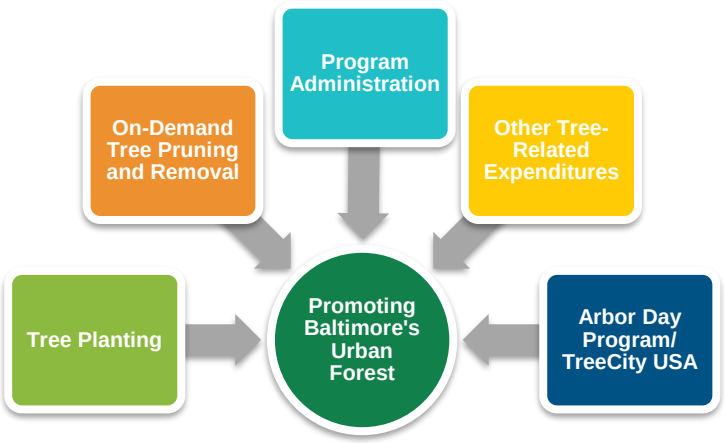
i-Tree Tools software was developed by the U.S. Department of Agriculture, Forest Service (USDA FS) with the help of several industry partners, including The Davey Tree Expert Company. Learn more at www.itreetools.org.

The assessment tool creates an annual benefit report that demonstrates the value street trees provide to a community.

These quantified benefits and the reports generated are described below:

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

i-Tree Streets Inputs



In addition to tree inventory data, i-Tree Streets requires cost-specific information to manage a community's tree management program—including administrative costs and costs for tree pruning, removal, and planting. Regional data, including energy prices, property values, and stormwater costs are required inputs to generate the environmental and economic benefits trees provide. If community program costs or local economic data are not available, i-Tree Streets uses default economic inputs from a reference city selected by United States Department of Agriculture (USDA) FS for the climate zone in which your community is located. Any default value can be adjusted for local conditions. Local data was supplied by the City for use in i-Tree Streets.

The City of Baltimore's Inputs

Local data input was supplied to DRG by the City and were used to the greatest extent possible with i-Tree Streets to calculate the benefits Baltimore's trees provide its citizens.

The input for the local benefits the community forest benefits were derived from these specified multipliers, and not the default Stratum Reference City. DRG used only ROW tree data for the i-Tree Streets assessment. Park tree data were excluded from the assessment due to data collection protocol, which included stands, but also because i-Tree Streets is primarily used to assess street tree populations.

Annual Benefits

The i-Tree Streets model estimated the inventoried trees provide a total annual benefit of $9,329,944. Essentially, $9.3 million was saved that would have otherwise been spent to cool and heat buildings, manage stormwater, and clean the air. In addition, community aesthetics were improved, and property values increased because of the presence of trees. On average, each of 120,700+ ROW trees of Baltimore contribute an annual benefit of $77.57.

The assessment found that aesthetics and other tangible and intangible benefits trees provide were the greatest value to the community. Approximately half of the total annual benefits were due to increases in property value. In addition, trees also play a major role in stormwater management. The city's trees provided a savings of over $2.7 million in stormwater management costs, comprising 29% of the annual benefits that the city's trees provide. Energy conservation, air quality, and reductions in CO_2 are important but account for lesser amounts of work performed by community trees. Energy reductions accounted for 11% of the annual benefits, air quality improvements for 4%, and CO_2 reductions accounted for 3%. Figure 10 summarizes the annual benefits and results for the street tree population.

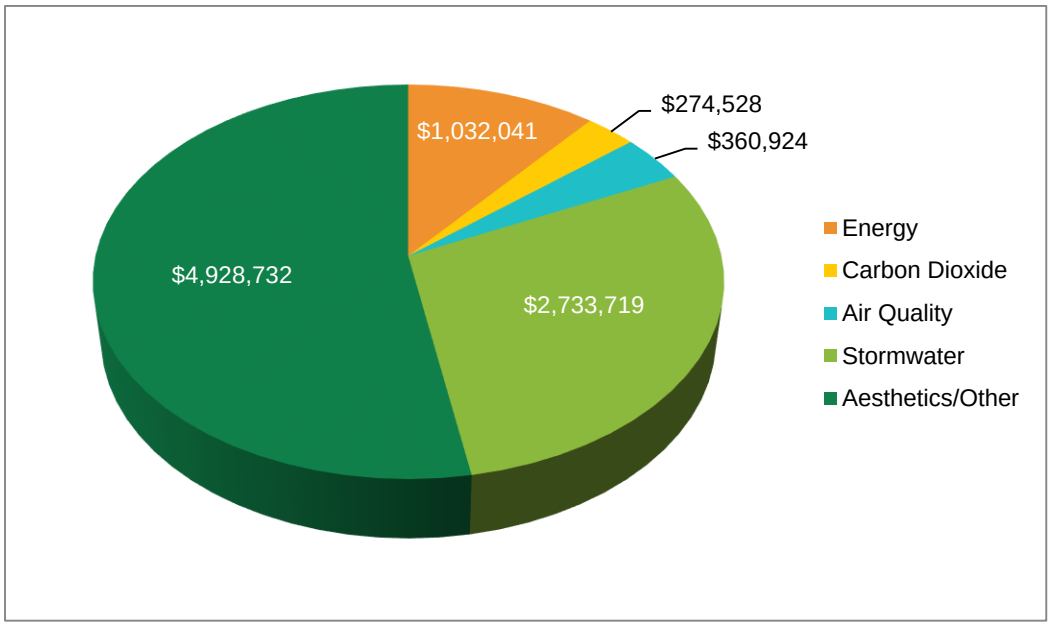


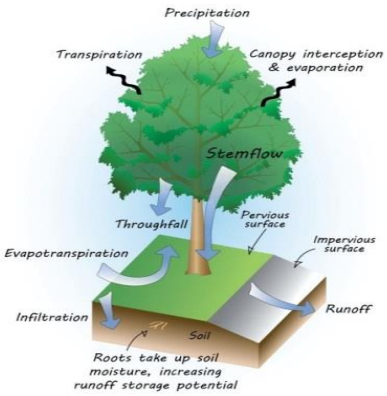
Figure 10. Breakdown of total annual benefits provided to Baltimore.

Aesthetic/Other Benefits

The total annual benefit associated with property value increases and other tangible and intangible benefits of the inventoried trees was $4,928,732. The average benefit to property values alone per tree equaled $40.98 per year.

Stormwater Benefits

Trees intercept and attenuate rainfall, which helps lower costs to manage stormwater runoff. On a per tree basis, large trees with leafy canopies provide the most value. The inventoried trees in Baltimore intercept over 276 million gallons of rainfall that would otherwise immediately enter the city's stormwater system. Through this service, Baltimore's trees provide an annual savings of $2,733,719. On average, the estimated annual savings for the city in stormwater runoff management is $22.73 per tree.



- *Trees reduce stormwater runoff by capturing and storing rainfall in their canopy and releasing water into the atmosphere.*
- *Tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil.*
- *Trees help slow down and temporarily store runoff and reduce pollutants by absorbing nutrients and other pollutants from soils and water through their roots.*
- *Trees transform pollutants into less harmful substances.*

Air Quality Improvements

The inventoried tree population annually removes 78,419 pounds of air pollutants (including ozone, nitrogen dioxide, sulfur dioxide, and particulate matter). The i-Tree Streets calculation considers the biogenic volatile organic compounds (BVOC's) that are released from trees in this calculation. While trees do a great deal to absorb air pollutants, they also contribute negatively to air pollution. Trees emit various BVOCs such as isoprenes and monoterpenes, which can also contribute to formation of ozone, a harmful gas that pollutes the air and damages vegetation. The net total value of these benefits is estimated to be $360,924. The inventoried trees removed or avoided more pollutants than they emitted, resulting in a positive economic value. On average, each tree provides $3.00 in air quality improvement benefits.

i-Tree Tools

A common example of a natural BVOC is the gas emitted from pine trees, which creates the distinct smell of a pine forest.

Carbon Storage and Carbon Sequestration

Trees store some of the carbon dioxide (CO_2) they absorb. This prevents CO_2 from reaching the upper atmosphere, where it can react with other compounds and form harmful gases like ozone, which adversely affects air quality. These trees also sequester some of the CO_2 during growth (Nowak et al. 2013).

The i-Tree Streets calculation considers the carbon emissions that are *not* released from power stations due to the heating and cooling effect of trees (i.e., conserved energy in buildings and homes). It calculates emissions released during tree care and maintenance, such as driving to the site and operating equipment. The net carbon benefit is approximately $274,528 per year.

Baltimore trees store 15,848 tons of carbon (measured in CO_2 equivalents). This amount reflects the amount of carbon they have amassed during their lifetimes. An additional 3,211 tons of CO_2 per year are mitigated through avoidance. On average, each tree provides $2.28 in benefits through CO_2 storage and sequestration.

Photograph 5. *Trees improve quality of life and help enhance the character of a community. Trees filter air, water, and sunlight, moderate local climate, slow wind and stormwater, shade homes, and provide shelter to animals and recreational areas for people.*

Energy Benefits

Baltimore's trees conserve energy by shading structures and surfaces, which reduces electricity use for air conditioning in the summer. In the winter, these same trees divert winds and reduce natural gas use. Based on the inventory data, the annual electric and natural gas savings are equivalent to approximately 9,112 megawatt-hours (MWh) of electricity and 325,455 therms (thm) of natural gas, which accounts for an annual savings of $1,032,041 in energy consumption. On average, each tree provides $8.58 in benefits through CO_2 storage and sequestration.

Discussion

The i-Tree Streets analysis revealed Baltimore trees provide environmental and economic benefits to the community by virtue of their mere presence on the streets. Currently, the 'aesthetic/other' category of benefits provided by the trees were rated as having the greatest value to the community. The property value increase provided by trees is important to stimulate economic growth. In addition to increasing aesthetics and property values, trees manage stormwater through rainfall interception, provide shade and windbreaks to reduce energy usage, and store and sequester CO_2. Singularly these environmental benefits were not found to be as great as the aesthetic/other benefits, together they account for the majority of the benefits.

To increase the benefits the urban forest provides, Baltimore should plant young, large-statured tree species that are low emitters of BVOCs wherever the planting site permits. Leafy, large-stature trees consistently created the most environmental and economic benefits. See Appendix C for recommended species for future plantings. The following list of tree species may be used for improving air quality (ICLEI 2006):

- *Betula nigra* (river birch)
- *Celtis laevigata* (sugar hackberry)
- *Fagus grandifolia* (American beech)
- *Metasequoia glyptostroboides* (dawn redwood)
- *Tilia tomentosa* (silver linden)
- *Ulmus americana* (American elm)
- *Ulmus procera* (English elm)

SECTION 3: TREE MANAGEMENT PROGRAM

This tree management program was developed to uphold The City of Baltimore's comprehensive vision for preserving its urban forest. This ten-year program is based on the tree inventory data. It aims to prioritize tree removal and pruning (based on DBH and ash removals) and presents a strong planting schedule to mitigate removals and increase canopy cover, eliminate all stumps found through the inventory, and expand the city's public outreach and education efforts.

The recommended tree maintenance work was divided into three categories; **priority maintenance**, **maintenance pruning**, or **proactive tree maintenance**. **Priority maintenance** includes tree removals and trees designated for priority pruning by the inventory that was performed by ISA Certified Arborists. **Proactive tree maintenance** includes all trees above 4.5 inch DBH for either pruning or removal neighborhood by neighborhood. Proactive tree maintenance that actively mitigates elevated-risk situations will promote public safety and potentially reduce storm damage. Tree planting, stump removal, inspections, and community outreach are also considered proactive maintenance. Inherently, tree removals create additional stumps during the removal process—where applicable, these costs are accounted for in the budget beyond the existing inventory stump count.

While implementing a tree care program is an ongoing process, tree work must always be prioritized to reduce public safety risks. DRG recommends completing the work identified during the inventory based on the type of work and diameter size class. Since risk rating information was not collected; these metrics provide the basis of tree work prioritization. High-diameter removals and pruning work should be considered before lower size classes. **Maintenance pruning** can occur after these priorities are addressed, again focusing on higher diameter trees first. Proactive pruning, existing stump removal and tree planting efforts will continue throughout all ten years of the plan.

Routine monitoring of the tree population is essential so that other trees of concern can be identified and systematically addressed. While regular pruning cycles and tree planting are important, priority work must sometimes take precedence to ensure that risk is expediently managed. Performing proactive tree maintenance concurrently with priority maintenance allows for the ability to perform more priority maintenance as well as some maintenance pruning to reduce the level of risk to people and property even more than just priority maintenance alone. Proactive tree maintenance also allows for the assessment of surrounding trees to keep the inventory up to date.

Additionally, updating the tree inventory data can streamline future workload management and lend insight into setting accurate budgets and staffing levels. Inventory updates should be made electronically and can be implemented using the city's internal computer software or TreeKeeper®.

Priority and Proactive Maintenance

Figure 11 shows the breakdown of recommended work on the inventoried trees and their respective diameter size classes.

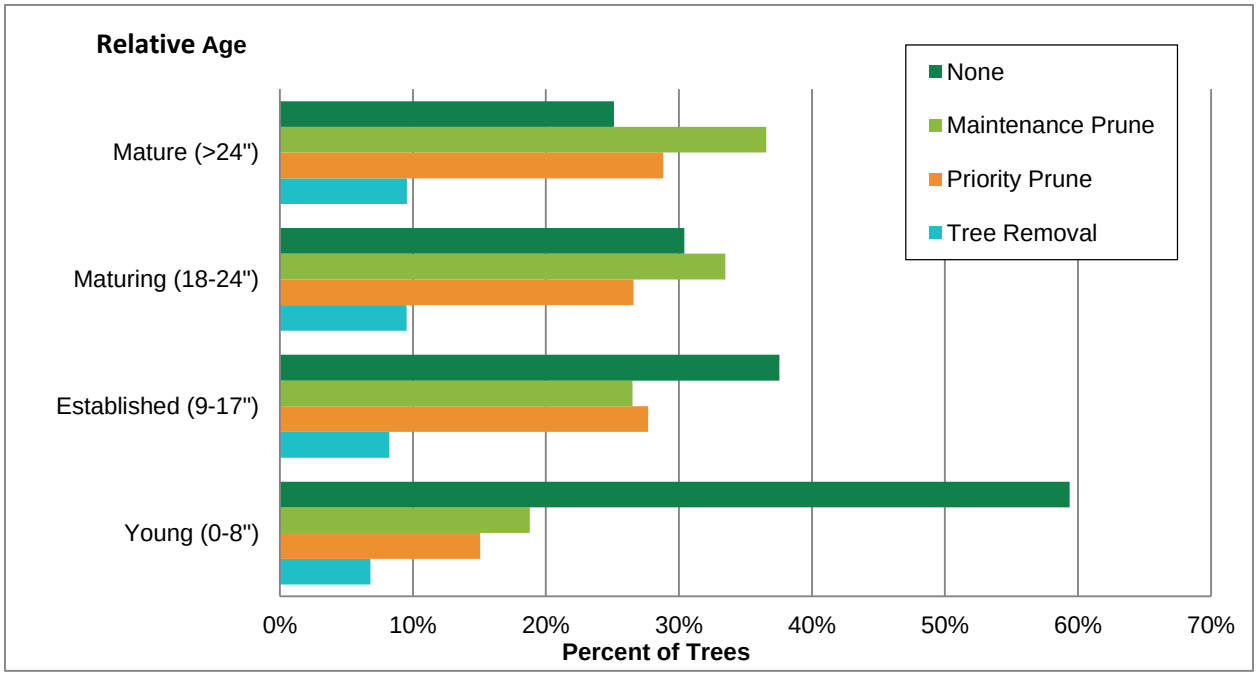


Figure 11. Tree maintenance by diameter size class.

Tree and Stump Removal

Although tree removal is usually considered a last resort and may sometimes create a reaction from the community, there are circumstances in which removal is necessary. Trees fail from natural causes, such as diseases, insects, and weather conditions. However, anthropogenic forces are always at work and tree mortality can be derived from physical injury due to vehicles, vandalism, and root disturbances. DRG recommends that trees be removed when corrective pruning will not adequately eliminate the hazard or when correcting problems would be cost-prohibitive. Trees that cause obstructions or interfere with power lines or other infrastructure should be removed when their defects cannot be corrected through pruning or other maintenance practices. Diseased, nuisance (as defined by the city), and invasive trees may also warrant removal.

Even though large short-term expenditures may be required, it is important to secure the funding needed to complete priority tree removals. Expedient removal reduces risk and promotes public safety.

Findings

Removals noted in the inventory were 1,248 mature trees (>24" diameter), 1,354 maturing trees (18-24" diameter), 2,870 established trees (9-17" diameter), and 3,951 young trees (8" or smaller in diameter). Note that the diameter classes present in the budget differ from these classes. The budget classes are based on contract unit pricing provided by the city.

The inventory also identified 5,108 stumps recommended for removal. Stump removals should likely be a lower priority, as the relative risk of a stump is low compared to tree failure, but removal can occur when convenient and will also increase the amount of potential new tree sites.

Discussion

Even though higher short-term expenditures may be required, it is important to secure the funding needed to complete priority, high-diameter tree removals. The proposed budget reflects prioritizing the largest diameter removals within the first few years. Further accuracy and prioritization can be applied by examining the condition and comments associated with proposed removals. The budget allows for some flexibility regarding small diameter size classes, as these trees can sometimes be a source of lower significant risk. Expedient tree removal reduces risk and promotes public safety.

Unless already slated for removal, trees with poor condition, or those noted as having poor structure, cavity or decay, or similar observations/comments, should be inspected on a regular basis. Corrective action should be taken when warranted. If their condition worsens, tree removal may be required. Proactive tree maintenance that actively mitigates elevated-risk situations will promote public safety and potentially reduce storm damage.

Tree Pruning

Pruning information in the inventory was collected per the ANSI A300 standards and divided into two categories: priority and maintenance pruning. In general, priority pruning was assigned to trees with a dead or otherwise dangerous defect of 7 inches in diameter or greater or where limbs provided a clearance issue. Maintenance pruning was generally assigned to trees with dead limbs or defects 2–7 inches in diameter or otherwise minor structural issues. Complete definitions of the primary maintenance recommendations can be found in the glossary.

Findings

For priority prune, the inventory identified 3,772 mature trees (>24” diameter), 3,780 maturing trees (18–24” diameter), 9,652 established trees (9–17” diameter), and 8,750 young trees (8” or smaller in diameter).

For maintenance prune, the inventory identified 4,784 mature trees (>24” diameter), 4,764 maturing trees (18–24” diameter), 9,243 established trees (9–17” diameter), and 10,912 young trees (8” or smaller in diameter).

Pruning Cycles

The goals of pruning cycles are to visit, assess, and prune trees on a regular schedule to improve health and reduce risk. DRG recommends that maintenance pruning cycles begin after the largest diameter removal and priority prune work has been completed, estimated to begin in Year 4 of the budget with the exception of proactive tree maintenance which is ongoing. The trees identified for maintenance prune can provide the basis of a routine pruning cycle. Further prioritization of maintenance pruning work can come from the forestry district or other stakeholder needs.

Note that the recommended number of trees in the pruning cycles will need to be modified to reflect changes in the tree population as trees are planted, age, and die. Newly planted trees will enter the cycle once they become established.

For many communities, a proactive tree management program is considered unfeasible. An on-demand response to urgent situations is the norm. Research has shown that a proactive program that includes a routine pruning cycle will improve the overall health of a tree population (Miller and Sylvester 1981). Proactive tree maintenance has many advantages over on-demand maintenance, the most significant of which is reduced risk. In a proactive program, trees are regularly assessed and pruned, which helps detect and eliminate most defects before they escalate to a hazardous situation with an unacceptable level of risk. Other advantages of a proactive program include increased environmental and economic benefits from trees, more predictable budgets and projectable workloads, and reduced long-term tree maintenance costs.

Figure 12 shows the decline in tree condition over longer pruning cycles.

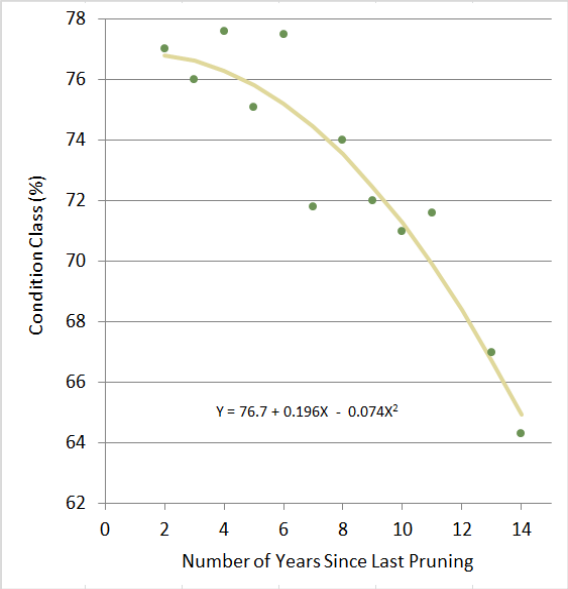


Figure 12. Relationship between average tree condition class and the number of years since the most recent pruning (adapted from Miller and Sylvester 1981).

Why Prune Trees on a Cycle?

Miller and Sylvester (1981) examined the frequency of pruning for 40,000 street and boulevard trees in Milwaukee, Wisconsin. They documented a decline in tree health as the length of the pruning cycle increased. When pruning was not completed for more than 10 years, the average tree condition was rated 10% lower than when trees had been pruned within the last several years. Miller and Sylvester suggested that a pruning cycle of five years is optimal for urban trees.

What is the Proactive Neighborhood Pruning Program?

The City of Baltimore has over 250 neighborhoods and over 93,000 trees along its streets. The city's goal is to perform proactive maintenance in every neighborhood. This program addresses trees greater than 4.5 inches in diameter by either pruning or removing the trees depending on their condition. This approach addresses multiple goals through structural pruning, removal of dead or decaying limbs, and the removal of trees when needed. Neighborhoods have been ranked based on a citywide inventory that identifies maintenance and condition of the trees. The higher the combined score for maintenance and condition, as well as the total number of trees in the neighborhood, the higher the ranking of maintenance need in the neighborhood.

Planting

Planting efforts are based on an estimated 2,000 annual tree plantings by city staff. These costs include establishment, watering, and site maintenance. Estimates also consider the percentage of potential vacant sites identified and account for the cost of cutting new tree pits across the various hardscape found along the city streets.

Maintenance Schedule

Utilizing data from the 2017–2018 tree inventory, an annual maintenance schedule was developed detailing the number and type of tasks recommended for completion each year. DRG made budget projections using industry knowledge, public bid tabulations, and information provided by the city. A complete table of estimated costs for Baltimore's ten-year tree management program is presented on the following page. With the backlog of priority prunes, the budget was presented as 10 years to provide a source of utility and feasibility given the current budget constraints.

The schedule provides a framework for completing the inventory maintenance recommendations over the next ten years. Following this schedule can shift tree care activities from an on-demand system to a more proactive tree care program.

To implement the maintenance schedule, the city's tree maintenance budget should be no less than $4,256,835 for the first year of implementation. Annual budget funds are needed to ensure that high-diameter, poor/dead removal and priority pruning needs are remediated and that crucial maintenance pruning cycles can begin. With proper professional tree care, the safety, health, and beauty of the urban forest will improve.

If routing efficiencies and/or contract specifications allow for the completion of more tree work, or if the schedule requires modification to meet budgetary or other needs, then the schedule should be modified accordingly. Unforeseen situations such as severe weather events may arise and change the maintenance needs of trees. Should conditions or maintenance needs change, budgets and equipment will need to be adjusted to meet the new demands.

Table 3. Estimated Contracted Tree Work Costs for Ten-Year Urban Forestry Management Program

Estimated Costs for Each Activity			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**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	
Tree Removal and Stump Grinding	0.0"-10.4"	$280	600	$168,000	600	$168,000	600	$168,000	600	$168,000	600	$168,000	600	$168,000	600	$168,000	300	$84,000	100	$28,000	48	$13,440	$1,301,440
	10.5"-20.4"	$590	300	$177,000	300	$177,000	300	$177,000	300	$177,000	300	$177,000	285	$168,150	250	$147,500	250	$147,500	250	$147,500	250	$147,500	$1,643,150
	20.5"-30.4"	$810	205	$166,050	200	$162,000	200	$162,000	200	$162,000	100	$81,000	100	$81,000	100	$81,000	100	$81,000	100	$81,000	100	$81,000	$1,138,050
	30.5"-40.4"	$1,280	50	$64,000	50	$64,000	50	$64,000	50	$64,000	50	$64,000	50	$64,000	50	$64,000	50	$64,000	50	$64,000	13	$16,640	$592,640
	40.5"-50.4"	$1,800	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	10	$18,000	$180,000
	50.5"-60.4"	$2,080	5	$10,400	5	$10,400	5	$10,400	5	$10,400	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$41,600
	60.5"-70.4"	$2,390	2	$4,780	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$4,780
Activity Total(s)			**1,172**	**$608,230**	**1,165**	**$599,400**	**1,165**	**$599,400**	**1,165**	**$599,400**	**1,060**	**$508,000**	**1,045**	**$499,150**	**1,010**	**$478,500**	**710**	**$394,500**	**510**	**$338,500**	**421**	**$276,580**	**$4,901,660**
Priority Pruning	0.0"-10.4"	$100	0	$0	2,000	$200,000	9,272	$927,200	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,127,200
	10.5"-20.4"	$125	2,000	$250,000	5,000	$625,000	2,016	$252,000	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,127,000
	20.5"-30.4"	$225	2,000	$450,000	1,722	$387,450	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$837,450
	30.5"-40.4"	$265	1,494	$395,910	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$395,910
	40.5"-50.4"	$265	355	$94,075	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$94,075
	50.5"-60.4"	$365	80	$29,200	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$29,200
	60.5"-70.4"	$390	13	$5,070	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$5,070
Activity Total(s)			**5,942**	**$1,224,255**	**8,722**	**$1,212,450**	**11,288**	**$1,179,200**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$0**	**$0**	**$3,615,905**
Maintenance Pruning	0.0"-10.4"	$100		$0		$0		$0	1,892	$189,200	1,892	$189,200	1,892	$189,200	1,892	$189,200	1,892	$189,200	1,891	$189,100	1,891	$189,100	$1,324,200
	10.5"-20.4"	$125		$0		$0		$0	1,350	$168,750	1,350	$168,750	1,349	$168,625	1,349	$168,625	1,349	$168,625	1,349	$168,625	1,349	$168,625	$1,180,625
	20.5"-30.4"	$225		$0		$0		$0	721	$162,225	721	$162,225	721	$162,225	721	$162,225	721	$162,225	720	$162,000	720	$162,000	$1,135,125
	30.5"-40.4"	$265		$0		$0		$0	258	$68,370	258	$68,370	257	$68,105	257	$68,105	257	$68,105	257	$68,105	257	$68,105	$477,265
	40.5"-50.4"	$265		$0		$0		$0	63	$16,695	63	$16,695	63	$16,695	63	$16,695	63	$16,695	63	$16,695	62	$16,430	$116,600
	50.5"-60.4"	$365		$0		$0		$0	11	$4,015	11	$4,015	11	$4,015	10	$3,650	10	$3,650	10	$3,650	10	$3,650	$26,645
	60.5"-70.4"	$390		$0		$0		$0	3	$1,170	3	$1,170	3	$1,170	2	$780	0	$0	0	$0	0	$0	$4,290
Proactive Pruning	Budget	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	1	$450,000	0	$450,000	$4,500,000
Activity Total(s)			**1**	**$450,000**	**1**	**$450,000**	**1**	**$450,000**	**4,299**	**$1,060,425**	**4,299**	**$1,060,425**	**4,297**	**$1,060,035**	**4,295**	**$1,059,280**	**4,293**	**$1,058,500**	**4,291**	**$1,058,175**	**4,289**	**$1,057,910**	**$8,764,750**
Existing Stump Removal	0.0"-10.4"	$115	200	$23,000	200	$23,000	200	$23,000	200	$23,000	200	$23,000	200	$23,000	200	$23,000	163	$18,745	150	$17,250	150	$17,250	$214,245
	10.5"-20.4"	$215	160	$34,400	170	$36,550	170	$36,550	170	$36,550	170	$36,550	170	$36,550	170	$36,550	164	$35,260	160	$34,400	160	$34,400	$357,760
	20.5"-30.4"	$315	100	$31,500	100	$31,500	100	$31,500	100	$31,500	100	$31,500	100	$31,500	100	$31,500	75	$23,625	75	$23,625	72	$22,680	$290,430
	30.5"-40.4"	$425	50	$21,250	50	$21,250	50	$21,250	50	$21,250	50	$21,250	50	$21,250	50	$21,250	40	$17,000	40	$17,000	33	$14,025	$196,775
	40.5"-50.4"	$550	15	$8,250	15	$8,250	15	$8,250	15	$8,250	15	$8,250	15	$8,250	15	$8,250	15	$8,250	15	$8,250	11	$6,050	$80,300
	50.5"-60.4"	$665	5	$3,325	5	$3,325	5	$3,325	5	$3,325	5	$3,325	5	$3,325	5	$3,325	5	$3,325	0	$0	0	$0	$26,600
	60.5"-70.4"	$765	5	$3,825	5	$3,825	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$7,650
Activity Total(s)			**535**	**$125,550**	**545**	**$127,700**	**540**	**$123,875**	**540**	**$123,875**	**540**	**$123,875**	**540**	**$123,875**	**540**	**$123,875**	**462**	**$106,205**	**440**	**$100,525**	**426**	**$94,405**	**$1,173,760**
Storm Response		$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	1	$400,000	$4,000,000
Activity Total(s)			**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**1**	**$400,000**	**$4,000,000**
Activity Grand Total			**7,651**		**10,434**		**12,995**		**6,005**		**5,900**		**5,883**		**5,846**		**5,466**		**5,242**		**5,137**		
Cost Grand Total				**$2,808,035**		**$2,789,550**		**$2,752,475**		**$2,183,700**		**$2,092,300**		**$2,083,060**		**$2,061,655**		**$1,959,205**		**$1,897,200**		**$1,828,895**	**$22,456,075**

Table 4. Estimated Additional Costs for Ten-Year Urban Forestry Management Program

Estimated Costs for Each Activity			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**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	**# of Trees**	**Total Cost**	
Tree Planting and 2-Year Warr		$335	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	2,000	$670,000	$6,700,000
2-Year Establishment		$75	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	2,000	$150,000	$1,500,000
Basin/Pit Maintenance		$60	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	850	$51,000	$510,000
Existing Basin/Pit Soil Levelin		$60	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	50	$3,000	$30,000
New Pit: Concrete		$175	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	400	$70,000	$700,000
New Pit: Brick		$200	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	200	$40,000	$400,000
New Pit: Paver		$224	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	200	$44,800	$448,000
Activity Total(s)			**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**5,700**	**$1,028,800**	**$10,288,000**
Admin and Outreach Costs		$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	1	$320,000	$3,200,000
Activity Total(s)			**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**1**	**$320,000**	**$3,200,000**
Maintenance Watering		$30	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	5,000	$150,000	$1,500,000
Pests and Disease Monitoring		$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	1	$25,000	$250,000
Integrated Vegetation Managen		$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	1	$15,000	$150,000
Activity Total(s)			**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**5,003**	**$190,000**	**$1,900,000**
Activity Grand Total			**21,311**		**24,094**		**26,655**		**15,367**		**15,262**		**15,247**		**15,212**		**14,844**		**14,622**		**14,612**		
Cost Grand Total				**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**		**$1,538,800**	**$15,388,000**

Administrative and Community Outreach

The data collected and analyzed to develop this plan contribute significant information about the tree population and can be utilized to guide the proactive management of them. This information can be utilized to justify administration and outreach costs. Through *TreeBaltimore* and other community led organizations, these data can be utilized to promote the value of the urban forest and the tree management program in the following ways:

- Tree inventory data can be used to justify necessary priority and proactive tree maintenance activities as well as tree planting and preservation initiatives.
- Species data can be used to guide tree species selection for planting projects with the goals of improving species diversity and limiting the introduction of invasive pests and diseases.
- Information in this plan can be used to advise citizens about threats to urban trees (such as granulate ambrosia beetle, spotted lanternfly, and emerald ash borer).

There are various avenues for outreach. Maps can be created and posted on websites, in parks, or in business areas. Public service announcements can be developed. Articles can be written and programs about trees and the benefits they provide can be developed. Arbor Day and Earth Day celebrations can become community traditions. Signs can be hung from trees to highlight the contributions trees make to the community. Contests can even be created to increase awareness of the importance of trees. Trees provide oxygen we need to breathe, shade to cool our neighborhoods, and canopies to stand under when it rains.

The City of Baltimore's data are instrumental in helping to provide tangible and meaningful outreach about the urban forest.

Other Maintenance Tasks

Additional maintenance tasks not associated with the inventory data must also be accounted for in the budget. These items include maintenance watering, pest and disease monitoring, litter and storm response, and integrated vegetation management. These tasks contribute directly and indirectly to Baltimore's canopy health. Further maintenance tasks, including inspections and inventory updates, can be included in the pruning and removal work as they occur.

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.

Trees along the street ROW should be regularly inspected and attended to as needed based on the inspection findings. When trees need additional or new work, they should be added to the maintenance schedule and budgeted as appropriate. In addition to locating potential new hazards, inspections are an opportunity to look for signs and symptoms of pests and diseases. Baltimore has a large population of trees that are susceptible to pests and diseases, such as ash, oak, and maple.

DRG also recommends that the inventory and management plan be updated using an appropriate computer software program (TreeKeeper®) where the city can sustain its program and accurately project future program and budget needs:

- Conduct inspections of trees after all severe weather events. Record changes in tree condition, maintenance needs, and risk rating in the inventory database. Update the tree maintenance schedule and acquire the funds needed to promote public safety. Schedule and prioritize work based on risk.
- Perform routine inspections of public trees as needed. Windshield surveys (inspections performed from a vehicle) in line with *ANSI A300 (Part 9)* (ANSI 2011) will help city staff stay apprised of changing conditions. Update the tree maintenance schedule and the budget as needed so that identified tree work may be efficiently performed. Schedule and prioritize work based on risk.
- If the recommended work cannot be completed as suggested in this plan, modify maintenance schedules and budgets accordingly.
- Update the city's inventory database as work is performed. Add new tree work to the schedule when work is identified through inspections or a citizen call process.
- Re-inventory the street ROW, and update all data fields in ten years, or a portion of the population (1/10) every year over the course of ten years.
- Revise the *Tree Management Plan* after ten years when the re-inventory has been completed.

CONCLUSIONS

Every hour of every day, public trees in Baltimore are supporting and improving the quality of life. The city's trees provide an annual benefit of over $9.3 million. When properly maintained, trees provide numerous environmental, economic, and social benefits that far exceed the time and money invested in planting, pruning, protection, and removal.

Managing trees in urban areas is often complicated, especially in a city the size of Baltimore. Navigating recommendations of experts, needs of residents, pressures of local policies, concerns for public safety and liability, physical components of trees, forces of nature and severe weather events, and the expectation that these issues are resolved all at once is a considerable challenge.

The city must carefully consider these challenges to fully understand the needs of maintaining an urban forest. With the knowledge and wherewithal to address the needs of the public trees, Baltimore's canopy is well positioned to thrive. If the management program is successfully implemented, the health and safety of Baltimore's trees and citizens will be maintained for years to come.

Photograph 6. *A street well stocked with trees provides economic, environmental, and social benefits, including temperature moderation, reduction of air pollutants, energy conservation, and increased property values.*

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APPENDIX A
DATA COLLECTION AND SITE LOCATION METHODS

Data Collection Methods

DRG collected tree inventory data using an internally developed computer-based system, Rover, loaded onto pen-based field computers equipped with geographic information system (GIS) and global positioning system (GPS) receivers. The data collected in this system were uploaded into DRG's TreeKeeper® 8 system for quality assurance and delivery. The knowledge and professional judgment of DRG's arborists ensure the high quality of inventory data.

Several data field explanations are included below. All other fields are defined in the glossary. At each site, the following data fields were collected:

- comments
- condition
- hardscape
- location*
- observations
- primary maintenance needs
- mapping coordinates
- space length
- space type
- space width
- species
- tree height
- tree size**
- utilities

* Multiple data fields including location type, address number, street name, and side.

** Measured to the tenth of an inch in diameter at 4.5 feet above ground (or diameter at breast height [DBH]). Stem count was also recorded in the case of trees with multiple stems.

The data collected were extracted from DRG's TreeKeeper® 8 inventory management software and provided as a geodatabase once per month during the collection seasons. A copy of the delivered data remained in TreeKeeper® 8. The data analyzed in this report were from the Baltimore TreeKeeper® 8 system and accessed on January 31, 2019.

Condition

In general, the health and structure of each tree was recorded in one of the following categories based on visible root, trunk, scaffold branch, twig, and foliage conditions at the time of the inventory and adapted from the rating system established by the International Society of Arboriculture:

- *Good*—A fully branched and leafed canopy, and with little to no mechanical damage to the trunk, and little to no branch dieback over 2 inches in diameter, and little to no suckering (water sprouts on the trunk or limbs, nor sprouts from the roots), and the form of the tree is characteristic of the species.
- *Fair*—The canopy is thinning and there is little to low amounts of new growth; or there is noticeable dead wood over 1" in diameter - or crown dieback throughout a majority of the crown, or there is significant mechanical damage to trunk (new or old) or two or more scaffold limbs; or insect/disease damage is visibly affecting growth; or the tree is visible stunted causing the form not to be representative of the species; or premature fall coloring on foliage; needs training prune.
- *Poor*—The tree is in decline. There are significant dead or dying limbs over 2" in diameter, or crown dieback, throughout the entire crown; or there are one or more dead, dying, or broken limbs 7+" in diameter; or there is severe mechanical damage to the trunk and/or scaffold limbs causing decay; or new growth is minimal or absent; needs priority pruning of dead wood.
- *Dead*—Standing dead tree, no signs of life with new foliage, and bark may be beginning to peel; a few suckers or water sprouts may be present; or the tree, alive or dead, has fallen or partially fallen.
- *Sprouts*—Only a stump of a tree is present with one or more water sprouts of 18 inches or greater in height growing from the base or remaining root system.
- *Stump*—Only a stump remains, no water sprouts over 18 inches high present.
- *Absent*—An existing or potential location for a tree, such as an empty tree ring in open ground or a tree pit within a sidewalk, or similar location that could be cut to house a tree, where no tree or stump is currently present.

Observations

When conditions with a specific tree warranted recognition, it was described in this set of three data field (Observations 1, 2, and 3). Additional notes were recorded in the Comments field. The Observations data fields had the following options:

- Temporary Staking—Stake and wire/rope support present on the tree.
- Temporary Trunk Protection—Typically wire fence, plastic pipe, or tape.
- Permanent Trunk Protection—This includes bolted down steel rod fencing and cages.
- Improperly Mulched—Over mulched (over 3"); remove mulch from trunk.
- Improperly Planted—Only to be used for newly planted trees. In other cases, use the 'Poor Location' or 'Growing into Sidewalk" comment as needed.

- Mechanical Damage—The tree has obvious mechanical damage that may affect the health of the tree.
- Nutrient Deficiency—the tree is showing signs of nutrient deficiency.
- Other—See notes.

Primary Maintenance Needs

The following primary maintenance needs were determined based on *ANSI A300 (Part 1)* (ANSI 2008).

- *Maintenance Prune*—A tree that requires maintenance pruning exhibited one or more of the following:
  - Dead limbs over 2" in diameter throughout the crown.
  - Suckers or water sprouts throughout the scaffold limbs or on the trunk.
  - More than one large crossing or rubbing limbs.
  - A younger tree with a double lead in which removal of one lead would be advantageous.
  - Tip dieback throughout the crown.
- *Priority Prune*—A tree that requires priority pruning exhibited one or more of the following:
  - One or more dead, hanging, broken, or otherwise dangerous limbs over 7" in diameter.
  - Limbs resting on roof or pushed up against a window.
  - Low limbs impeding traffic, where the tree is large enough so that the limbs can be raised to 7 feet over sidewalks or to 14 feet over roads.
  - Limbs blocking the need for visibility for safety related items, such as stop signs, stop lights, or when the natural shape of the tree can be maintained - sidewalk lighting.
- *Tree Removal*—The tree is either dead, or no remedial action can alleviate the poor condition of the tree. Trees designated as removal should be rated as poor or dead.
- *Stump Removal*—This category indicates an existing stump that should be removed.
- *Plant Tree*—Identifies a site suitable in its current condition for planting (no growspace expansion needed).
- *None*—A site with either: a tree that does not require immediate work or a potential or vacant site that is currently unsuitable for planting.

Space Type

Information about the type and size of the growing space was recorded. Growing space size was recorded as length and width, up to 20 feet. Growing space types are categorized as follows:

- *Tree Lawn/Grass Strip*—The strip of land between a sidewalk and a road.
- *Well/Pit*—A square, rectangular, or round hole cut in a paved surface for the purpose of planting a tree.
- *Open/Unrestricted*—Includes areas such as open park space, or a street tree that is not confined by a Tree Lawn/Grass Strip, Planter/Raised Bed or Well/Pit.

- *Median/Island*—A median is the strip of land between the lanes of opposing traffic and a divided highway. An island is a piece of land surrounded by road.
- *Planter/Raised Bed*—A planting space similar to or built on a tree pit which raises the soil surface above the sidewalk or street surface.
- *Natural Area*—An area that is not maintained but includes a tree that would be considered part of a park feature.
- *Bump Out*—An area created in a paved surface for planting trees or herbaceous plants.
- *Other*—An area that does not otherwise fit into the above categories.
- Potential Well/Pit—Used exclusively for potential vacant sites. A site where a well or pit could be dug to house a tree in the future.

Tree Size

Diameter was measured to the nearest tenth of an inch at 4.5 feet above the ground, or DBH. If a tree split into several trunks close to ground, the diameter of the five largest stems was measured and a single diameter is obtained by taking the square root of the sum of all squared stem diameters. If a tree was measured at a height other than 4.5 feet, the height was recorded in the comments. If a tree was less than 4.5 feet tall or has a DBH of less than 1 inch, the diameter was measured at 12 inches above ground. For stumps the diameter of the stump was measured on the cut surface of the stump with two, averaged perpendicular measurements. For clusters of stems such as crape myrtle, the diameter was a measurement of the cluster.

Site Location Methods

Equipment and Base Maps

Inventory arborists use CF-19 Panasonic Toughbook® or FZ-G1 Panasonic Toughpad® unit(s) and Trimble® GPS Pathfinder® ProXH™ or internal GPS receiver(s).

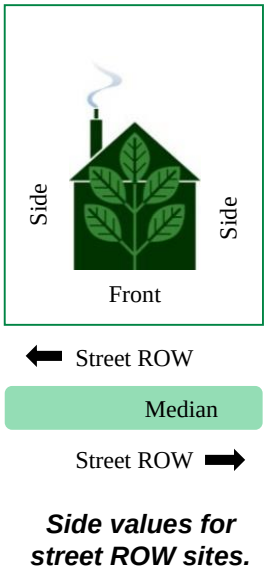
Base map layers were loaded onto these unit(s) to help locate sites during the inventory. The table below lists the base map layers, utilized along with source and format information for each layer.

Base Map Layers Utilized for Inventory

Imagery/Data Source	Date	Projection
Shapefiles: Department of Recreation and Parks Urban Forestry Division Nathan Randolph GIS Specialist	2017–2019	NAD 1983 HARN State Plane Maryland; Feet
Aerial Imagery NearMap Inc. 1ft https://www.nearmap.com	2017-2019	NAD 1983 HARN State Plane Maryland; Feet

Street ROW Site Location

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



Side values for street ROW sites.

Address Number and Street Name

The *address number* was recorded based on visual observation by the arborist at the time of the inventory or based on provided GIS parcel data. Where there was no posted address number on a building, or no GIS parcel data was provided, the arborist used their best judgment to assign an address number based on opposite or adjacent addresses.

Sites in medians or islands were assigned an address number using the address of the building or parcel located most closely to the site.

The *street name* assigned to a site was determined by street ROW parcel information and posted street name signage.

Side Value

Each site was assigned a *side value* and *site number*. Side values include: *front*, *side*, *rear,* or *opposite* based on the site's location in relation to the lot's street frontage. The *front* side is the side that faces the address street. *Sides* are the name of the street the arborist walks toward or away from as data are being collected. The *rear* is the side of the lot opposite the front. *Opposite* is used if the address for the actual location is hard to find, or a very large property.

Park and/or Public Space Site Location

Park and/or public space site locations were collected using the same methodology as street ROW sites; however, the *on street* match the *street* name, *side value* is always *N/A*, and the address is consistent with any parcels.

Site Location Examples

The tree trimming crew in the truck traveling westbound on E. Mac Arthur Street is trying to locate an inventoried tree with the following location information:

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

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

Location information collected for inventoried trees at Corner Lots A and B.

Corner Lot A

Address/Street Name:	205 Hoover St.
E Mac Arthur St.	
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
E Mac Arthur St.	
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
E Mac Arthur 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
Side:	Side
On Street:	Davis St.
Address/Street Name:	226
Side:	Front
On Street:	E Mac Arthur St.
Address/Street Name:	226
Side:	Front
On Street:	E Mac Arthur St.

APPENDIX B
RISK ASSESSMENT, PRIORITY AND PROACTIVE MAINTENANCE

Priority Maintenance

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

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

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

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

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

Proactive Maintenance

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

APPENDIX C
RECOMMENDED SPECIES FOR FUTURE PLANTING

Proper landscaping and tree planting are critical components of the atmosphere, livability, and ecological quality of a community's urban forest. The tree species listed below have been evaluated for factors such as size, disease and pest resistance, seed or fruit set, and availability. The following list is offered to assist all relevant community personnel in selecting appropriate tree species. These trees have been selected because of their aesthetic and functional characteristics and their ability to thrive in the soil and climate conditions throughout Zone 7 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 × freemanii	Freeman maple	
*Aesculus flava**	yellow buckeye	
*Betula alleghaniensis**	yellow birch	
*Betula lenta**	sweet birch	
Betula nigra	river birch	Heritage®
Carya glabra	pignut hickory	
*Carya illinoensis**	pecan	
*Carya ovata**	shagbark hickory	
*Castanea mollissima**	Chinese chestnut	
Celtis laevigata	sugar hackberry	
Celtis occidentalis	common hackberry	'Prairie Pride'
Cercidiphyllum japonicum	katsuratree	'Aureum'
*Diospyros virginiana**	common persimmon	
*Fagus grandifolia**	American beech	
*Fagus sylvatica**	European beech	(Numerous exist)
Ginkgo biloba	ginkgo	(Male trees only)
Gleditsia triacanthos inermis	thornless honeylocust	'Shademaster'
Gordonia lasianthus	loblolly bay	
Gymnocladus dioica	Kentucky coffeetree	Prairie Titan®
*Juglans nigra**	black walnut	
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	black tupelo	
*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 falcata	southern red oak	
Quercus imbricaria	shingle oak	
Quercus lyrata	overcup oak	
Quercus laurifolia	laurel oak	
Quercus macrocarpa	bur oak	
Quercus montana	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus palustris	pin oak	
Quercus phellos	willow oak	
Quercus robur	English oak	Heritage®
Quercus rubra	northern red oak	'Splendens'
Quercus shumardii	Shumard oak	
*Quercus stellata**	post 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 americana	American elm	'Valley Forge', 'New Harmony', 'Princeton'
Ulmus parvifolia	Chinese elm	Allée®
Ulmus x	hybrid elm	
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 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 nigrum	black 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'
Cercis chinensis	Chinese redbud	
Chionanthus virginicus	white fringetree	
Chionanthus retusus	Chinese fringetree	
Cornus alternifolia	pagoda dogwood	
Cornus florida	flowering dogwood	(Numerous exist)
Cornus kousa	Kousa dogwood	(Numerous exist)
Cornus mas	corneliancherry dogwood	'Spring Sun'
Cornus officinalis	Japanese dogwood	
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'
Hamamelis virginiana	witchhazel	(Numerous exist)
Lagerstroemia indica	common crapemyrtle	'Muskogee', 'Natchez'
Lagerstroemia fauriei	Japanese crapemyrtle	'Townhouse', 'Fantasy'
Laburnum × watereri	goldenchain tree	
*Magnolia × soulangiana**	saucer magnolia	'Alexandrina'
*Magnolia stellata**	star magnolia	'Centennial'
*Magnolia tripetala**	umbrella magnolia	
*Magnolia virginiana**	sweetbay magnolia	Moonglow®
Malus species	flowering crabapple	(Disease resistant only)
*Myrica cerifera**	southern waxmyrtle	
Oxydendrum arboreum	sourwood	'Mt. Charm'
Prunus subhirtella	Higan cherry	'Pendula'
Prunus × incamp	Okame cherry	'Okame'
*Staphylea trifolia**	American bladdernut	
Stewartia ovata	mountain stewartia	
*Styrax japonicus**	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'
Vitex agnus-castus	chastetree	
Vitex negundo	cutleaf chastetree	'Heterophylla'

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 concolor	white fir	'Violacea'
*Cedrus deodara**	Deodar cedar	
Cedrus libani	cedar-of-Lebanon	
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica	Japanese cryptomeria	'Sekkan-sugi'
× *Cupressocyparis leylandii*	Leyland cypress	
Ilex opaca	American holly	
*Magnolia grandiflora**	southern magnolia	
Picea omorika	Serbian spruce	
Picea orientalis	Oriental spruce	
Pinus densiflora	Japanese red pine	
*Pinus palustris**	longleaf pine	
Pinus strobus	eastern white pine	
Pinus sylvestris	Scotch pine	
Pinus taeda	loblolly pine	
Pinus virginiana	Virginia pine	
Quercus myrsinifolia	Chinese evergreen oak	
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	

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
TREE PLANTING GUIDE

Tree Planting

Planting trees is a valuable goal as long as tree species are carefully selected and correctly planted. When trees are planted, they are planted selectively and with purpose. Without proactive planning and follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the community.

When planting trees, it is important to be cognizant of the following:

- Consider the specific purpose of the tree planting.
- Assess the site and know its limitations (i.e., confined spaces, overhead wires, and/or soil type).
- Select the species or cultivar best suited for the site conditions.
- Examine trees before buying them and buy for quality.

Tree Species Selection

Selecting a limited number of species could simplify decision-making processes; however, careful deliberation and selection of a wide variety of species is more beneficial and can save money. Planting a variety of species can decrease the impact of species-specific pests and diseases by limiting the number of susceptible trees in a population. This reduces time and money spent to mitigate pest- or disease-related problems. A wide variety of tree species can help limit the impacts from physical events, as different tree species react differently to stress. Species diversity helps withstand drought, ice, flooding, strong storms, and wind.

Baltimore is located in USDA Hardiness Zone 7, which is identified as a climatic region with average annual minimum temperatures between 0°F and 5°F. Tree species selected for planting in Baltimore should be appropriate for this zone.

Tree species should be selected for their durability and low-maintenance characteristics. These attributes are highly dependent on-site characteristics below ground (soil texture, soil structure, drainage, soil pH, nutrients, road salt, and root spacing). Matching a species to its favored soil conditions is the most important task when planning for a low-maintenance landscape. Plants that are well matched to their environmental site conditions are much more likely to resist pathogens and insect pests and will, therefore, require less maintenance overall.

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. Some grow tall, some grow wide, and some have extensive root systems. 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 some shade may be a priority, but it is important to consider how a tree may impact existing utility lines as it grows taller, wider, and deeper. If the tree's canopy, at maturity, will reach overhead lines, it is best to choose another tree or a different location. Taking the time to consider location before planting can prevent power disturbances and improper utility pruning practices.

A major consideration for street trees is the amount of litter dropped by mature trees. Trees such as *Acer saccharinum* (silver maple) have weak wood and typically drop many small branches during a growing season. Others, such as *Liquidambar styraciflua* (American sweetgum), drop high volumes of fruit. In certain species, such as *Ginkgo biloba* (ginkgo), female trees produce large odorous fruit; male ginkgo trees, however, do not produce fruit. Furthermore, a few species of trees, including *Crataegus* spp. (hawthorn) and *Gleditsia triacanthos* (honeylocust), may have substantial thorns. These species should be avoided in high-traffic areas.

Seasonal color should also be considered when planning tree plantings. Flowering varieties are particularly welcome in the spring, and deciduous trees that display bright colors in autumn can add a great deal of appeal to surrounding landscapes.

Tips for Planting Trees

To ensure a successful tree planting effort, the following measures should be taken:

- Handle trees with care. Trees are living organisms and are perishable. Protect trees from damage during transport and when loading and unloading. Use care not to break branches, and do not lift trees by the trunk.
- If trees are stored prior to planting, keep the roots moist.
- Dig the planting hole according to the climate. Generally, the planting hole is two to three times wider and not quite as deep as the root ball. The root flair is at or just above ground level.
- Fill the hole with native soil unless it is undesirable, in which case soil amendments should be added as appropriate for local conditions. Gently tamp and add water during filling to reduce large air pockets and ensure a consistent medium of soil, oxygen, and water.
- Stake the tree as necessary to prevent it from shifting too much in the wind.
- Add a thin layer (1–2 inches) of mulch to help prevent weeds and keep the soil moist around the tree. Do not allow mulch to touch the trunk.

Newly Planted and Young Tree Maintenance

Caring for trees is just as important as planting them. Once a tree is planted, it must receive maintenance for several years.

Watering

Initially, watering is the key to survival; new trees typically require at least 60 days of watering to establish. Determine how often trees should be irrigated based on time of planting, drought status, species selection, and site condition.

Mulching

Mulch can be applied to the growspace around a newly planted tree (or even a more mature tree) to ensure that no weeds grow, that the tree is protected from mechanical damage, and that the growspace is moist. Mulch should be applied in a thin layer, generally 1 to 2 inches, and the growing area should be covered. Mulch should not touch the tree trunk or be piled up around the tree.

Lifelong Tree Care

After the tree is established, it will require routine tree care, which includes inspections, routine pruning, watering, plant health care, and integrated pest management as needed.

Baltimore should employ qualified arborists to provide most of the routine tree care. An arborist can determine the type of pruning necessary to maintain or improve the health, appearance, and safety of trees. These techniques may include: eliminating branches that rub against each other; removing limbs that interfere with wires and buildings or that obstruct streets, sidewalks, or signage; removing dead, damaged, or weak limbs that pose a hazard or may lead to decay; removing diseased or insect-infested limbs; creating better structure to reduce wind resistance and minimize the potential for storm damage; and removing branches—or thinning—to increase light penetration.

An arborist can help decide whether a tree should be removed and, if so, to what extent removal is needed. Additionally, an arborist can perform—and provide advice on—tree maintenance when disasters such as storms or droughts occur. Storm-damaged trees can often be dangerous to remove or trim. An arborist can assist in advising or performing the job in a safe manner while reducing further risk of damage to property.

Plant Health Care, a preventive maintenance process that keeps trees in good health, helps a tree better defend itself against insects, disease, and site problems. Arborists can help determine proper plant health so that the campus tree population will remain healthy and provide benefits to the community for as long as possible.

Integrated Pest Management is a process that involves common sense and sound solutions for treating and controlling pests. These solutions incorporate basic steps: identifying the problem, understanding pest biology, monitoring trees, and determining action thresholds. The practice of integrated pest management can vary depending on the site and based on each individual tree. A qualified arborist will be able to make sure that the campus' trees are properly diagnosed and that a beneficial and realistic action plan is developed.

The arborist can also help with cabling or bracing for added support to branches with weak attachment, aeration to improve root growth, and installation of lightning protection systems.

Educating the community on basic tree care is a good way to promote the campus' urban forestry program and encourage tree planting on private property. Baltimore should encourage citizens to water trees on the ROW adjacent to their homes and to reach out to the campus if they notice any changes in the trees, such as signs or symptoms of pests, early fall foliage, or new mechanical or vehicle damage.

APPENDIX E 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 clean-up costs. Keeping these pests and diseases out of the country is the number one priority of the USDA 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, hungry pests grow and spread rapidly because controls, such as native predators, are lacking. Invasive pests disrupt the landscape by pushing out native species, reducing biological diversity, killing trees, altering wildfire intensity and frequency, and damaging crops. Some pests may even push species to extinction. The following sections include key pests and diseases that adversely affect trees in America at the time of this plan's development. This list is not comprehensive and may not include all threats.

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

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

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

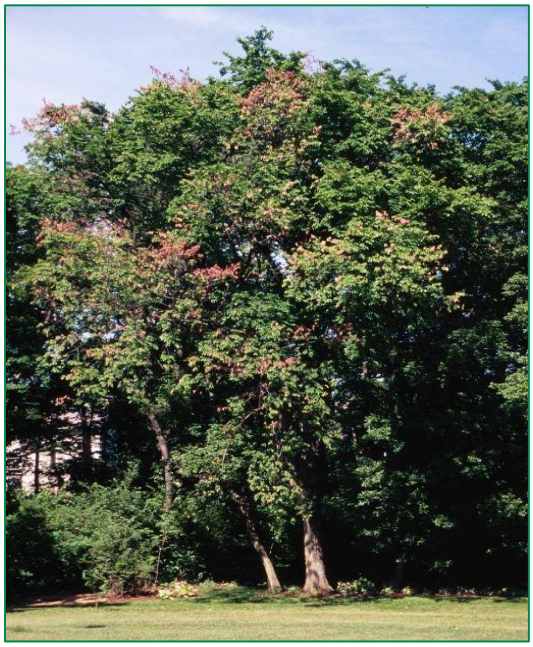
Adult Asian longhorned beetle

Photograph courtesy of New Bedford Guide 2011

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

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. By 1959, it had killed thousands of elms. Today, DED covers about two-thirds of the eastern United States, including Illinois, and annually kills many of the remaining and newly planted elms. The disease is caused by a fungus that attacks the vascular system of elm trees blocking the flow of water and nutrients, resulting in rapid leaf yellowing, tree decline, and death.



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

Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwood.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 elms by elm bark beetles. Two species carry the fungus: native elm bark beetle (*Hylurgopinus rufipes*) and European elm bark beetle (*Scolytus multistriatus)*.

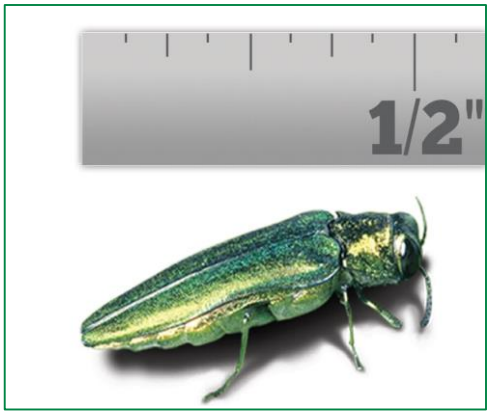
The species most affected by DED is the *Ulmus americana* (American elm).

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.

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).



Close-up of the emerald ash borer

Photograph courtesy of APHIS (2011)

Gypsy Moth

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

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

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

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

Photograph courtesy of APHIS (2011b)

Granulate Ambrosia Beetle

Adult granulate ambrosia beetle

Photograph courtesy of Paul M. Choate, University of Florida (Atkinson et al. 2011)

The granulate ambrosia beetle (*Xylosandrus crassiusculus*), formerly the Asian ambrosia beetle, was first found in the United States in 1974 on peach trees near Charleston, South Carolina. The native range of the granulate ambrosia beetle is probably tropical and subtropical Asia. The beetle is globally present in countries such as equatorial Africa, Asia, China, Guinea, Hawaii, India, Japan, New South Pacific, Southeast Indonesia, Sri Lanka, and the United States. In the United States, this species has spread along the lower Piedmont region and coastal plain to East Texas, Florida, Louisiana, and North Carolina. Populations were found in Oregon and Virginia in 1992, and in Indiana in 2002.

Adults are small and have a reddish-brown appearance with a downward facing head. Most individuals have a reddish head region and a dark brown to black elytra (hard casings protecting the wings). Light-colored forms that appear almost yellow have also been trapped. A granulated (rough) region is located on the front portion of the head and long setae (hairs) can be observed on the back end of the wing covers. Females are 2–2.5mm and males are 1.5mm long. Larvae are C-shaped with a defined head capsule.

The granulate ambrosia beetle is considered an aggressive species and can attack trees that are not highly stressed. It is a potentially serious pest of ornamentals and fruit trees and is reported to be able to infest most trees and some shrubs (azalea, rhododendron) but not conifers. Known hosts in the United States include: *Acer* (maple); *Albizia* (albizia); *Carya* (hickory); *Cercis canadensis* (eastern redbud); *Cornus* (dogwood); *Diospyros* (persimmon); *Fagus* (beech); *Gleditsia* or *Robinia* (locust); *Juglans* (walnut); *Koelreuteria* (goldenrain tree); *Lagerstroemia* (crapemyrtle); *Liquidambar styraciflua* (sweetgum); *Liriodendron tulipifera* (tulip poplar); *Magnolia* (magnolia); *Populus* (aspen); *Prunus* (cherry); *Quercus* (oak); and *Ulmus parvifolia* (Chinese elm). *Carya illinoinensis* (pecan) and *Pyrus calleryana* (Bradford pear) are commonly attacked in Florida and in the southeastern United States.

Hemlock Woolly 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 the hemlock trees, as they feed 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 *Tsuga canadensis* (eastern or Canadian hemlock) and *T. caroliniana* (Carolina hemlock), often damaging and killing them within a few years of becoming infested.

The 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 USDA Forest Service (2011a)

Oak Wilt

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

Oak wilt symptoms on red and white oak leaves

Photograph courtesy of USDA Forest Service (2011a)

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

Sirex Woodwasp

Sirex woodwasp (*Sirex noctillio*) has been the most common species of exotic woodwasp detected at United States ports-of-entry associated with solid wood-packing materials. Recent detections of sirex woodwasp outside of port areas in the United States have raised concerns because this insect has the potential to cause significant mortality of pines. Awareness of the symptoms and signs of a sirex woodwasp infestation increases the chance of early detection, thus increasing the rapid response needed to contain and manage this exotic forest pest.

Close-up of female Sirex Woodwasp

Photograph courtesy of USDA (2005)

Woodwasps (or horntails) are large robust insects, usually 1.0 to 1.5 inches long. Adults have a spear-shaped plate (cornus) at the tail end; in addition, females have a long ovipositor under this plate. Larvae are creamy white, legless, and have a distinctive dark spine at the rear of the abdomen. More than a dozen species of native horntails occur in North America.

Sirex woodwasps can attack living pines, while native woodwasps attack only dead and dying trees. At low populations, sirex woodwasp selects suppressed, stressed, and injured trees for egg laying. Foliage of infested trees initially wilts, and then changes color from dark green to light green, to yellow, and finally to red, during the three to six months following attack. Infested trees may have resin beads or dribbles at the egg laying sites, but this is more common at the mid-bole level. Larval galleries are tightly packed with very fine sawdust. As adults emerge, they chew round exit holes that vary from 1/8 to 3/8 inch in diameter.

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 yellow pines including *P. strobus* (eastern white pine). 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 (wood), 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. Spotted lanternfly feeds on a wide range of fruit, ornamental and woody trees, with tree-of-heaven (*Ailanthus altissima)* being one of the preferred hosts. Spotted lanternflies are invasive and can be spread long distances through movement of 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.

Profile of spotted lanternfly adult at rest

Photograph courtesy of Pennsylvania Department of Agriculture

Adult spotted lanternflies are approximately one inch long and one-half inch wide, and they have large and visually striking wings. Their forewings are light brown with black spots at the front and a speckled band at the rear. Their hind wings are scarlet with black spots at the front and white and black bars at the rear. Their abdomen is yellow with black bars. Nymphs in their early stages of development appear black with white spots and turn to a red phase before becoming adults. Egg masses are yellowish-brown in color, covered with a gray, waxy coating prior to hatching.

The spotted lanternfly lays its eggs on smooth host plant surfaces and on non-host material, such as bricks, stones, and dead plants. Eggs hatch in the spring and early summer, and nymphs begin feeding on a wide range of host plants by sucking sap from young stems and leaves. Adults appear in late July and tend to focus their feeding on tree-of-heaven (*A. altissima*) and grapevine (*Vitis vinifera*). As the adults feed, they excrete sticky, sugar-rich fluid called honeydew. The fluid can build up on plants and on the ground underneath infested plants, causing the formation of sooty mold.

Sudden Oak Death

The causal agent of sudden oak death (SOD, also known as *Phytophthora* canker disease), *Phytophthora ramorum*, was first identified in 1993 in Germany and the Netherlands on ornamental rhododendrons. In 2000, the disease was found in California. Since its discovery in North America, SOD has been confirmed in forests in California and Oregon and in nurseries in British Columbia, California, Oregon, and Washington. In July 2019, SOD was confirmed in Ohio. SOD has been potentially introduced into other states through exposed nursery stock. Through ongoing surveys, APHIS continues to define the extent of the pathogen's distribution in the United States and limit its artificial spread beyond infected areas through quarantine and a public education program.

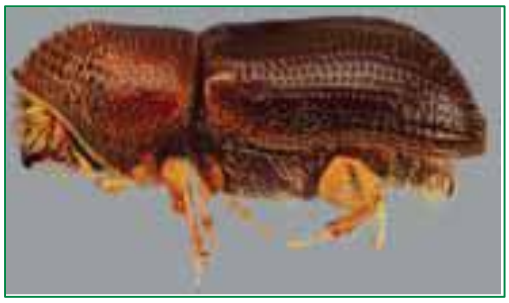
Drooping tanoak shoot

Photograph courtesy of Indiana Department of Natural Resources (2012)

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

Thousand Cankers Disease

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



Walnut twig beetle, side view

Photograph courtesy of USDA Forest Service (2011b)

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

Xm Ambrosia Beetle

The Xm ambrosia beetle (*Xylosandrus mutilatus*), is native to Asia and was first detected in the United States in 1999 in traps near Starkville, Mississippi. By 2002, the beetle spread throughout Missouri and quickly became well-established in Florida. The species also has been found in Alabama, northern Georgia, and Texas. In addition to its prevalence in the southeastern United States, the Xm ambrosia beetle is currently found in China, India, Indonesia, Japan, Korea, Malaya, Myanmar, Papua New Guinea, Sri Lanka, Taiwan, and Thailand.

Xm ambrosia beetle

Photograph courtesy of Michael C. Thomas, Florida Department of Agriculture and Consumer Services (Rabaglia et al 2003)

This species generally targets weakened and dead trees. Since the beetle attacks small diameter material, it may be commonly transported in nursery stock. Female adults are prone to dispersal by air currents and can travel 1–3 miles in pursuit of potential hosts. This active capability results in a broad host range and high probability of reproduction. The species is larger than any other species of *Xylosandrus* (greater than 3 millimeters) in the U.S. and is easily recognized by its steep declivity and dark brown to black elytra (hard casings protecting the wings). Larvae are white and c-shaped with an amber colored head capsule.

Known hosts in the U.S. include: *Acer* (maple); *Albizia* (silktree); *Benzoin* (northern spicebush); *Camellia* (camellia); *Carpinus laxiflora* (looseflower hornbeam); *Castanae* (sweet chestnut); *Cinnamomum camphora* (camphor tree); *Cornus* (dogwood); *Cryptomeria japonica* (Japanese cedar); *Fagus crenata* (Japanese beech); *Lindera erythrocarpa* (spicebush); *Machilus thurnbergii* (Japanese persea); *Ormosia hosiei* (ormosia); *Osmanthus fragrans* (sweet osmanthus); *Parabezion praecox*; *Platycarpa*; and *Sweitenia macrophylla* (mahogany).

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