TREE MANAGEMENT PLAN

City of Carmel, Indiana

June 2018

Prepared for:
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ACKNOWLEDGMENTS

Carmel'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 continuity, which will reduce stormwater runoff and improve aesthetic value, air quality, and public health.

Notice of Disclaimer: Inventory data provided by Davey Resource Group, Inc. "DRG" are based on visual recording at the time of inspection. Visual records do not include individual testing or analysis, nor do they include aerial or subterranean inspection. DRG is not responsible for the discovery or identification of hidden or otherwise non-observable hazards. Records may not remain accurate after inspection due to the variable deterioration of inventoried material. DRG provides no warranty with respect to the fitness of the urban forest for any use or purpose whatsoever. Clients may choose to accept or disregard DRG's recommendations or to seek additional advice. Important: know and understand that visual inspection is confined to the designated subject tree(s) and that the inspections for this project are performed in the interest of facts of the tree(s) without prejudice to or for any other service or any interested party.

EXECUTIVE SUMMARY

This plan was developed for the City of Carmel by DRG with a focus on addressing short-term and long-term maintenance needs for inventoried street 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 Carmel.

State of the Existing Urban Forest

Completed in April 2018, the inventory included trees along public street rights-of-way (ROW). A total of 29,235 trees were recorded during the inventory. Analysis of the street tree inventory data found the following:

- The inventory found 156 species representing 71 genera.
- The species *Acer rubrum* (red maple) comprised 9% of the tree population, followed by *A. saccharum* (sugar maple), 6%; *Gleditsia triacanthos inermis* (thornless honeylocust), 6%; *Celtis occidentalis* (common hackberry), 4%; *Ulmus x* (hybrid elm), 4%; and all other species, 71%.
- The genus *Acer* (maple) was found in abundance (21%), which is a concern for the city's biodiversity.
- A majority (66%) of the tree population is young (tree size class 0–8 inches).
- The overall condition of the inventoried tree population is rated Fair.
- Stocking level, measured by trees per mile, is 60 and above average in the state of Indiana.
- Overhead utilities in conflict with street trees occurs among 10% of the population.
- Approximately 45% of the inventoried trees are located in tree lawns.
- Approximately 60% of the inventoried trees are located where grow space size are equal to or greater than 8 feet.
- Scale, bagworms, and looper complex pose the biggest threats to the health of the inventoried population.
- Trees provide approximately $2.9 million in the following annual benefits:
  - *Aesthetic and other benefits*: valued at $2,539,022 per year.
  - *Air quality improvement*: 17,331 pounds of pollutants removed valued at $25,475 per year.
  - *Carbon sequestered and avoided*: 2,009 tons valued at $12,069 per year.
  - *Energy conservation:* 943,931 kilowatt-hours (kWh) and 18,303 therms valued at $92,573 per year.
  - *Stormwater management reductions:* 37,559,345 gallons valued at $232,868 per year.

Tree Maintenance and Planting Needs

Trees provide many environmental and economic benefits that justify the time and money invested in planting and maintenance. Recommended maintenance needs include: Tree Removal (4%); Tree Clean (49%); and Young Tree Train (47%). Maintenance should be prioritized by addressing trees with the highest risk first. The inventory noted many High and Moderate Risk trees (2% of trees assessed); these trees should be removed or pruned immediately to promote public safety. Low Risk trees should be addressed after all elevated risk tree maintenance has been completed. Trees should be planted to mitigate removals and create canopy.

REMOVAL

- Total = 1,208 trees
- Extreme Risk = 0 trees
- High Risk = 62 trees
- Moderate Risk = 316 trees
- Low Risk = 830 trees

PRIORITY PRUNING

- Total = 283 trees
- Extreme Risk = 0 trees
- High Risk = 10 trees
- Moderate Risk = 273 trees

ROUTINE PRUNING CYCLE

- Total = 13,974 trees
- Number of trees in cycle each year = approximately 1,996

YOUNG TREE TRAINING CYCLE

- Total = 13,770 trees
- Number of trees in cycle each year = at least 4,589

TREE PLANTING

- Number of trees each year = at least 522

Carmel's urban forest will benefit greatly from a three-year young tree training cycle and a seven-year routine pruning cycle. 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. Based on inventory data, at least 4,589 young trees should be structurally pruned each year during the young tree training cycle, and approximately 1,996 trees should be cleaned each year during the routine pruning cycle.

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). DRG recommends planting at least 522 trees of a variety of species each year to offset these losses, increase canopy, and maximize benefits.

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* (maple) should be limited until the species distribution normalizes.

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. The estimated total cost for the first year of this five-year program is $649,986. This total will decrease to approximately $545,060 per year by Year Four of the program. High-priority removal and pruning is costly; since most of this work is scheduled during the first year of the program, the budget is higher for that year. 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.

FY 2019 $649,986

- 378 High or Moderate Risk Removals
- 130 High or Moderate Risk Prunes
- 378 Stump Removals
- YTT 3-Year Cycle: 4,589 Trees
- 242 Trees Recommended for Re-Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal, Pruning, and Re-Planting): Costs TBD

FY 2020 $652,744

- 469 Low Risk Removals
- 153 Moderate Risk Prunes
- 469 Stump Removals
- YTT 3-Year Cycle: 4,589 Trees
- 242 Trees Recommended for Re-Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal, Pruning, and Re-Planting): Costs TBD

FY 2021 $574,949

- 361 Low Risk Removals
- 361 Stump Removals
- RP 7-Year Cycle: 1,996 Trees
- YTT 3-Year Cycle: 4,489 Trees
- 242 Trees Recommended for Re-Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal, Pruning, and Re-Planting): Costs TBD

FY 2022 $545,060

- RP 7-Year Cycle: 1,996 Trees
- YTT 3-Year Cycle: 5,111 Trees
- 242 Trees Recommended for Re-Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal, Pruning, and Re-Planting): Costs TBD

FY2023 $545,060

- RP 7-Year Cycle: 1,996 Trees
- YTT 3-Year Cycle: 5,111 Trees
- 242 Trees Recommended for Re-Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal, Pruning, and Re-Planting): Costs TBD

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 using *TreeKeeper*® or similar software is crucial for making informed management decisions and projecting accurate maintenance budgets.

Carmel 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.

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INTRODUCTION

The City of Carmel is home to more than 95,000 full-time residents who enjoy the beauty and benefits of their urban forest. The city's Urban Forestry Division of the Department of Community Services manages and maintains trees on public property, including trees, stumps, and planting sites along the street rights-of-way (ROW). The city's Urban Forestry Committee assists, advises, and directs the urban forestry program for the City of Carmel. For more than 20 years, Carmel has been practicing arboriculture or had someone responsible to manage street trees.

Funding for Carmel's urban forestry program comes from the city's general fund. Urban Forestry Division staff include three urban foresters who are all college educated with ISA arborist certifications and tree risk assessment qualifications. Carmel conducted a sample street tree inventory in 2010 and completed a comprehensive inventory of street trees in 2018. The city has a tree ordinance, maintains a budget of more than $2 per capita for tree-related expenses, celebrates Arbor Day, has been a Tree City USA community for 24 years. Past urban forestry projects have demonstrated a desire to improve the environment through higher levels of tree care and have earned the city a SMA (Society of Municipal Arborists) Accreditation.

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, tree management plan, and tree inventory software) 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.

Beginning January 2017, the City of Carmel 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 street trees. The following tasks were completed:

- Inventory of trees along the street ROW.
- 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 and environmental benefits that trees provide to the community.
- *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 five-year period.

SECTION 1: TREE INVENTORY ANALYSIS

From January 2017 to April 2018 and in 2 phases, DRG arborists assessed and inventoried trees along the street ROW. A total of 29,235 trees were collected during the inventory. The city's public street rights-of-way were selected by the City of Carmel for the inventory, which included the newly annexed area of Home Place.

Assessment of Tree Inventory Data

Data analysis and professional judgment are used to make generalizations about the state of the inventoried tree population. Recognizing trends in the data can help guide short-term and long-term management planning. See Appendix A for more information on data collection and site location methods. In this plan, the following criteria and indicators of the inventoried tree population were assessed:

- *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*, 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.
- *Street ROW 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 potential planting spaces); stocking level can help determine tree planting needs and budgets.
- *General Observations* include inventory data analysis that provides insight into past maintenance practices and growing conditions; such observations may affect future management decisions.

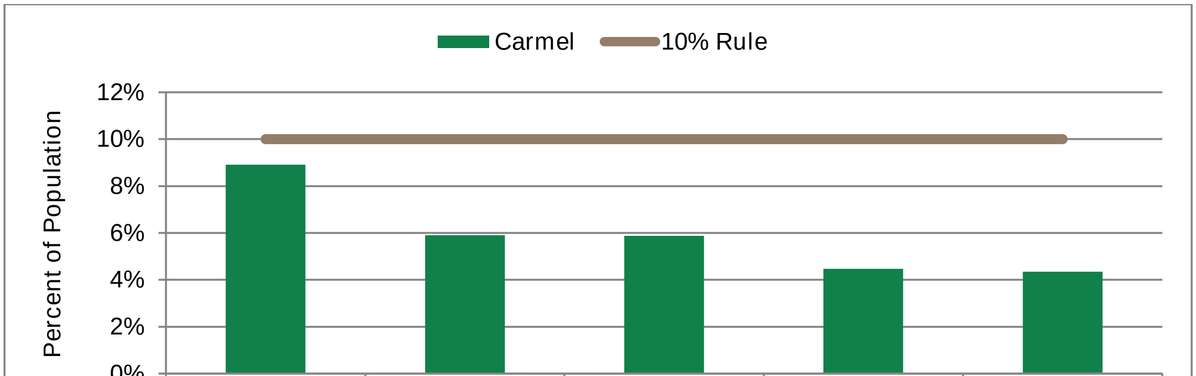
Species Diversity

Species diversity affects maintenance costs, planting goals, canopy continuity, and the forestry program's ability to respond to threats from invasive pests or diseases. 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 Midwestern cities and towns, have perished (Karnosky 1979). Several Midwestern 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. EAB 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.

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%.

Findings

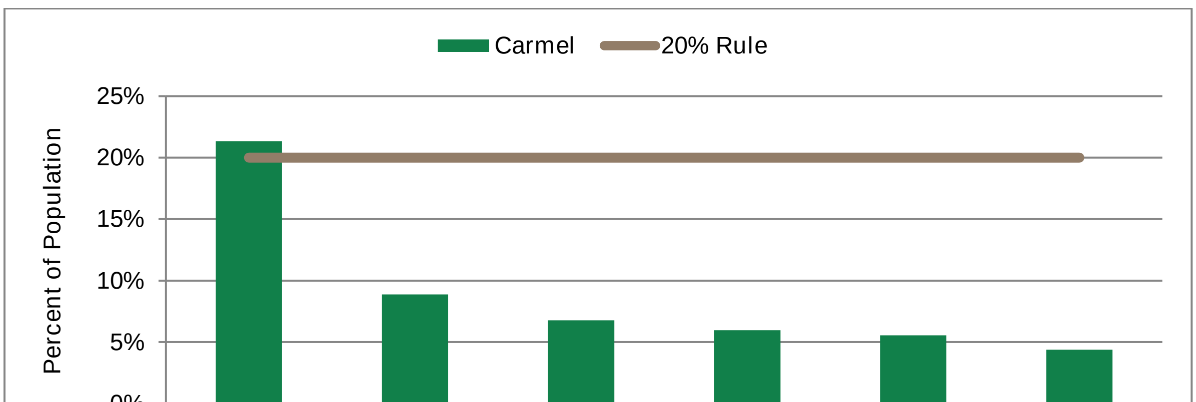
Analysis of Carmel's tree inventory data indicated that the street tree population had relatively good diversity, with 71 genera and 156 species represented. Figure 1 uses the 10% Rule to compare the percentages of the five most common species identified during the inventory to the street tree population. No species exceeds the recommended 10% maximum for a single species in a population. Closest to the 10% threshold is *Acer rubrum* (red maple) at 9%.



	red maple	sugar maple	thornless honeylocust	common hackberry	hybrid elm
Carmel	9%	6%	6%	4%	4%
10% Rule	10%	10%	10%	10%	10%

Figure 1. Five most abundant species of the inventoried population compared to the 10% Rule.

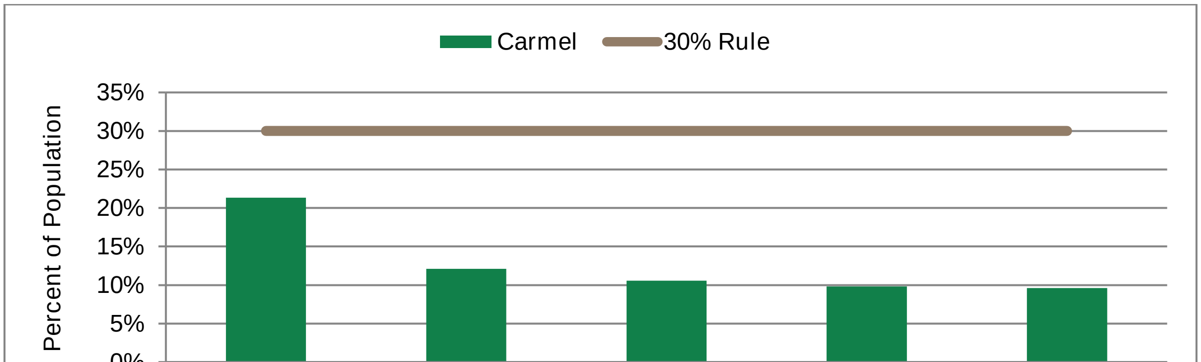
Figure 2 uses the 20% Rule to compare the percentages of the six most common genera identified during the inventory to the street tree population. *Acer* (maple) exceeds the recommended 20% maximum for a single genus in a population, comprising 21% of the inventoried tree population. No other genera are within 10% of the 20% threshold.



	maple	oak	spruce	honeylocust	elm	ash
Carmel	21%	9%	7%	6%	6%	4%
20% Rule	20%	20%	20%	20%	20%	20%

Figure 2. Six most abundant genera of the inventoried population compared to the 20% Rule.

Figure 3 uses the 30% Rule to compare the percentages of the five most common genera identified during the inventory to the street tree population. *Aceraceae* is nearest the recommended 30% maximum for a single family in a population, comprising 21% of the inventoried tree population. No other genera are within 15% of the 30% threshold.



	Aceraceae	Ulmaceae	Rosaceae	Fabaceae	Pinaceae
Carmel	21%	12%	11%	10%	10%
30% Rule	30%	30%	30%	30%	30%

Figure 3. Five most abundant families of the inventoried population compared to the 30% Rule.

Discussion/Recommendations

Acer (maple) dominates the streets. This is a biodiversity concern because its abundance in the landscape makes it a limiting species. Carmel's tree species recommendation list does acknowledge the need to limit the planting of maple as the list includes all *Acer* species in the Undesirable Trees and Comments listing. Continued diversity of tree species is an important objective that will ensure Carmel's urban forest is sustainable and resilient to future invasive pest infestations.

Considering the large quantity of maple in the city's population, along with its susceptibility to ALB, the planting of maple should be limited to minimize the potential for loss in the event that ALB threatens Carmel's urban tree population. See Appendix B 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.

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 were chosen so that the population could be analyzed according to 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. Richards' ideal distribution suggests that 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.

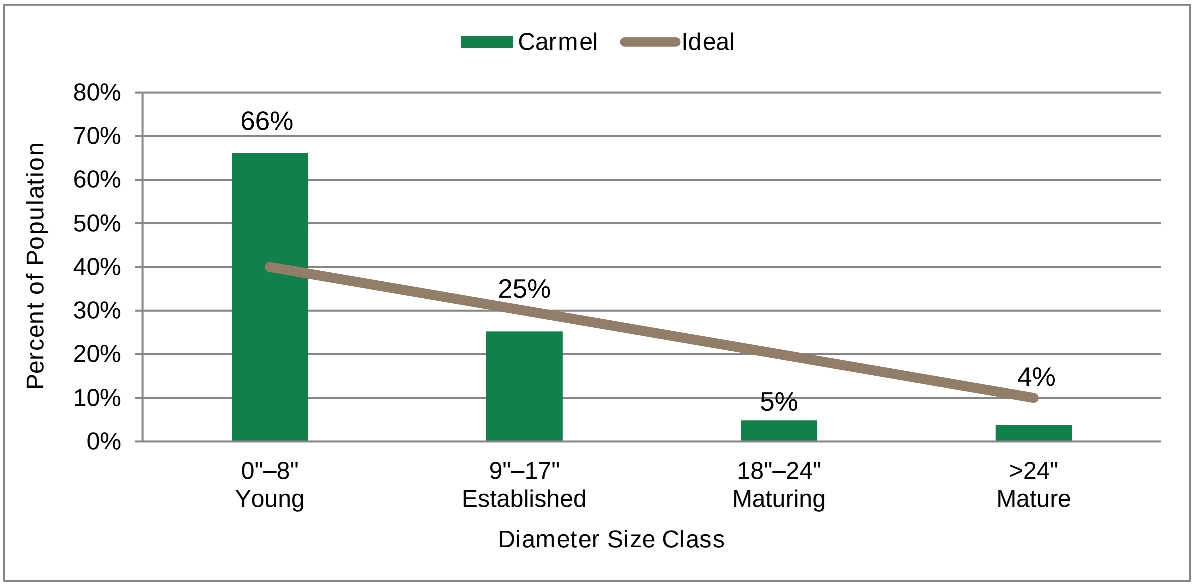


Figure 4. Comparison of diameter size class distribution for inventoried trees to the ideal distribution.

Findings

Figure 4 compares Carmel's diameter size class distribution of the inventoried tree population to the ideal proposed by Richards (1983). Carmel's distribution trends towards the ideal; young trees exceed the ideal by over 26%, while larger diameter size classes fall short of the ideal.

Discussion/Recommendations

Even though it may appear that Carmel may have too many young trees, this is not the case. Actually, by comparison, Carmel has too few established, maturing, and mature trees, which indicates that the distribution is heavily skewed. One of Carmel's objectives is to have an uneven-aged distribution of trees. DRG recommends that Carmel, in addition to supporting a strong planting program, support a young tree maintenance program to ensure that young, healthy trees are well established to fill in gaps in tree canopy and replace declining trees. Tree planting and young tree maintenance will allow the distribution to normalize over time. See Appendix C for planting suggestions and newly planted and young tree maintenance.

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.

Caring for trees is necessary to increase canopy cover and have healthy trees to reduce air and noise pollution, save energy with shade and windbreaks, mitigate stormwater costs, make habitat for wildlife, enhance aesthetics and property values, and contribute to community image, pride, and quality of life.

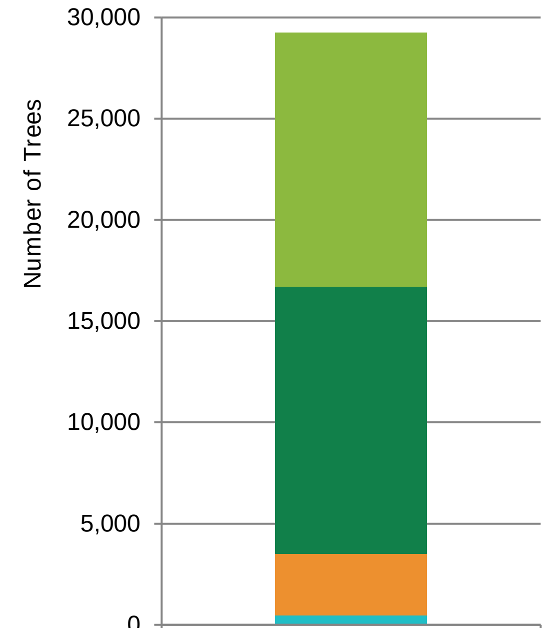
Condition

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, heights, and crown spreads, actual tree age cannot be determined from diameter size class alone. However, 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 5 and 6 illustrate the general health and distribution of young, established, mature, and maturing trees relative to their condition.



	Condition Rating
Good	12,536
Fair	13,201
Poor	3,022
Dead	476

Figure 5. Conditions of inventoried trees.

Findings

Most of the inventoried trees were recorded to be in Fair or Good condition, 45% and 43%, respectively (Figure 5). Based on these data, the general health of the overall inventoried tree population is rated Fair. Figure 6 illustrates that most of the young trees were rated to be in Good condition, and that most of the established, maturing, and mature trees were rated to be in Fair condition.

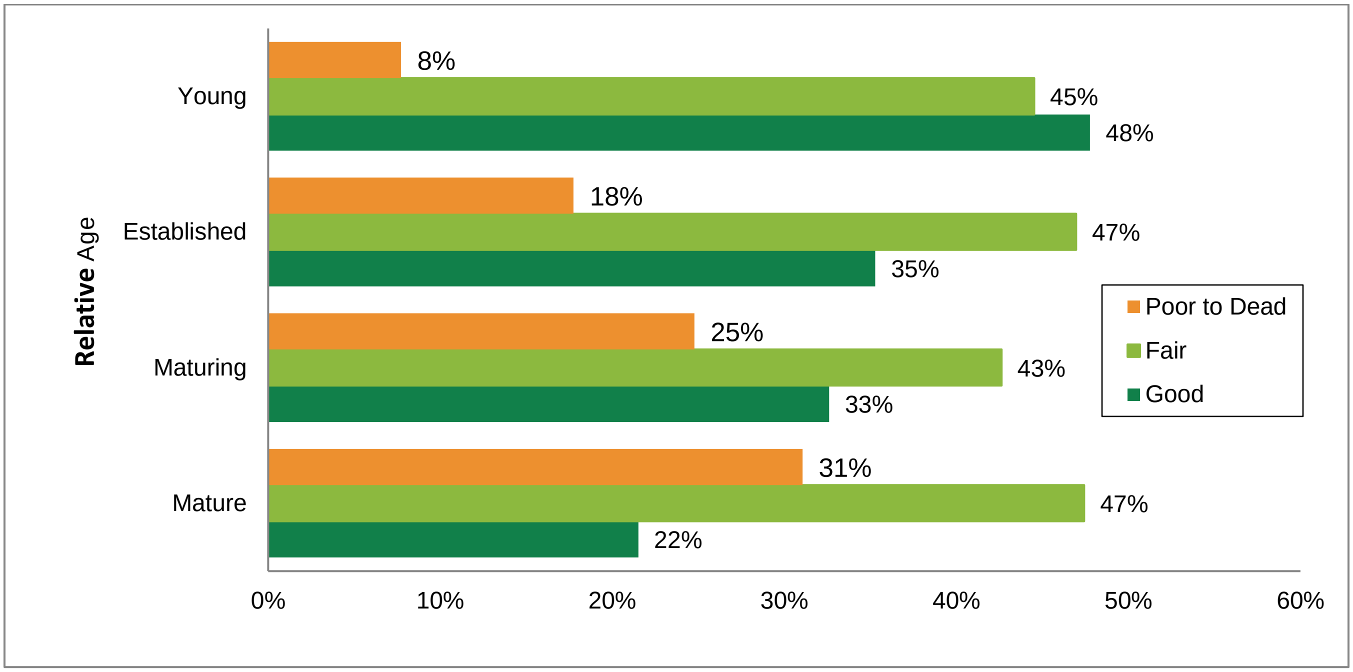


Figure 6. Tree condition by relative age during the inventory.

Discussion/Recommendations

The condition of Carmel's inventoried tree population is typical for most communities. Data analysis has provided the following insight into maintenance needs:

- Dead trees should be removed because of their failed health; these trees will likely not recover, even with increased care.
- Poor condition ratings 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.
- Young and established trees in Fair condition may benefit from improvements in structure that may improve their health over time. Structural pruning should follow *ANSI A300 (Part 1)* (ANSI 2008).
- Proper tree care practices, such as mulching and pest management, are needed for the long-term general health of the urban forest. Following guidelines developed by ISA and those recommended by *ANSI A300 (Parts 1, 2, 6, 7, and 8)* (ANSI 2017, 2011, 2012, 2012, 2013) will ensure that 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 forest such as Carmel's, stocking level is used to estimate the total number of sites along the street ROW that could contain trees.

Stocking level is the ratio of street ROW spaces occupied by trees to the total street ROW spaces suitable for trees. 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 potential planting sites along the street ROW are vacant.

Street ROW stocking levels may be estimated using information about the community, tree inventory data, and common street tree planting practices. Inventory data that contain the number of existing trees and planting sites along the street ROW will increase the accuracy of the projection. However, street ROW stocking levels can be estimated using only the number of trees present and the number of street miles in the community.

To estimate stocking level based on total street ROW miles and the number of existing trees, it is assumed that any given street ROW should have room for 1 tree for every 50 feet along each side of the street. For example, 10 linear miles of street ROW with spaces for trees to grow at 50-foot intervals along each side of the street account for a potential 2,112 trees. If the inventory found that 1,055 trees were present, the stocking level would be 50%.

The potential stocking level for a community with 10 street miles is as follows:

5,280 feet/mile ÷ 50 feet = 106 trees/mile

106 trees/mile × 2 sides of the street = 212 trees/mile

212 trees per street mile × 10 miles = 2,112 potential sites for trees

1,055 inventoried trees ÷ 2,112 potential sites for trees = 50% stocked

When the estimated stocking level is determined using theoretical assumptions, the actual number of planting sites may be significantly less than estimated due to unknown growing space constraints, including inadequate growing space size, proximity of private trees, and utility conflicts.

Carmel's inventory data set did not include planting sites. Since the data did not include planting sites, only the theoretical stocking level for the city is presented.

Findings

Based on a theoretical stocking level, the city has 485 linear miles of street ROW (Indiana Department of Transportation, 2017) and 29,235 trees, which comes to an average of 60 trees per street mile. In theory, any given street should have growing space for 1 tree every 50 feet along each side of a street, or 212 trees per mile. This suggests that there is room for an additional 73,720 street trees (28% stocked) in Carmel to reach full stocking potential or 63,303 to reach DRG's recommended goal of 90%.

Discussion/Recommendation

Fully stocking the street ROW with trees is an excellent goal. Inadequate tree planting and maintenance budgets, along with tree mortality, will result in lower stocking levels. Nevertheless, working to attain a fully stocked street ROW is important to promote canopy continuity and environmental sustainability. Generally, this entails a planned program of planting, care, and maintenance for the city's street trees.

DRG recommends that the city replant all trees removed, approximately 522 trees (242 inventory removal recommendations and 280 accounting for 1% tree mortality). If possible, exceed this recommendation to increase the benefits provided by the urban forest.

The City of Carmel estimates that it plants 250 to 500 trees per year. Theoretically, with 63,303 planting sites along the street ROW, it would take approximately 127 years (not including a 1% mortality factor) for the city to reach the recommended stocking level of 90% (at a rate of 500 trees planted a year).

DRG recommends Carmel use TreeKeeper® to catalog locations and size of planting sites that are available along the street ROW to get a better measurement of stocking level. Having a better account of the number of available planting sites will provide better information for maintenance budgets and drive efficiency in the planting program.

Carmel's trees per street mile is 60—which is more than the mean of 49 for Class 2 Cities in Indiana and less than the mean of 80 reported in New York statewide (Cowett and Bassuk 2011). Table 1 provides a list of the 11 Indiana communities with inventoried street trees and their accounting of trees per street mile. Of the 11 communities, 7 meet or exceed the reported average number of trees per mile in the state of Indiana. The New York statewide trees per mile reference is a benchmark as this may be an attainable goal for Carmel, without an account of available planting sites in Carmel. By planting 500 trees, a year Carmel could achieve 80 trees per mile in 19 years (not including inventory removal recommendations and mortality factor).

Table 1. Street Trees Densities of Class 2 Indiana Cities

Indiana Class 2 Cities	Trees per Mile	People per Tree
Gary, IN	101	3.0
Carmel, IN	60	3.3
South Bend, IN	129	3.3
Valparaiso	57	3.7
Anderson, IN	21	4.4
Fort Wayne, IN	49	4.5
West Lafayette, IN	95	4.9
Bloomington, IN	49	5.2
Lafayette, IN	44	6.1
Muncie, IN	30	6.3
Mishawaka, IN	35	8.2
Average	49	4.5

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

Carmel's ratio of street trees per capita is 0.31, which falls slightly below the mean ratio of 0.37 reported for 22 U.S. cities (McPherson and Rowntree 1989). There is 1 tree for every 3.3 Carmel residents. At 80 trees per mile, Carmel's potential is 1 tree for every 2.5 residents. Table 1 also provides reference to the number of residents per tree in the 11 Indiana communities with inventoried street trees.

General Observations

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. Existing or possible conflicts between trees and infrastructure recorded during the inventory include:

- *Overhead Utilities*—The presence of overhead utility lines above a tree was noted; it is important to consider these data when planning pruning activities and selecting tree species for replacement planting.

Findings

There were 3,047 trees with utilities directly above, or passing through, the tree canopy. Of those trees, 74% were large- or medium-size trees.

Table 2. Trees Noted to be Conflicting with Infrastructure

Conflict	Presence	Number of Trees	Percent
Overhead Utilities	Not Present	26,188	90%
	Present (any Line)	2,859	10%
	Present and Conflicting (w/ Primary Line)	188	<1%
Total		29,235	100%

Discussion/Recommendations

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

Growing Space

Information about the type and size of the growing space was recorded. Growing space size was recorded as the minimum width of the growing space needed for root development. Growing space types are categorized as follows:

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

Findings

Most (45%) of the tree population is located in tree lawns that range between 2 feet and 60 feet wide, with the greatest percentage (68%) being in 4- to 5-foot tree lawns.

A majority (60%) of the tree population is located in a space size of 8 feet or greater.

Table 3. Tree Growth Space Type and Space Size

Grow Space Type	Grow Space Size				Total
	0–3 feet	4–5 feet	6–7 feet	8 feet	
Island	-	3	17	371	391
Median	22	124	164	3,371	3,681
Natural Area	-	-	-	474	474
Open/Restricted	9	70	101	1,425	1,605
Open/Unrestricted	-	-	-	9,846	9,846
Raised Planter	-	1	2	2	5
Tree Lawn/Parkway	570	8,823	1,544	2,078	13,015
Unmaintained Area	-	-	-	103	103
Well/Pit	63	28	13	13	117
Total	664	9,051	1,841	17,681	29,237
Percent	2%	31%	6%	60%	100%

Discussion/Recommendations

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.

Further Inspection

This data field indicates whether a particular tree requires further inspection, such as a Level III risk inspection in accordance with ANSI A300, Part 9 (ANSI, 2011), or periodic inspection due to particular conditions that may cause it to be a safety risk and, therefore, hazardous. If a tree was noted for further inspection, city staff should investigate as soon as possible to determine corrective actions.

Findings

DRG recommended 633 trees for further inspection. Of the 633 trees, 91% need to be monitored for insect/disease problems.

Discussion/Recommendations

The 575 inventoried trees that showed signs or symptoms of pests or diseases should be monitored. If signs or symptoms of pests or diseases exceed the infestation threshold affecting tree health or aesthetics, the pests or diseases should be treated or the tree should be inspected for potential replacement.

An ISA Certified Arborist with a Tree Risk Assessment Qualification should perform additional inspections of the 12 trees with a recommendation of Level 3 inspection and routine inspections of the 46 trees with a recommendation of multi-year annual inspection. If it is determined that these trees exceed the threshold for acceptable risk, the defective part(s) of the trees should be corrected or removed, or the entire tree may need to be removed.

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 trees. Appendix D provides information about some of the current potential threats to Carmel's trees and includes websites where more detailed information can be found.

Many 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 Indiana (see Figure 7). It is important to note that the figure only presents data collected from the inventory. Many more trees throughout Carmel, including those on public and private property, may be susceptible to these invasive pests.

Findings

Scale, bagworms, and looper complex [(*Erannis tiliaria*) and (*Phigalia titea*)] are known threats to a large percentage of the inventoried street trees (67%, 53%, and 48%, respectively). The occurrence of pest presence was not identified during the inventory in Carmel. However, if the following pests are present, the city could see severe losses in its tree population.

- More than 50 species of scale occur in Indiana. Scale insects feed on tree sap and some secret honeydew. The loss of tree sap and collection of honeydew diminishes tree health and causes an aesthetic issue. Scale will cause yellowing of leaves, reduced year's growth, and branch dieback. Tree bark and leaves may also turn black from sooty mold, caused by honeydew, which may also damage tree health. Heavy, reoccurring infestations of scale may kill a tree. These insects threaten 67% of the street tree population.
- Bagworm caterpillars feed on tree leaves and cause irrecoverable damage to conifers. Heavy, reoccurring infestations of bagworms may kill a tree. This insect threatens 53% of the street tree population.
- Linden looper (*Erannis tiliaria*) and spiny looper (*Phigalia titea*) feed on many species and may cause widespread defoliation. These insects may not directly kill trees, but they can severely damage tree health. These insects threaten 48% of the street tree population.
- Calico scale (*Eulecanium cerasorym*) is recognized by Carmel as a pest problem. Calico scale feeds on crabapple, dogwood, elm, hackberry, and honey locust. This insect threatens 19% of the street tree population.
- Emerald ash borer (EAB, *Agrilus planipennis*) is recognized by Carmel as a pest problem. EAB is an insect that bores into and kills most *Fraxinus* species. The presence of EAB in Carmel was first noticed in 2006. The city has been proactively removing dead and dying ash trees for the last few years. There were 1,281 ash trees inventoried along Carmel's street ROW. EAB poses a threat to 4% of the street tree population.

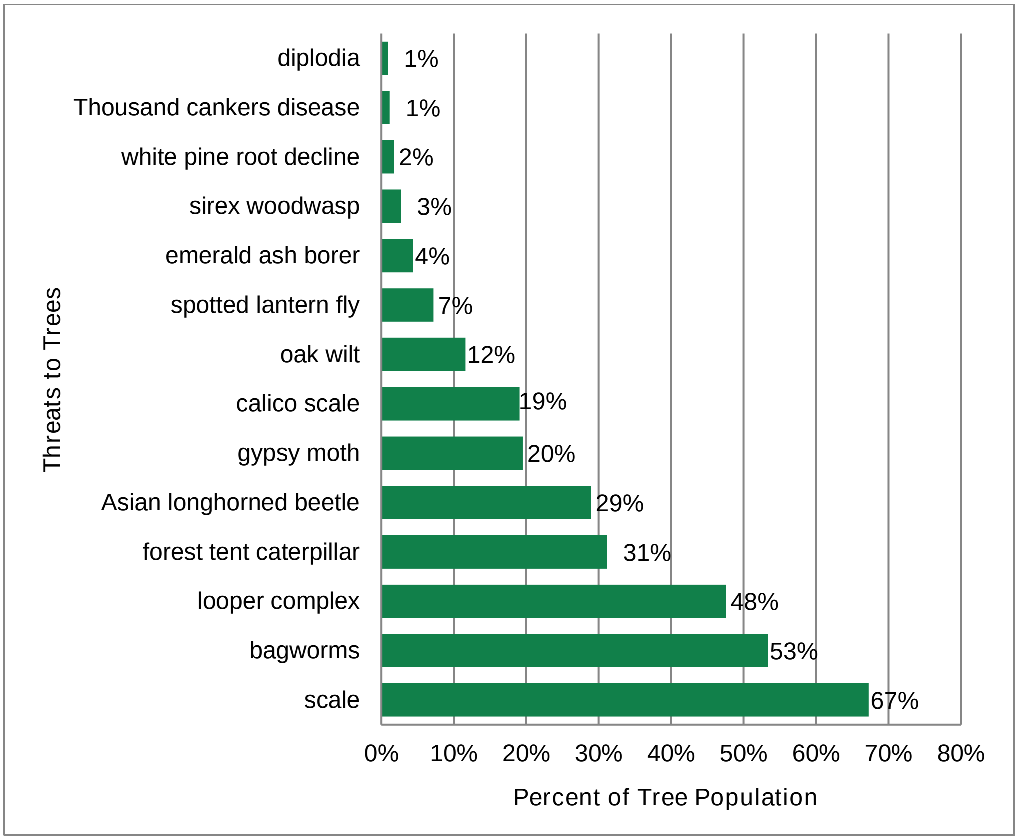


Figure 7. Potential impact of insect and disease threats noted during the inventory.

Discussion/Recommendations

Carmel 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. An integrated pest management plan should be established. The plan should focus on identifying and monitoring threats, understanding the economic threshold, 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. A tree's shade and beauty contribute to a community's quality of life and soften the often hard appearance of urban landscapes and streetscapes. When properly maintained, trees provide communities abundant environmental, economic, and social benefits that far exceed 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, education, and aesthetics.

The services and benefits of trees in the urban and suburban setting were once considered to be unquantifiable. However, 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 the City of Carmel's tree inventory data are summarized in this report using DRG's TreeKeeper® inventory management software. The results of Carmel's 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.

Tree Benefit Analysis

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

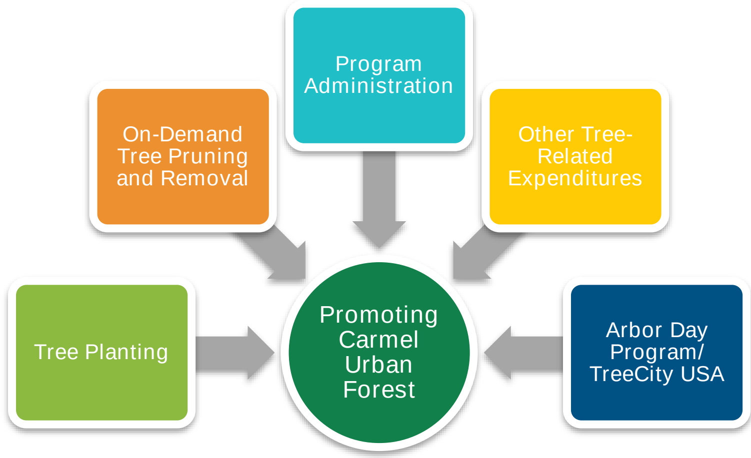
- **Aesthetic/Other Benefits:** Shows the tangible and intangible benefits of trees reflected by increases in property values (in dollars).
- **Stormwater:** Presents reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons.
- **Energy:** Presents the contribution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

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 Benefits of Carmel's Urban Forest

In addition to tree inventory data, TreeKeeper® requires regional data, including energy prices, property values, stormwater, and air quality costs, to generate the environmental and economic benefits trees provide. If community program local economic data are not available, TreeKeeper® uses default economic inputs from a reference city selected by USDA FS for the climate zone in which the community is located. Any default value can be adjusted for local conditions by contacting the TreeKeeper® support team.



Carmel's Inputs

Local data were available at the time of this plan and were used to the greatest extent possible with TreeKeeper® to calculate the benefits Carmel's street trees provide its citizens. DRG used the street ROW data for the benefits assessment. i-Tree Streets methods DRG used for Carmel are further described in Appendix E.

Carmel's Annual Benefits

TreeKeeper® estimated that the street ROW trees provide a total annual benefit of $2.9 million. Essentially, $2.9 million annually is saved to cool 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, one of Carmel's trees provides an annual benefit of $99.26.

The assessment found that aesthetics and other tangible and intangible benefits trees provide were the greatest value to the community (approximately $2,539,022, 87% of total benefit). In addition to increasing property values, trees also play a major role in stormwater management. The city's trees managed nearly 37.6 million gallons of stormwater, which equates to a savings of approximately $232,868 in stormwater management costs. Stormwater management comprises 8% of the annual benefits street trees provide. Energy conservation, reductions in CO_2, and removal of other air pollutants are important benefits as well. Energy conservation accounted for 3% of the annual benefits, while CO_2 and air pollutant reductions accounted for nearly 2% of the annual benefits. Figure 8 summarizes the categories of annual benefits for the tree population.

Table 4 presents results for individual tree species from the benefit analysis. The population of red maple is the most beneficial ($262,591 annually). If this species was lost to ALB or other threats, its loss would be felt more than the community may realize.

The average benefit per tree is $99.26. Of 42 species with population representing 1% or more of the population, 21 species are performing above the average. Top 5 performers are common hackberry at $192.80 per tree, hybrid elm at $188.64 per tree, pin oak at $164.03 per tree, eastern cottonwood at $154.85 per tree, and white mulberry at $150.27 per tree.

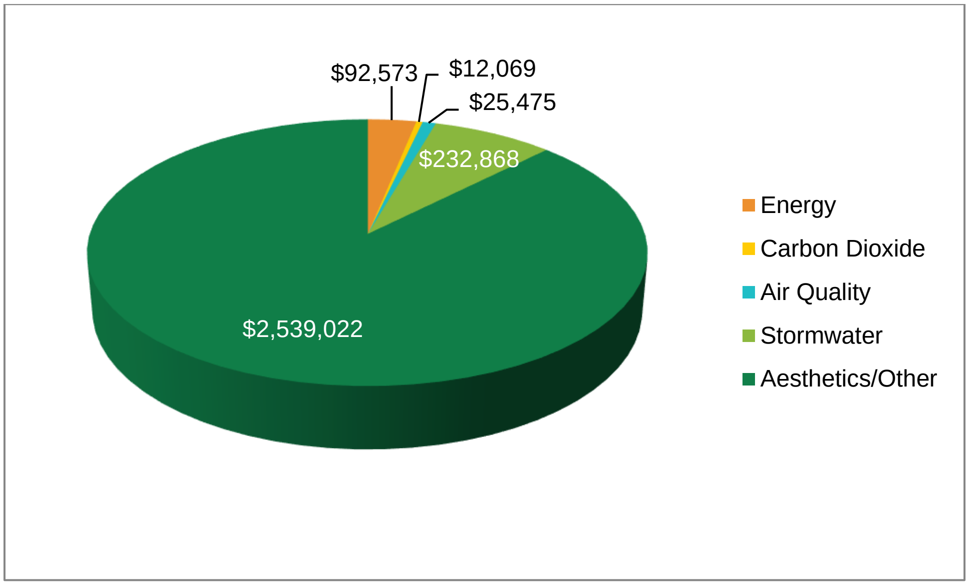


Figure 8. Breakdown of total annual benefits provided to Carmel.

Table 4. Benefit Data for Common Trees by Species

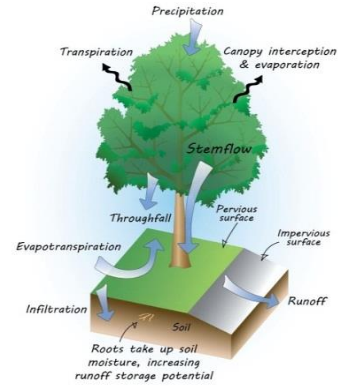
Most Common Trees Collected During Inventory		Number of Trees	Percent of Total Trees	Total Benefit	Benefit per Tree	Performing Above Average
Common Name	Botanical Name		(%)	($)	($)	(YES/NO/AVG)
red maple	Acer rubrum	2,606	9%	262,591	100.76	Yes
sugar maple	Acer saccharum	1,728	6%	205,568	118.96	Yes
thornless honeylocust	Gleditsia triacanthos inermis	1,718	6%	180,001	104.77	Yes
common hackberry	Celtis occidentalis	1,308	4%	252,184	192.80	Yes
hybrid elm	Ulmus x	1,270	4%	239,569	188.64	Yes
Norway spruce	Picea abies	1,174	4%	68,277	58.16	No
northern red oak	Quercus rubra	874	3%	110,594	126.54	Yes
white ash	Fraxinus americana	827	3%	102,059	123.41	Yes
callery pear	Pyrus calleryana	809	3%	30,832	38.11	No
flowering crabapple	Malus spp.	790	3%	38,858	49.19	No
London planetree	Platanus x acerifolia	783	3%	66,921	85.47	No
Japanese tree lilac	Syringa reticulata	727	2%	39,344	54.12	No
ginkgo	Ginkgo biloba	717	2%	41,865	58.39	No
swamp white oak	Quercus bicolor	682	2%	78,603	115.25	Yes
Colorado spruce	Picea pungens	675	2%	38,896	57.62	No
Japanese zelkova	Zelkova serrata	610	2%	48,670	79.79	No
Norway maple	Acer platanoides	608	2%	58,639	96.45	No
tuliptree	Liriodendron tulipifera	604	2%	42,980	71.16	No
silver maple	Acer saccharinum	537	2%	71,017	132.25	Yes
eastern white pine	Pinus strobus	518	2%	45,721	88.27	No
serviceberry spp.	Amelanchier spp.	500	2%	24,723	49.45	No
cherry/plum spp.	Prunus spp.	484	2%	24,780	51.20	No
eastern redbud	Cercis canadensis	450	2%	20,938	46.53	No
green ash	Fraxinus pennsylvanica	377	1%	46,793	124.12	Yes
river birch	Betula nigra	354	1%	34,675	97.95	No
hawthorn spp.	Crataegus spp.	351	1%	17,250	49.15	No
American sweetgum	Liquidambar styraciflua	337	1%	38,401	113.95	Yes
black walnut	Juglans nigra	336	1%	40,527	120.62	Yes
bur oak	Quercus macrocarpa	290	1%	41,396	142.75	Yes
white mulberry	Morus alba	282	1%	42,375	150.27	Yes
Freeman maple	Acer x freemanii	280	1%	28,491	101.75	Yes
yellowwood	Cladrastis kentukea	274	1%	10,923	39.87	No
arborvitae spp.	Thuja spp.	261	1%	8,209	31.45	No
common baldcypress	Taxodium distichum	253	1%	25,537	100.94	Yes
Austrian pine	Pinus nigra	233	1%	20,078	86.17	No
shingle oak	Quercus imbricaria	231	1%	26,758	115.83	Yes
European hornbeam	Carpinus betulus	228	1%	10,826	47.48	No
English oak	Quercus robur	213	1%	24,220	113.71	Yes
black locust	Robinia pseudoacacia	188	1%	24,280	129.15	Yes
eastern redcedar	Juniperus virginiana	167	1%	10,348	61.96	No
eastern cottonwood	Populus deltoides	158	1%	24,466	154.85	Yes
pin oak	Quercus palustris	153	1%	25,096	164.03	Yes
other trees	~114 varying species	3,270	11%	307,726	94.11	---
Total	~156 species	29,235	100%	2,902,007	99.26	AVG

Aesthetic/Other Benefits

The total annual benefit associated with property value increases and other tangible and intangible benefits of trees inventoried is $2,539,022 The average benefit per tree equals $86.85 per year.

Air Quality Benefits

The inventoried tree population annually removes 17,331 pounds of air pollutants (including ozone, nitrogen dioxide, sulfur dioxide, and particulate matter) through deposition and avoidance. The air quality benefit is approximately $25,475 annually. The average benefit per tree equals $0.87 per year.



- *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.*

Carbon Benefits

Trees sequester carbon dioxide (CO_2) during growth (Nowak et al. 2013). 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. The i-Tree Streets model takes into account 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 also calculates emissions released during tree care and maintenance, such as driving to the site and operating equipment. The net carbon benefit is approximately $12,069 per year. The average benefit per tree equals $0.41 per year.

Energy Benefits

Street trees conserve energy by shading structures and surfaces, which reduces electricity use for air conditioning in the summer. Trees divert wind in the winter to reduce natural gas use. Based on the inventoried trees, the annual electric and natural gas savings are equivalent to 943,931 kWh of electricity and 18,303 therms of natural gas, which accounts for an annual savings of $92,573 in energy consumption at $3.17 per tree.

Stormwater Benefits

Trees intercept rainfall, which helps lower costs to manage stormwater runoff. The inventoried trees in Carmel intercept 37,559,345 gallons of rainfall annually. On average, the estimated annual savings for the city in stormwater runoff management is $232,868 ($7.97 per tree).

Discussion/Recommendations

The TreeKeeper® benefits analysis found that trees provide environmental and economic benefits to the community by virtue of their mere presence on the streets. Currently, the aesthetic/other benefits provided 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 provide shade and windbreaks to reduce energy usage, manage stormwater through rainfall interception, sequester CO_2, and remove air pollutants.

To increase the benefits the urban forest provides, the city should plant young, large-statured tree species that manage the most stormwater, absorb the most CO_2, and remove the most air pollutants. Leafy, large-stature trees consistently created the most environmental and economic benefits. The following list of tree species is used for improving environmental benefits (i-Tree Species 2017):

Pollutant Removal

- *Tsuga cannadensis* (eastern hemlock)
- *Ulmus americana* (American elm)
- *Liriodendron tulipifera* (tuliptree)
- *Betula alleghaniensis* (yellow birch)
- *Tilia americana* (American linden)

Carbon Storage

- *Platanus occidentalis* (American sycamore)
- *Zelkova serrata* (Japanese zelkova)
- *Ulmus americana* (American elm)
- *Betula alleghaniensis* (yellow birch)
- *Quercus montana* (chestnut oak)

Stormwater Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Magnolia acuminata* (cucumber magnolia)

Energy Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Platanus occidentalis* (American sycamore)

SECTION 3: TREE MANAGEMENT PROGRAM

This tree management program was developed to uphold Carmel's comprehensive vision for preserving its urban forest. This five-year program is based on the tree inventory data; the program was designed to reduce risk through prioritized tree removal and pruning, and to improve tree health and structure through proactive pruning cycles. Tree planting to mitigate removals and increase canopy cover and public outreach are important parts of the program as well.

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 assigned risk rating; however, routinely monitoring the tree population is essential so that other Extreme, High, or Moderate Risk trees can be identified and systematically addressed. While regular pruning cycles and tree planting are important, priority work (especially for Extreme, High, or Moderate Risk trees) must sometimes take precedence to ensure that risk is expediently managed.

Priority and Proactive Maintenance

In this plan, the recommended tree maintenance work was divided into either priority or proactive maintenance. Priority maintenance includes tree removals and pruning of trees with an assessed risk rating of Moderate, High, and Extreme Risk. Proactive tree maintenance includes pruning of trees with an assessed risk of Low Risk and trees that are young. Tree planting, inspections, and community outreach are also considered proactive maintenance. See Appendix F for more information on risk assessment and proactive maintenance.

Extreme Risk
- Perform tree maintenance immediately to reduce hazards
- Includes tree removal and pruning
- Mostly high-use areas

High Risk
- Perform tree maintenance immediately to reduce hazards and improve tree health
- Includes tree removal and pruning
- Generally high-use areas

Moderate Risk
- Perform tree maintenance as soon as possible to improve tree health
- Includes tree removal and pruning
- May be high- or low-use areas

Low Risk
- Perform tree maintenance when convenient to improve aesthetics and eliminate nuisance trees and stumps
- Includes tree removals and pruning
- Mostly low-use areas but may be high-use areas as well

Routine Pruning
- Perform tree maintenance when convenient to improve aesthetics and eliminate nuisance trees

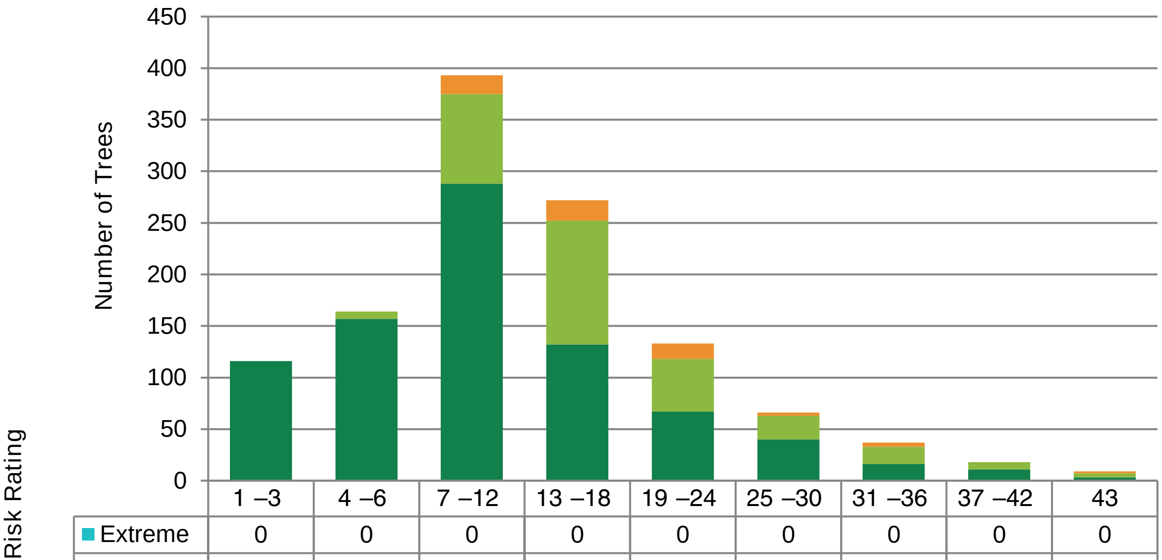
Training Prune
- Perform corrective pruning to young trees to increase structural integrity and develop a strong architecture of branches before serious problems develop

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, and 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 and nuisance trees also warrant removal.

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

Figure 9 presents tree removals by risk rating and diameter size class. The following sections briefly summarize the recommended removals identified during the inventory.



	1 –3	4 –6	7 –12	13 –18	19 –24	25 –30	31 –36	37 –42	43
Extreme	0	0	0	0	0	0	0	0	0
High	0	0	18	20	15	3	4	0	2
Moderate	0	7	87	120	51	23	17	7	4
Low	116	157	288	132	67	40	16	11	3

Diameter Size Class

Figure 9. Tree removals by risk rating and diameter size class.

Findings

The inventory identified 62 High Risk trees, 316 Moderate Risk trees, and 830 Low Risk trees that are recommended for removal.

The diameter size classes for High Risk trees ranged between 7–12 inches diameter at breast height (DBH) and ≥ 43 inches DBH. These trees should be removed immediately based on their assigned risk.

Most Moderate Risk trees were 18 inches DBH or smaller. Moderate Risk trees should be removed as soon as possible after all High Risk removals have been completed.

Low Risk removals pose little threat; these trees are generally small, dead, invasive, or poorly formed trees that need to be removed. Eliminating these trees will reduce breeding site locations for insects and diseases and will increase the aesthetic value of the area. Healthy trees growing in poor locations or undesirable species are also included in this category. All Low Risk trees should be removed when convenient and after all High and Moderate Risk removals have been completed.

Discussion/Recommendations

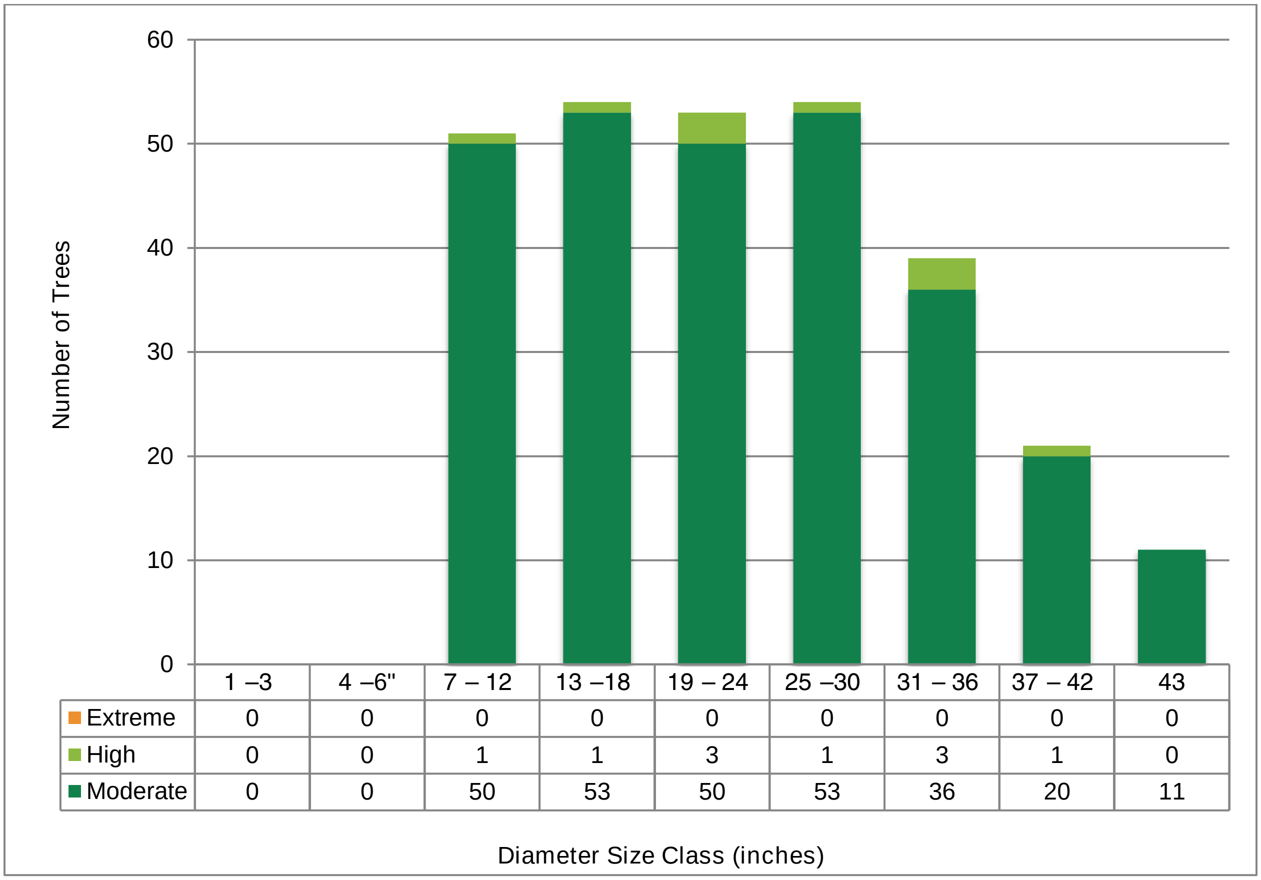
The inventory identified 400 ash trees recommended for removal. These trees should be removed based on the assessed risk rating. There are 881 ash trees with a primary maintenance designation of Tree Clean. These trees should be evaluated for preservation through insecticide treatment. If treatment is not to occur for a number of these trees, then the city should consider adding them to a removal schedule.

Updating the tree inventory data can streamline workload management and lend insight into setting accurate budgets and staffing levels. Inventory updates should be made electronically and can be implemented using TreeKeeper® or similar computer software.

Tree Pruning

High and Moderate Risk pruning generally require cleaning the canopy of both small and large trees to remove defects such as dead and/or broken branches that may be present even when the rest of the tree is sound. In these cases, pruning the branch or branches can correct the problem and reduce risk associated with the tree.

Figure 10 presents the number of High and Moderate Risk trees recommended for pruning by size class. The following sections briefly summarize the recommended pruning maintenance identified during the inventory.



	1 –3	4 –6"	7 – 12	13 –18	19 – 24	25 –30	31 – 36	37 – 42	43
Extreme	0	0	0	0	0	0	0	0	0
High	0	0	1	1	3	1	3	1	0
Moderate	0	0	50	53	50	53	36	20	11

Figure 10. Extreme and High Risk pruning by diameter size class.

Findings

The inventory identified 10 High Risk trees and 273 Moderate Risk trees recommended for pruning.

High Risk trees ranged in diameter size classes from 7–12 inches DBH to 37–42 inches DBH. This pruning should be performed immediately based on assigned risk.

Most Moderate Risk trees were smaller than 24 inches DBH. Moderate Risk trees should be pruned as soon as possible after all High Risk prunes have been completed.

Low Risk trees recommended for pruning should be included in a proactive, routine pruning cycle after all the higher risk trees are addressed.

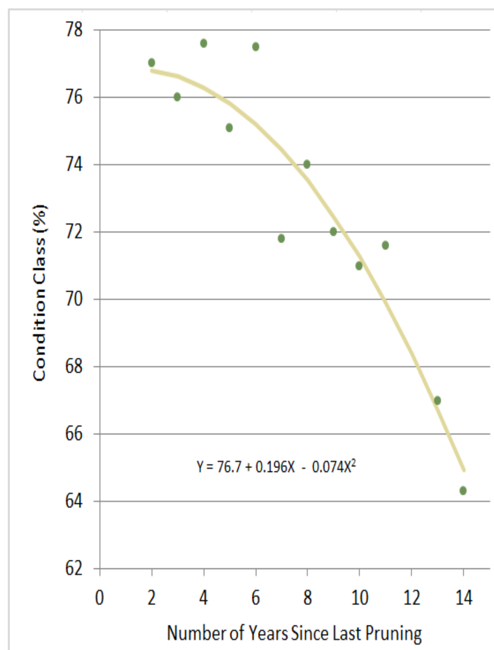


Figure 11. Relationship between average tree condition class and the number of years since the most recent pruning (adapted from Miller and Sylvester 1981).

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 pruning cycles begin after all High and Moderate Risk trees are corrected through removal or pruning. However, due to the long-term benefits of pruning cycles, DRG recommends that the cycles be implemented as soon as possible. To ensure that all trees receive the type of pruning they need to mature with better structure and lower associated risk, two pruning cycles are recommended: the young tree training cycle (YTT Cycle) and the routine pruning cycle (RP Cycle). The cycles differ in the type of pruning, the general age of the target tree, and length.

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 YTT Cycle once they become established. As young trees reach maturity, they will be shifted from the YTT Cycle into the RP Cycle. When a tree reaches the end of its useful life, it should be removed and eliminated from the RP Cycle.

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.

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.

Young Tree Training Cycle

Trees included in the YTT Cycle are generally less than 8 inches DBH. These younger trees sometimes have branch structures that can lead to potential problems as the tree ages. Potential structural problems include codominant leaders, multiple limbs attaching at the same point on the trunk, or crossing/interfering limbs. If these problems are not corrected, they may worsen as the tree grows, increasing risk and creating potential liability.

YTT pruning is performed to improve tree form or structure; the recommended length of a YTT Cycle is three years because young trees tend to grow at faster rates (on average) than more mature trees.

The YTT Cycle differs from the RP Cycle in that these trees generally can be pruned from the ground with a pole pruner or pruning shear. The objective is to increase structural integrity by pruning for one dominant leader. YTT Pruning is species-specific, since many trees such as *Betula nigra* (river birch) may naturally have more than one leader. For such trees, YTT pruning is performed to develop a strong structural architecture of branches so that future growth will lead to a healthy, structurally sound tree.

Recommendations

During the inventory, 13,770 trees smaller than 13 inches DBH were inventoried and recommended for young tree training. Since the number of existing young trees is relatively large (47% of inventoried population), and the benefit of beginning the YTT Cycle is substantial, DRG recommends that an average of 4,589 trees be structurally pruned each year over 3 years, beginning in Year One of the management program.

If trees are planted, they will need to enter the YTT Cycle after establishment, typically a few years after planting.

In future years, the number of trees in the YTT Cycle will be based on tree planting efforts and growth rates of young trees. The city should strive to prune approximately one-third of its young trees each year.

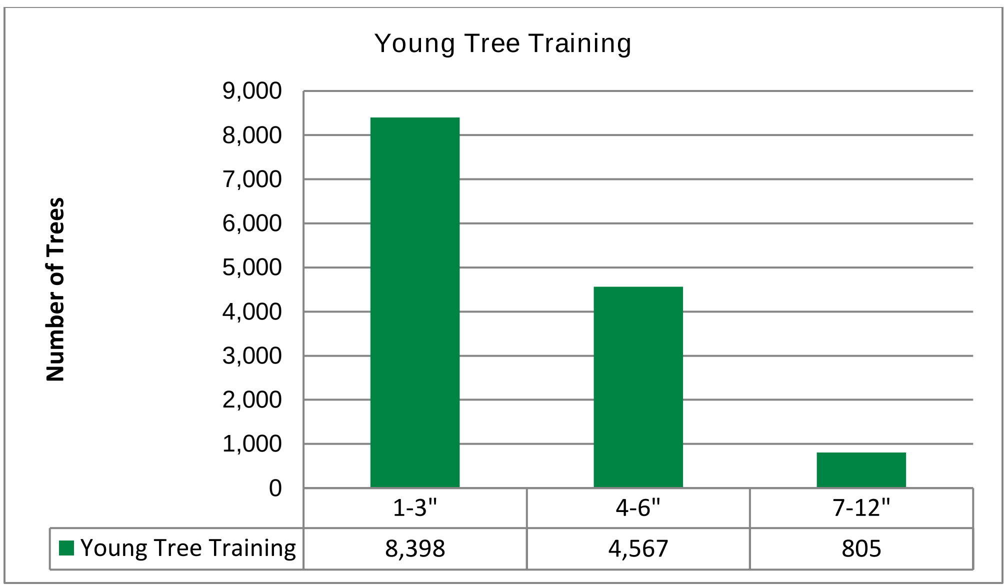


Figure 12. Trees recommended for the YTT Cycle by diameter size class.

Routine Pruning Cycle

The RP Cycle includes established, maturing, and mature trees (mostly greater than 7 inches DBH) that need cleaning, crown raising, and reducing to remove deadwood and improve structure. Over time, routine pruning can reduce reactive maintenance, minimize instances of elevated risk, and provide the basis for a more defensible risk management program. Included in this cycle are Low Risk trees that require pruning and pose some risk but have a smaller size of defect and/or less potential for target impact. The defects found within these trees can usually be remediated during the RP Cycle.

The length of the RP Cycle is based on the size of the tree population and what was assumed to be a reasonable number of trees for a program to prune per year. Generally, the RP Cycle recommended for a tree population is five years but may extend to seven years if the population is large.

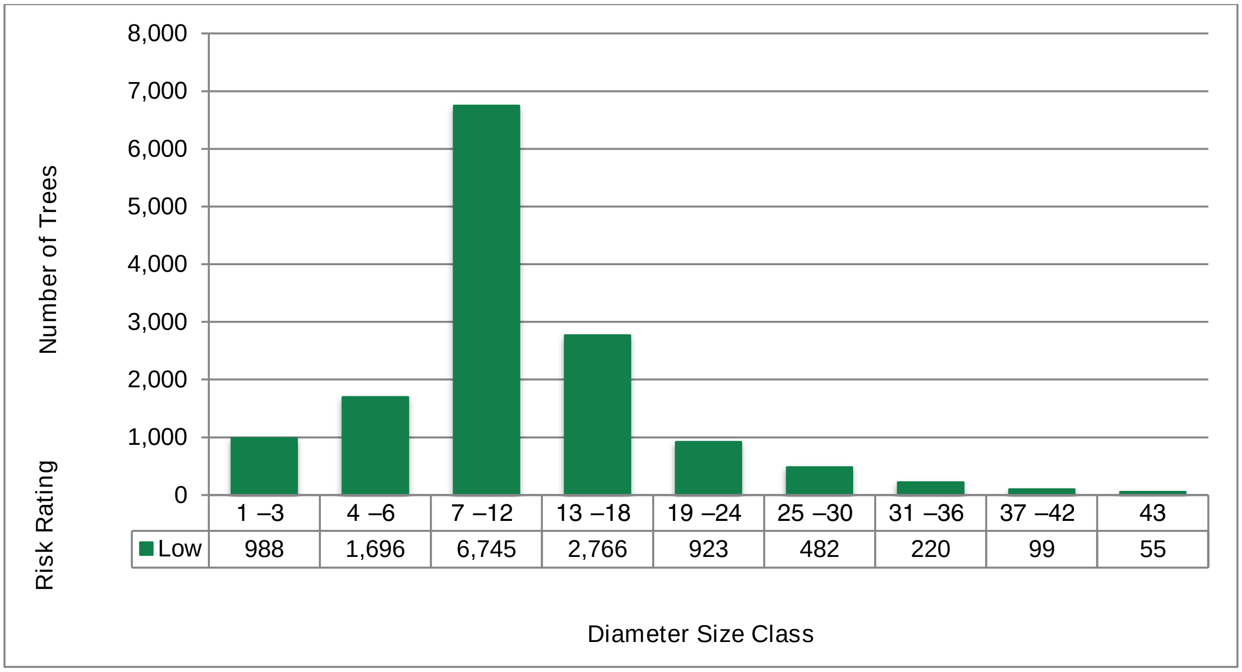


Figure 13. Trees recommended for the RP Cycle by diameter size class.

<u>Recommendations</u>

DRG recommends that the city establish a seven-year RP Cycle in which approximately one-seventh of the tree population is to be pruned each year. The tree inventory identified approximately 13,974 trees that should be pruned over a seven-year RP Cycle. An average of 1,996 trees should be pruned each year over the course of the cycle. DRG recommends that the RP Cycle begin in Year Three of this five-year plan, after all High and Moderate Risk trees are pruned.

The inventory found that most trees (48%) on the street ROW needed routine pruning. Figure 13 shows that a variety of tree sizes will require pruning; however, most of the trees that require routine pruning were smaller than 19 inches DBH.

Maintenance Schedule

Utilizing data from Carmel's street tree inventory, an annual maintenance schedule was developed that details the number and type of tasks recommended for completion each year. DRG made budget projections using industry knowledge and public bid tabulations. Actual costs were not specified by Carmel. A complete table of estimated costs for Carmel's five-year tree management program is presented in Table 5.

The schedule provides a framework for completing the inventory maintenance recommendations over the next five 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 $649,986 for the first year of implementation, no less than $652,744 for the second year, no less than $574,949 for the third year, and no less than $545,060 for the final two years of the maintenance schedule. Annual budget funds are needed to ensure that high and moderate risk trees are remediated and that crucial YTT and RP 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 5. Estimated Costs for Five-Year Urban Forestry Management Program

Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Five-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	
Extreme, High, Moderate Risk Removals	1-3"	$28	-	$0	-	$0	-	$0	-	$0	-	$0	$0
	4-6"	$58	7	$595	-	$0	-	$0	-	$0	-	$0	$595
	7-12"	$138	105	$13,440	-	$0	-	$0	-	$0	-	$0	$13,440
	13-18"	$314	140	$71,400	-	$0	-	$0	-	$0	-	$0	$71,400
	19-24"	$605	66	$50,490	-	$0	-	$0	-	$0	-	$0	$50,490
	25-30"	$825	26	$33,150	-	$0	-	$0	-	$0	-	$0	$33,150
	31-36"	$1,045	21	$32,130	-	$0	-	$0	-	$0	-	$0	$32,130
	37-42"	$1,485	7	$14,280	-	$0	-	$0	-	$0	-	$0	$14,280
	43"+	$2,035	6	$15,300	-	$0	-	$0	-	$0	-	$0	$15,300
Activity Total(s)			378	$230,785	-	$0	-	$0		$0	-	$0	$230,785
Low Risk Removals	1-3"	$28	-	$0	-	$0	116	$4,988	-	$0	-	$0	$4,988
	4-6"	$58	-	$0	-	$0	157	$13,345	-	$0	-	$0	$13,345
	7-12"	$138	-	$0	200	$25,600	88	$11,264	-	$0	-	$0	$36,864
	13-18"	$314	-	$0	132	$67,320	-	$0	-	$0	-	$0	$67,320
	19-24"	$605	-	$0	67	$51,255	-	$0	-	$0	-	$0	$51,255
	25-30"	$825	-	$0	40	$51,000	-	$0	-	$0	-	$0	$51,000
	31-36"	$1,045	-	$0	16	$24,480	-	$0	-	$0	-	$0	$24,480
	37-42"	$1,485	-	$0	11	$22,440	-	$0	-	$0	-	$0	$22,440
	43"+	$2,035	-	$0	3	$7,650	-	$0	-	$0	-	$0	$7,650
Activity Total(s)			-	$0	469	$249,745	361	$29,597	-	$0	-	$0	$279,342
Stump Removals	-	$18	-	$0	-	$0	116	$2,552	-	$0	-	$0	$2,552
	4-6"	$28	7	196	-	$0	157	$4,396	-	$0	-	$0	$4,592
	7-12"	$44	105	$4,515	200	$8,600	88	$3,784	-	$0	-	$0	$16,899
	13-18"	$72	140	$11,900	132	$11,220	-	$0	-	$0	-	$0	$23,120
	19-24"	$94	66	$7,062	67	$7,169	-	$0	-	$0	-	$0	$14,231
	25-30"	$110	26	$3,328	40	$5,120	-	$0	-	$0	-	$0	$8,448
	31-36"	$138	21	$3,150	16	$2,400	-	$0	-	$0	-	$0	$5,550
	37-42"	$160	7	$1,190	11	$1,870	-	$0	-	$0	-	$0	$3,060
	43"+	$182	6	$1,260	3	$630	-	$0	-	$0	-	$0	$1,890
Activity Total(s)			378	$32,601	469	$37,009	361	$10,732	-	$0	-	$0	$80,342
Extreme, High, Moderate Risk Pruning	1-3"	$20	-	$0	-	$0	-	$0	-	$0	-	$0	$0
	4-6"	$30	-	$0	-	$0	-	$0	-	$0	-	$0	$0
	7-12"	$75	1	$75	50	$3,750	-	$0	-	$0	-	$0	$3,825
	13-18"	$120	1	$120	53	$6,360	-	$0	-	$0	-	$0	$6,480
	19-24"	$170	3	$510	50	$8,500	-	$0	-	$0	-	$0	$9,010
	25-30"	$225	54	$12,150	-	$0	-	$0	-	$0	-	$0	$12,150
	31-36"	$305	39	$11,895	-	$0	-	$0	-	$0	-	$0	$11,895
	37-42"	$380	21	$7,980	-	$0	-	$0	-	$0	-	$0	$7,980
	43"+	$590	11	$6,490	-	$0	-	$0	-	$0	-	$0	$6,490
Activity Total(s)			130	$39,220	153	$18,610	-	$0	-	$0	-	$0	$57,830
Routine Pruning (7-year cycle)	1-3"	$20	-	$0	-	$0	141	$2,820	141	$2,820	141	$2,820	$8,460
	4-6"	$30	-	$0	-	$0	242	$7,260	242	$7,260	242	$7,260	$21,780
	7-12"	$75	-	$0	-	$0	964	$72,300	964	$72,300	964	$72,300	$216,900
	13-18"	$120	-	$0	-	$0	395	$47,400	395	$47,400	395	$47,400	$142,200
	19-24"	$170	-	$0	-	$0	132	$22,440	132	$22,440	132	$22,440	$67,320
	25-30"	$225	-	$0	-	$0	69	$15,525	69	$15,525	69	$15,525	$46,575
	31-36"	$305	-	$0	-	$0	31	$9,455	31	$9,455	31	$9,455	$28,365
	37-42"	$380	-	$0	-	$0	14	$5,320	14	$5,320	14	$5,320	$15,960
	43"+	$590	-	$0	-	$0	8	$4,720	8	$4,720	8	$4,720	$14,160
Activity Total(s)			-	$0	-	$0	-	$187,240	1,996	$187,240	1,996	$187,240	$561,720
Young Tree Training Pruning (3-year cycle)	1-3"	$20	2,799	$55,980	2,799	$55,980	2,799	$55,980	3,321	$66,420	3,321	$66,420	$300,780
	4-6"	$30	1,522	$45,660	1,522	$45,660	1,522	$45,660	1,522	$45,660	1,522	$45,660	$228,300
	7-12"	$75	268	$20,100	268	$20,100	268	$20,100	268	$20,100	268	$20,100	$100,500

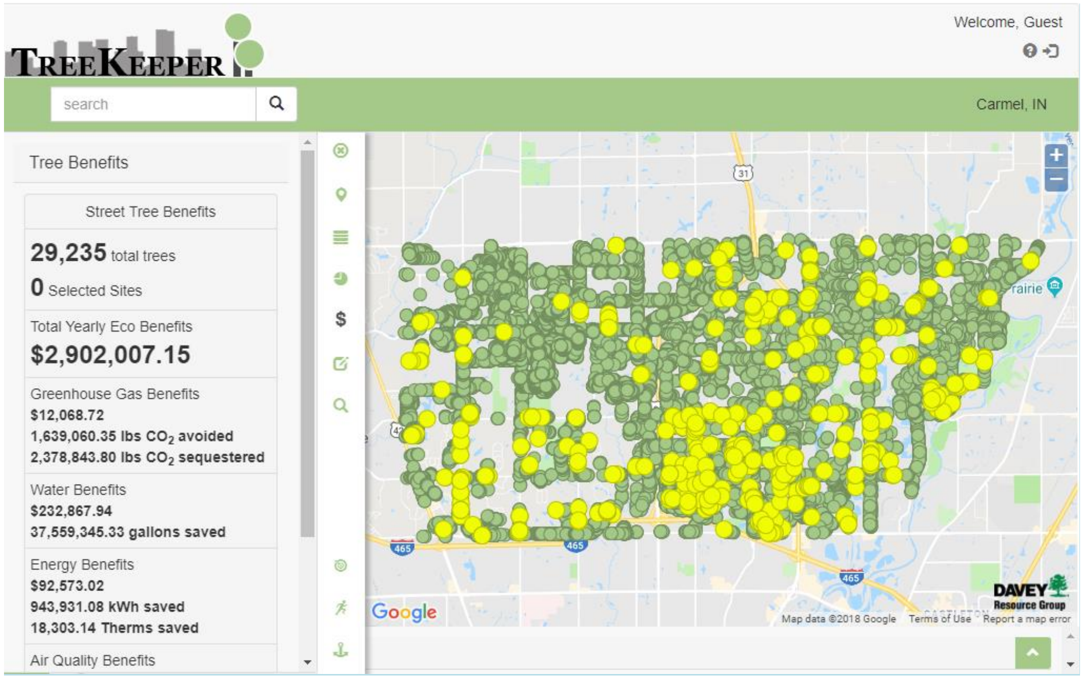
Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Five-Year Cost
Activity	Diameter	Cost/Tree	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Activity Total(s)			4,589	$121,740	4,589	$121,740	4,589	$121,740	5,111	$132,180	5,111	$132,180	$629,580
Replacement Tree Planting	Purchasing	$170	242	$41,140	242	$41,140	242	$41,140	242	$41,140	242	$41,140	$205,700
	Planting	$110	242	$26,620	242	$26,620	242	$26,620	242	$26,620	242	$26,620	$133,100
Activity Total(s)			484	$67,760	484	$67,760	484	$67,760	484	$67,760	484	$67,760	$338,800
Replacement Young Tree Maintenance	Mulching	$100	242	$24,200	242	$24,200	242	$24,200	242	$24,200	242	$24,200	$121,000
	Watering	$100	242	$24,200	242	$24,200	242	$24,200	242	$24,200	242	$24,200	$121,000
Activity Total(s)			484	$48,400	484	$48,400	484	$48,400	484	$48,400	484	$48,400	$242,000
Annual Mortality (1%) Removals	Average Tree	$138	280	$35,840	280	$35,840	280	$35,840	280	$35,840	280	$35,840	$179,200
Activity Total(s)			280	$35,840	280	$35,840	280	$35,840	280	$35,840	280	$35,840	$179,200
Annual Mortality (1%) Stump Removals	Average Tree	$44	280	$12,040	280	$12,040	280	$12,040	280	$12,040	280	$12,040	$60,200
Activity Total(s)			280	$12,040	280	$12,040	280	$12,040	280	$12,040	280	$12,040	$60,200
Annual Mortality (1%) Planting	Average Tree	$220	280	$61,600	280	$61,600	280	$61,600	280	$61,600	280	$61,600	$308,000
Activity Total(s)			280	$61,600	280	$61,600	280	$61,600	280	$61,600	280	$61,600	$308,000
Activity Grand Total			6,799		7,004		8,631		8,431		8,431		
Cost Grand Total				$649,986		$652,744		$574,949		$545,060		$545,060	$2,967,799

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 that resource. These data can also 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 scale, bagworms, looper complex, and emerald ash bored).

There are various avenues for outreach. TreeKeeper® quick filters can be utilized to know and share the value and character of the urban forest. 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. Carmel's tree inventory data are instrumental in helping to provide tangible and meaningful outreach about the urban forest.



Davey Resource Group's *TreeKeeper®* calculates the ecosystem benefits of individual trees, groups of trees, or an entire urban forest using inventory data and highlights gold medal, most beneficial, trees.

Inspections

Inspections are essential to uncovering potential problems with trees. They should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees. Arborists are knowledgeable about the needs of trees and are trained and equipped to provide proper care.

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. Use appropriate computer management software such as TreeKeeper® to update inventory data and work records. In addition to locating potential new hazards, inspections are an opportunity to look for signs and symptoms of pests and diseases. Carmel has a large population of trees that are susceptible to pests and diseases, such as maple, oak, and honeylocust.

Inventory and Plan Updates

Davey Resource Group recommends that the inventory and management plan be updated using TreeKeeper® or an appropriate computer software program so that 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 inventory database using TreeKeeper® 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 in five years or update a portion of the population (1/7) every year over the course of seven years.
- Revise the *Tree Management Plan* after five years when the re-inventory has been completed or after seven years with the update has completed a cycle.

CONCLUSIONS

Every hour of every day, public trees in Carmel are supporting and improving the quality of life. The city's trees provide an annual benefit of $2.9 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. The majority of Carmel's tree population is young. As these trees mature this overall benefit will also grow.

Managing trees in urban areas is often complicated. Navigating the recommendations of experts, the needs of residents, the pressures of local economics and politics, 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 city's trees, Carmel is well positioned to thrive. If the management program is successfully implemented, the health and safety of Carmel's trees and citizens will be maintained for years to come.

GLOSSARY

aboveground utilities (data field): Shows the presence or absence of overhead utilities at the tree site.

address (data fields): A collection of data fields collected during the inventory to aid in finding trees, including address number, street name, and on street.

Aesthetic/Other Report: The TreeKeeper® Aesthetic/Other Report presents the tangible and intangible benefits of trees reflected by increases in property values in dollars ($).

Air Quality Report: The TreeKeeper® Air Quality Report quantifies the air pollutants (ozone [O_3], nitrogen dioxide [NO_2], sulfur dioxide [SO_2], coarse particulate matter less than 10 micrometers in diameter [PM_{10}]) deposited on tree surfaces and reduced emissions from power plants (NO_2, PM_{10}, Volatile Oxygen Compounds [VOCs], SO_2) due to reduced electricity use measured in pounds (lbs.). Also reported are the potential negative effects of trees on air quality due to Biogenic Volatile Organic Compounds (BVOC) emissions.

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

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

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

block side (data field): Address information for a site that includes the *on street*. The *on street* is the street on which the site is actually located.

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

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

Carbon Dioxide Report: The TreeKeeper® Carbon Dioxide Report presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reduced energy use in pounds. The model accounts for CO_2 released as trees die and decompose and CO_2 released during the care and maintenance of trees.

community forest: see **urban forest**.

condition (data field): The general condition of each tree rated during the inventory according to the following categories adapted from the International Society of Arboriculture's rating system: Good (>80%), Fair (80-50%), Poor, (<50%), Dead (0%).

cycle: Planned length of time between vegetation maintenance activities.

defect: See **structural defect**.

diameter: See **tree size**.

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

Energy Report: The TreeKeeper® Energy Report presents the contribution of the urban forest toward conserving energy in terms of reduced natural gas use in winter measured in therms (th) and reduced electricity use for air conditioning in summer measured in megawatt-hours (MWh).

Extreme Risk tree: Applies in situations where tree failure is imminent, there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area in order to prevent injury.

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

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

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

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

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

grow space size (data field): Identifies the minimum width of the tree grow space for root development.

grow space type (data field): Best identifies the type of location where a tree is growing. During the inventory, grow space types were categorized as island, median, open/restricted, open/unrestricted, raised planter, tree lawn/parkway, unmaintained/natural area, or well/pit.

High Risk tree: The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.

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

inventory: See **tree inventory**.

i-Tree Streets: i-Tree Streets is a street tree management and analysis tool that uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits: energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase.

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

Low Risk tree: The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.

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

Moderate Risk tree: The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.

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

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

ordinance: See **tree ordinance**.

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

Particulate Matter (PM_{10}): A major class of air pollutants consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists.

Primary Maintenance Need (data field): The type of tree work needed to reduce immediate risk.

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

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

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

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

risk assessment (data fields): Level 2 qualitative risk assessment will be performed on the ANSI A300 (Part 9) and the companion publication *Best Management Practices: Tree Risk Assessment*, published by International Society of Arboriculture (2011). Trees can have multiple failure modes with various risk ratings. One risk rating per tree will be assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. The specified time period for the risk assessment is one year.

risk rating (data field): The overall risk rating of the tree determined based on combining the likelihood of tree failure impacting a target and the consequence of failure.

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

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

Stormwater Report: A report generated by TreeKeeper® that presents the reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons (gals.).

street name (data field): The name of a street right-of-way or road identified using posted signage or parcel information.

street right-of-way (ROW): A strip of land generally owned by a public entity over which facilities, such as highways, railroads, or power lines, are built.

street tree: A street tree is defined as a tree within the right-of-way.

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

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

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

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

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

Tree Clean (Primary Maintenance Need): Based on *ANSI A300 Standards*, these trees require selective removal of dead, dying, broken, and/or diseased wood to minimize potential risk.

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

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

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

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

Young Tree Train (Primary Maintenance Need): Data field based on *ANSI A300* standards, this maintenance activity is characterized by pruning of young trees to correct or eliminate weak, interfering, or objectionable branches to improve structure. These trees can be up to 20 feet tall and can be worked with a pole pruner by a person standing on the ground.

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APPENDIX A
DATA COLLECTION AND SITE LOCATION METHODS

Data Collection Methods

DRG collected tree inventory data using a system that operates a DRG proprietary mapping program loaded onto pen-based field computers equipped with geographic information system (GIS) and global positioning system (GPS) receivers. The knowledge and professional judgment of Davey Resource Group's arborists ensure the high quality of inventory data.

Data fields are defined in the glossary of the management plan. At each site, the following data fields were collected:

• Aboveground utilities	• Mapping coordinates
• Address	• Primary maintenance needs
• Block side	• Risk assessment
• Condition	• Risk rating
• Further inspection	• Species
• Grow space size	• Tree size*
• Grow space type	

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

Maintenance needs are based on *Best Management Practices: Tree Risk Assessment* (International Society of Arboriculture [ISA] 2011).

The data collected were provided in an ESRI® shapefile, Access™ database, Microsoft Excel™ spreadsheet, and Google Earth's KML on a CD-ROM that accompanies this plan.

Site Location Methods

Equipment and Base Maps

Inventory arborists use CF-19 Panasonic Toughbook® unit(s) with internal GPS receiver(s).

Base map layers were loaded onto these unit(s) to help locate sites during the inventory. Table 1 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
City of Carmel GIS Terry Krueskamp	2015-2017	NAD 1983 StatePlane Indiana East, Feet

Street ROW Site Location

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

Address Number and Street Name

The *address number* was recorded based on visual observation by the arborist at the time of the inventory (the address number was posted on a building at the inventoried site). Where there was no posted address number on a building, or where the site was located by a vacant lot with no GIS parcel addressing data available, the arborist used his/her 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 on the right side of the street in the direction of collection closest to the site. Each segment was numbered with an assigned address that was interpolated from addresses facing that median/island. If there were multiple median/islands between cross streets, each segment was assigned its own address.

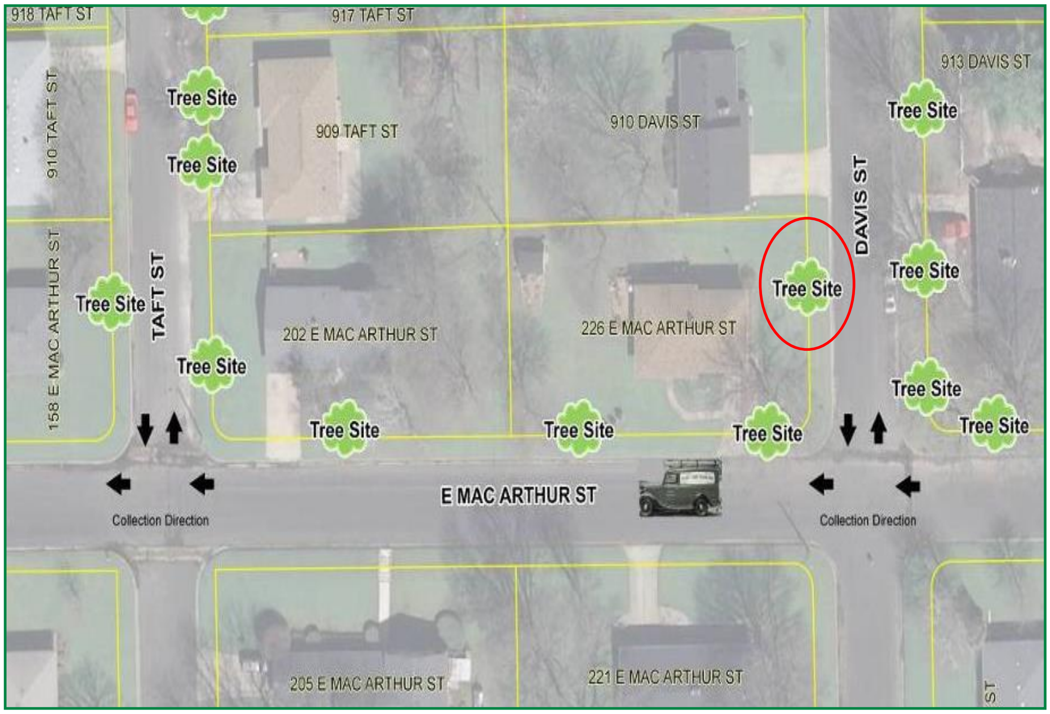
The *street name* assigned to a site was determined by street ROW parcel information and posted street name signage.

Block Side

Block side information for a site includes the *on street*.

- The *on street* is the street on which the site is located. The *on street* may not match the address street. A site may be physically located on a street that is different from its street address (i.e., a site located on a side street).

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
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		Corner Lot B	
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
On Street:	Taft St.	On Street:	Davis St.
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
On Street:	Taft St.	On Street:	E Mac Arthur St.
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
On Street:	Taft St.	On Street:	E Mac Arthur St.
Address/Street Name:	205 Hoover St.		
On Street:	Hoover St.		

APPENDIX B
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 Zones 5 and 6 on the USDA Plant Hardiness Zone Map.

Deciduous Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Betula alleghaniensis*	yellow birch	
Betula lenta*	sweet birch	
Betula nigra	river birch	Heritage®
Carya illinoensis*	pecan	
Carya lacinata*	shellbark hickory	
Carya ovata*	shagbark hickory	
Catalpa speciosa	northern catalpa	
Castanea mollissima*	Chinese chestnut	
Celtis laevigata	sugarberry	
Celtis occidentalis	common hackberry	'Prairie Pride'
Cercidiphyllum japonicum	katsuratree	'Aureum'
Diospyros virginiana*	common persimmon	
Fagus grandifolia*	American beech	
Fagus sylvatica*	European beech	(Numerous exist)
Ginkgo biloba	ginkgo	(Choose male trees only)
Gleditsia triacanthos inermis	thornless honeylocust	'Shademaster'
Gymnocladus dioica	Kentucky coffeetree	Prairie Titan®
Juglans nigra*	black walnut	
Larix decidua*	European larch	
Liquidambar styraciflua	American sweetgum	'Rotundiloba'
Liriodendron tulipifera*	tuliptree	'Fastigiatum'
Magnolia acuminata*	cucumbertree magnolia	(Numerous exist)
Magnolia macrophylla*	bigleaf magnolia	
Metasequoia glyptostroboides	dawn redwood	'Emerald Feathers'
Nyssa sylvatica	blackgum	
Platanus occidentalis*	American sycamore	
Platanus × acerifolia	London planetree	'Yarwood'
Quercus alba	white oak	

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

Scientific Name	Common Name	Cultivar
Quercus bicolor	swamp white oak	
Quercus coccinea	scarlet oak	
Quercus lyrata	overcup oak	
Quercus macrocarpa	bur oak	
Quercus montana	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus imbricaria	shingle oak	
Quercus phellos	willow oak	
Quercus robur	English oak	Heritage®
Quercus rubra	northern red oak	'Splendens'
Quercus shumardii	Shumard oak	
Styphnolobium japonicum	Japanese pagodatree	'Regent'
Taxodium distichum	common baldcypress	'Shawnee Brave'
Tilia americana	American linden	'Redmond'
Tilia cordata	littleleaf linden	'Greenspire'
Tilia × euchlora	Crimean linden	
Tilia tomentosa	silver linden	'Sterling'
Ulmus parvifolia	Chinese elm	Allée®
Ulmus ×	hybrid elm	'Frontier' 'Homestead' 'Pioneer' 'Regal' 'Urban'
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	
Carpinus betulus	European hornbeam	'Franz Fontaine'
Cladrastis kentukea	American yellowwood	'Rosea'
Corylus colurna	Turkish filbert	
Eucommia ulmoides	hardy rubber tree	
Koelreuteria paniculata	goldenraintree	
Ostrya virginiana	American hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Phellodendron amurense	Amur corktree	'Macho'
Pistacia chinensis	Chinese pistache	
Prunus maackii	Amur chokecherry	'Amber Beauty'
Prunus sargentii	Sargent cherry	
Pterocarya fraxinifolia*	Caucasian wingnut	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
Sassafras albidum*	sassafras	

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer buergerianum	trident maple	Streetwise®
Acer campestre	hedge maple	Queen Elizabeth™
Acer cappadocicum	coliseum maple	'Aureum'
Acer ginnala	Amur maple	Red Rhapsody™
Acer griseum	paperbark maple	
Acer oliverianum	Chinese maple	
Acer pensylvanicum*	striped maple	
Acer triflorum	three-flower maple	
Aesculus pavia*	red buckeye	
Amelanchier arborea	downy serviceberry	(Numerous exist)
Amelanchier laevis	Allegheny serviceberry	
Carpinus caroliniana*	American hornbeam	
Cercis canadensis	eastern redbud	'Forest Pansy'
Chionanthus virginicus	white fringetree	
Cornus alternifolia	pagoda dogwood	
Cornus kousa	kousa dogwood	(Numerous exist)
Cornus mas	corneliancherry dogwood	'Spring Sun'
Corylus avellana	European filbert	'Contorta'
Cotinus coggygria*	common smoketree	'Flame'
Cotinus obovata*	American smoketree	
Crataegus phaenopyrum*	Washington hawthorn	Princeton Sentry™
Crataegus viridis	green hawthorn	'Winter King'
Franklinia alatamaha*	Franklinia	
Halesia tetraptera*	Carolina silverbell	'Arnold Pink'
Laburnum × watereri	goldenchain tree	
Maackia amurensis	Amur maackia	
Magnolia × soulangiana*	saucer magnolia	'Alexandrina'
Magnolia stellata*	star magnolia	'Centennial'
Magnolia tripetala*	umbrella magnolia	
Magnolia virginiana*	sweetbay magnolia	Moonglow®
Malus spp.	flowering crabapple	(Disease resistant only)
Oxydendrum arboreum	sourwood	'Mt. Charm'
Prunus subhirtella	Higan cherry	'Pendula'
Prunus virginiana	common chokecherry	'Schubert'
Staphylea trifolia*	American bladdernut	
Stewartia ovata	mountain stewartia	
Styrax japonicus*	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'

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

Coniferous and Evergreen Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Abies balsamea	balsam fir	
Abies concolor	white fir	'Violacea'
Cedrus libani	cedar-of-Lebanon	
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica	Japanese cryptomeria	'Sekkan-sugi'
× Cupressocyparis leylandii	Leyland cypress	
Ilex opaca	American holly	
Picea omorika*	Serbian spruce	
Picea orientalis*	Oriental spruce	
Pinus densiflora*	Japanese red pine	
Pinus strobus*	eastern white pine	
Pinus sylvestris*	Scotch pine	
Pinus taeda*	loblolly pine	
Pinus virginiana*	Virginia pine	
Psedotsuga menziesii	Douglas-fir	
Thuja plicata	western arborvitae	(Numerous exist)
Tsuga canadensis	eastern hemlock	

Medium Trees: 31 to 45 Feet in Height at Maturity

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

Small Trees: 15 to 30 Feet in Height at Maturity

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

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

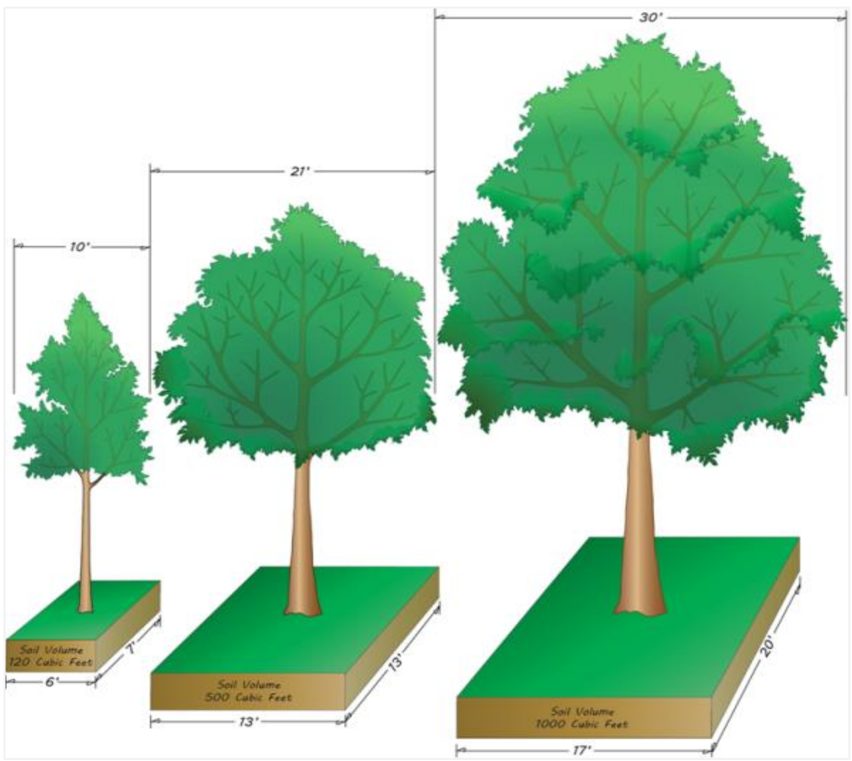
APPENDIX C
TREE PLANTING

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.



Minimum recommended requirements for tree sites is based on tree size/dimensions.
This illustration is based on the work of Casey Trees (2008).

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.

Carmel is located in USDA Hardiness Zone 5b, which is identified as a climatic region with average annual minimum temperatures between −15°F and −10°F. Tree species selected for planting in Carmel 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.

Structural Pruning

Young trees must be pruned to correct or eliminate weak, interfering, or objectionable branches in order to minimize future maintenance requirements. Generally, these trees may be up to 20 feet in height and can be worked with a pole pruner by a person standing on the ground. Structural pruning will promote tree longevity, decrease maintenance costs overtime, reduce future problems that elevate risk to people or property, and uphold invested environmental benefits to the community.

Lifelong Tree Care

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

The city 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 care so that the city's 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 city's trees are properly diagnosed and that a beneficial and realistic action plan is developed.

Educating the community on basic tree care is a good way to promote the city's urban forestry program and encourage tree planting on private property. The city should encourage citizens to water trees on the ROW adjacent to their homes and to reach out to the city 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 D
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 United States Department of Agriculture's (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.

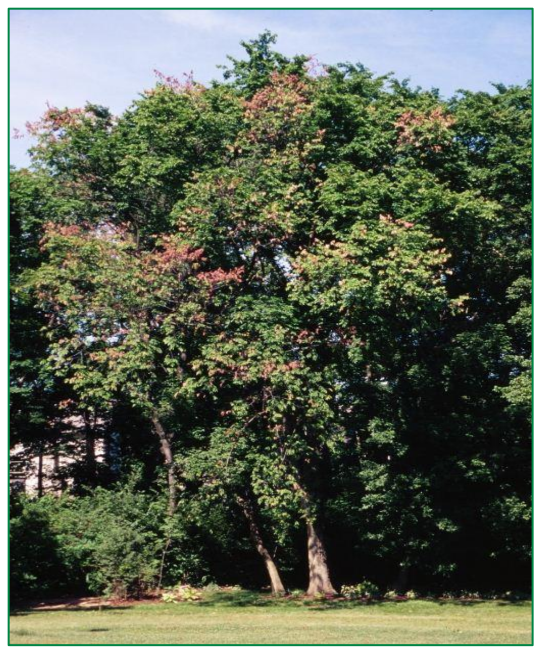
Adult Asian longhorned beetle

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

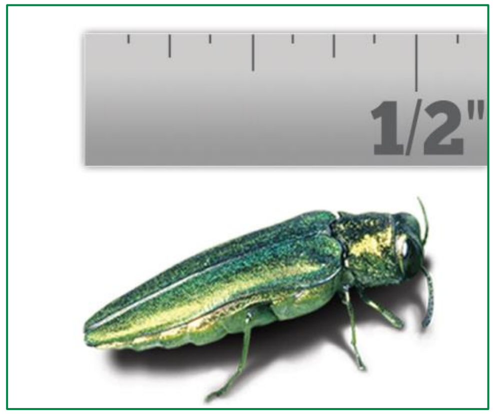
Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2011)

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.



Close-up of the emerald ash borer

Photograph courtesy of APHIS (2011)

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).

Forest Tent Caterpillar

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

Forest tent caterpillar larva with blue *stripe and white "keyhole" pattern* running down its back.

Photograph courtesy of Greg Hume USDA Forest Service, Penn State Extension (2018).

Gypsy Moth

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

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

Photograph courtesy of APHIS (2011b)

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).

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.

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.

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.

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APPENDIX E
i-TREE STREETS METHODOLOGY

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

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

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

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

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

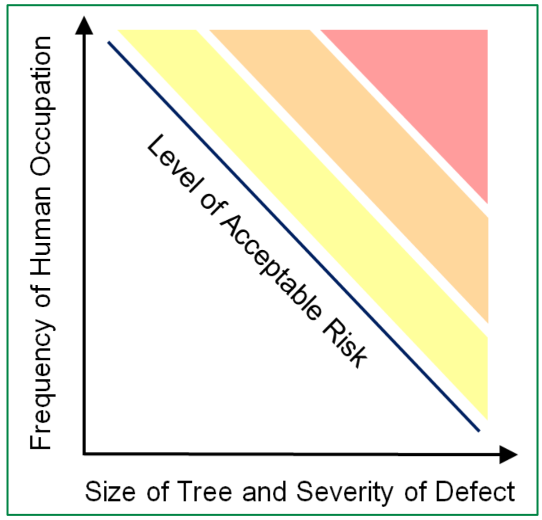
Carmel's Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$0.092945	$/Kwh	Duke rate
Natural Gas	$0.2644	$/Therm	Vectren rate
CO_2	$0.0033	$/lb	Streets default- Midwest
PM_{10}	$0.99	$/lb	Streets default- Midwest
NO_2	$.82	$/lb	Streets default- Midwest
SO_2	$1.50	$/lb	Streets default- Midwest
VOC	$0.30	$/lb	Streets default- Midwest
Stormwater Interception	$0.0062	$/gallon	Streets default- Midwest
Average Home Resale Value	$337,254	$	Zillow rate

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

APPENDIX F
RISK ASSESSMENT/PRIORITY AND PROACTIVE MAINTENANCE

Risk Assessment



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

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

- Medium—The failed tree or branch may or may not impact the target.
  - Frequently used areas that are partially exposed to the tree on one side
  - Constantly occupied area partially protected from the tree
- High—The failed tree or branch will most likely impact the target.
  - Fixed target is fully exposed to the tree or tree part

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

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

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

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

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

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

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

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

- None—Used for planting and stump sites only.
- Low—The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.
- Moderate—The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.
- High—The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.

- Extreme—The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

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

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

Priority Maintenance

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

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

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

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

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

Proactive Maintenance

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