Tree Management Plan

City of Liberty, Missouri

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Acknowledgments

Liberty'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 air quality, public health, and aesthetic values.

Liberty is thankful for the grant funding they received from the Missouri Department of Conservation (MDC) in cooperation with the Missouri Community Forestry Council and the U.S. Forest Service through its Tree Resource Improvement and Maintenance (TRIM) cost-share program. The TRIM grant program is designed to encourage communities to create and support long-term and sustained urban and community forestry programs. Liberty is also thankful for the support they receive from Tree Liberty and the Heartland Tree Alliance.

Notice of Disclaimer. Inventory data collected during the December 2013 inventory are provided by Davey Resource Group, a division of The Davey Tree Expert Company, and inventory data collected during the January 2006 inventory were collected by Skip Kincaid and Associates. Inventory data are based on visual recording at the time of inspection. Visual records do not include individual testing or analysis and do not include aerial or subterranean inspection. Data collection in January 2006 was not conducted by the Davey Resource Group and records may not remain accurate after inspection due to variable deterioration of inventoried material. Davey Resource Group is not responsible for differences and inaccuracies in data collected prior to the 2013 inventory. Davey Resource Group 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 Davey Resource Group'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 Liberty, Missouri, by Davey Resource Group with a focus on addressing short- and long-term maintenance needs for inventoried public trees. Davey Resource Group 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 was utilized, along with information about the City's existing program and vision for the urban forest, to develop this *Tree Management Plan*. The economic, environmental, and social benefits that trees provide to Liberty is presented, and a strategy for addressing and managing the threat of the emerald ash borer in the city's urban forest is also included in the plan.

State of the Existing Urban Forest

The December 2013 and the January 2006 inventories collected trees and stumps along public street rights-of-way (ROW). The City selected areas for the inventory, which included Downtown Liberty and the majority of the neighborhoods south of S. 291 Highway to South Liberty Parkway between W. Liberty Drive and Birmingham Road. A total of 1,825 sites were recorded during the inventory: 1,789 individual trees and 36 stumps. Analysis of the tree inventory data found:

- The overall condition of the inventoried tree population was rated to be Fair.
- Two species, *Pyrus calleryana* (Callery pear) and *Quercus palustris* (pin oak), make up such a large percentage of the street ROW (12%) and (11%) that it threatens biodiversity.
- Overall, the diameter size class distribution of the inventoried tree population trends towards the ideal, with a greater number of young trees (0–8 inches in diameter at breast height [DBH]) than established, maturing, or mature trees (9–17 inches DBH, 18–24 inches DBH, and >24 inches DBH, respectively).
- Trees provide approximately $89 in annual benefits.
- Energy Savings: 82 megawatt-hours (MWh) and 2,000 therms equaling $7,500/year.
- Stormwater Interception: 3,789,000 gallons valued at $23,500/year.
- Carbon Sequestration: 2,420 tons valued at $16,000/year.
- Avoided Carbon Emissions: 213 tons valued at $1,500/year.

Tree Maintenance and Planting Needs

Trees provide many environmental and economic benefits that justify spending the time and money for planting and maintenance. Maintenance needs recommended during the inventory include tree and stump removal (12%), pruning (63%), and training of young trees (25%). Reducing tree-related risk should be prioritized so that those with the highest risk are addressed first. The inventory noted several Severe and High Risk trees (1% and 7% of trees assessed, respectively); these trees should be removed or pruned immediately to promote public safety. Moderate and 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.

Liberty's urban forest will benefit greatly from a three-year young tree training cycle and a five-year routine pruning cycle and. 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, approximately 260 trees should be cleaned each year during the five-year routine pruning cycle, and at least 153 young trees should be structurally pruned each year during the three-year young tree training prune.

Tree Removal	• Severe Risk = 21 trees • High Risk =46 trees • Moderate Risk =32 trees • Low Risk =91 trees
Pruning	• Severe Risk = 1 trees • High Risk = 83 trees
RP Cycle	• Number of trees in cycle each year = approximately 260
YTT Cycle	• Number of trees in cycle each year = at least 153
Tree Planting	• Number of trees each year = at least 55

Planting trees is necessary to maintain 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 storms, wind, ice, snow, flooding, and drought). If budgets allow and follow-up maintenance is feasible, the City should increase the number of trees planted to exceed what is recommended in this plan to better prepare for impending threats and to increase urban forest benefits.

Photograph 1. The City of Liberty recognizes that its urban forest is critical to ecosystem health and economic growth. Planning and action is required to promote and sustain a healthy urban forest.

Citywide tree planting should focus on creating canopy in areas that promote economic growth (such as business districts), in parking lots and near buildings with insufficient shade, and where there are gaps in the existing canopy. Trees of varied species should be planted; however, the planting of pin oak should be limited until the species distribution normalizes. The City's existing planting list offers smart choices for species selection. Due to the species distribution and impending threats from emerald ash borer (EAB, *Agrilus plannipennis*), Callery pear and all *Fraxinus* spp. (ash) trees should be temporarily removed from the planting list or planted only when a landscape plan is in place.

Urban Forest Program Needs

Adequate funding will be needed for the City to implement an effective management program that will provide short- and long-term public benefit, to ensure that priority maintenance is performed expediently, and to establish proactive maintenance cycles. The estimated total cost for the first year of this five-year program is approximately $71,000; this total will decrease by Year 3 of the program to approximately $37,500 per year. High-priority removal and pruning is costly; most of this work is scheduled during the first year of the program, which is why the budget is higher for that year. After this priority work has been completed, the urban forestry program will mostly involve proactive work, which is generally less costly, so budgets for later years are projected to be lower.

Supporting proactive management of trees through funding will over the long term reduces municipal tree care management costs and possibly the costs to build, manage, and support some city infrastructure.

Liberty has many opportunities to improve its urban forest. Planned tree planting and a systematic approach to tree maintenance will transform an on-demand, priority-based operation into a cost-effective, proactive program. Investing in this tree management program will increase the economic and environmental benefits the community receives from its trees, improve tree care efficiency, and promote public safety.

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Introduction

The City of Liberty is home to more than 29,140 full-time residents who enjoy the beauty and benefits of their urban forest. The City's forestry program manages trees on public property: along the street ROW, in parks, and in public spaces. For approximately 10 years, Liberty's Parks and Open Space Department has included a staff of nine who are dedicated to the urban forestry program.

Funding for the City's urban forestry program comes from the Parks fund which is generated by sales tax along with money received from TreeLiberty and the Heartland Tree Alliance. Money received from TRIM grants through the MDC has also been beneficial in funding urban forestry projects within the city. Liberty conducted an inventory of public trees in 2006 and 2013. The City has a tree ordinance, maintains a budget of more than $1.80 per capita for tree-related expenses, celebrates Arbor Day, and has been a Tree City USA for 10 years. Past urban forestry projects have demonstrated a desire to improve the environment through higher levels of tree care and have earned the City one Tree City USA Growth Award.

Approach to Tree Management

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

In December 2013, Liberty worked with Davey Resource Group to inventory trees and develop a management plan. This plan also utilizes data collected in a 2006 tree inventory conducted by Skip Kincaid and Associates. This plan considers the general condition, diversity, and distribution of the inventoried trees and provides a prioritized system for managing street ROW trees. The following tasks were completed:

- Inventory of trees and stumps within the street ROW
- Analysis of tree inventory data from the 2006 and 2013 and inventories
- Development of a plan that prioritizes the recommended tree maintenance

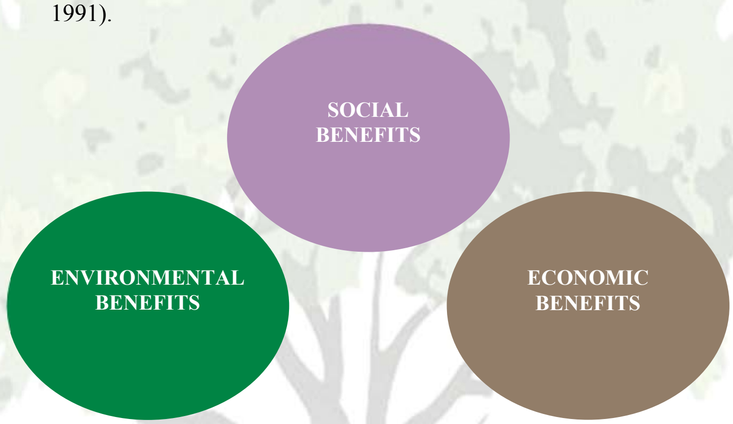
This plan is divided into four sections:

- Section 1 (*Benefits of the Urban Forest*) summarizes the economic, environmental, and social benefits that trees provide to the city.
- Section 2 (*Tree Inventory Analysis*) summarizes the tree inventory data and presents trends, results, and observations.
- Section 3 (*Tree Management Program*) utilizes the inventory data to develop a prioritized maintenance schedule and projected budget for the implementation of the recommended tree maintenance over a five-year period.
- Section 4 (*Emerald Ash Borer Strategy*) presents proactive maintenance and policy strategies for the prevention and mitigation of an EAB infestation.

Section 1: Benefits of the Urban Forest

The urban forest plays an important role in supporting and improving the ecology of urban areas. A tree's shade and beauty contributes to the community's quality of life and softens the often hard appearance of urban landscapes and streetscapes. When properly maintained, trees provide abundant economic, environmental, and social benefits to a community far in excess of the time and money invested in their planting, protection, pruning, and removal.

- 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 2001b).
- Chicago apartment buildings with medium amounts of greenery had 42% fewer crimes than those without any trees (Kuo and Sullivan 2001a).
- Chicago apartment buildings with high levels of greenery had 52% fewer crimes than those without any trees (Kuo and Sullivan 2001a).
- Employees who see nature 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 3–4 minutes (Ulrich 1991).



- 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. 100 mature tree crowns intercept ~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.

- Trees increase residential property values an average of 7% when present in the yard or neighborhood. Commercial property rental rates were 7% higher when trees were on the property (Wolf 2007).
- Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State Univ. 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 the products is better in business districts having trees than those considered barren (Wolf 1998b).
- The quality of landscaping along the routes leading to the business district had a positive influence on consumers' perceptions of the area (Wolf 2000).

There is a growing understanding and validation of the importance of trees to a community. Scientists and researchers have studied the effects of trees on air quality, crime rates, human behavior, property values, stormwater runoff, and traffic patterns. Trees are demonstrably beneficial and positively affect public health. The benefits trees provide are commonly divided into three categories—economic, environmental, and social.

Photograph 2. Trees provide economic, environmental, and social benefits, including energy conservation, increased property values, reduction of air pollutants, and temperature moderation.

The i-Tree Streets application was used to assess the trees inventoried—this management and analysis tool uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits provided by trees, including air quality improvement, carbon dioxide (CO_2) reduction, energy conservation, increases in property value, and stormwater control. It estimates the costs and benefits of a street tree population and creates annual benefit reports that demonstrate the value street trees have and give to a community.

Environmental

Energy Use

The contribution of the public trees towards conserving energy is reflected in their ability to shade structures and surfaces, reduce electricity use for air conditioning in the summer, and divert wind in the winter reducing natural gas use. Based on the inventoried trees, the annual electric and natural gas savings are equivalent to 82.1 MWh of electricity and 2,020 therms of natural gas. When converted into monetary values using default economic data, this accounts for a savings of $7,547 in energy consumption each year. *Platanus occidentalis* (American sycamore), *Ulmus parvifolia* (Chinese elm), and *Quercus muehlenbergii* (chinkapin oak) contribute the most to the annual energy benefits by providing over $11 per tree. These large leafy canopies provide shade, which reduces energy usage and increases their value. Smaller trees inventoried, such as *Acer ginnala* (Amur maple), *Amelanchier arborea* (downy serviceberry), and *Cercid canadensis* (eastern redbud), were found to have smaller reductions in energy usage on a per tree basis. Callery pear trees, which compose over 12% of the inventory, are valued at only $1.95 per tree.

Photograph 3. Residential trees provide benefits to homeowners in the form of energy conservation by shading homes during the summer and providing a buffer against the wind in the winter.

Economic

Liberty's inventoried urban forest of has recorded benefit savings of $88,926 annually from energy savings, increased property values, overall air quality improvements, and stormwater reduction. Figure 1 provides a breakdown of the annual benefits provided to the city. Table 1 shows the amount of energy savings provided by species.

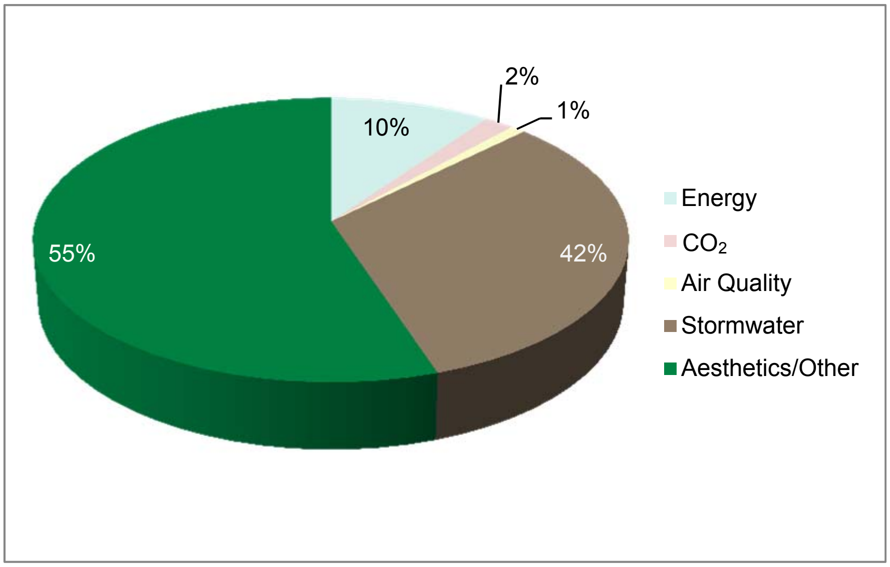


Figure 1. Annual i-Tree benefits provided to Liberty, Missouri, from the inventoried street tree population.

Table 1. i-Tree Energy Report

Liberty

Annual Energy Benefits of Public Trees

1/17/2014

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
pear, callery	4.9	334	101.8	99	433	(N/A)	12.4	5.7	1.95
oak, pin	19.9	1,354	613.0	596	1,951	(N/A)	11.7	25.8	9.33
maple, silver	9.6	653	281.9	274	927	(N/A)	7.3	12.3	7.13
maple, red	4.7	320	155.8	152	471	(N/A)	6.3	6.2	4.17
ash, white	3.0	205	76.3	74	279	(N/A)	6.0	3.7	2.59
apple	1.3	91	-2.6	-3	89	(N/A)	6.0	1.2	0.82
ash, green	6.7	457	187.9	183	640	(N/A)	6.0	8.5	5.98
maple, sugar	2.7	184	91.5	89	273	(N/A)	4.7	3.6	3.25
elm, Siberian	8.5	577	139.7	136	713	(N/A)	4.0	9.4	10.04
redbud, eastern	1.2	80	-7.3	-7	73	(N/A)	3.7	1.0	1.10
tupelo, black	0.5	33	8.8	9	41	(N/A)	2.9	0.5	0.81
maple, Freeman	0.3	18	11.7	11	29	(N/A)	2.5	0.4	0.65
sweetgum	2.6	175	74.2	72	247	(N/A)	2.0	3.3	6.86
honeylocust, thornless	0.7	46	-3.7	-4	42	(N/A)	1.6	0.6	1.51
ginkgo	0.3	23	2.1	2	25	(N/A)	1.5	0.3	0.91
oak, northern red	0.9	59	24.1	23	82	(N/A)	1.5	1.1	3.16
hackberry, northern	1.5	105	32.4	31	136	(N/A)	1.3	1.8	5.92
walnut, black	1.0	71	-16.4	-16	55	(N/A)	1.1	0.7	2.87
elm, hybrid	0.2	12	-1.7	-2	10	(N/A)	1.0	0.1	0.56
oak, scarlet	0.4	29	11.6	11	40	(N/A)	1.0	0.5	2.34
maple, Norway	0.7	46	19.3	19	65	(N/A)	0.9	0.9	4.06
plum	0.3	21	-2.4	-2	19	(N/A)	0.8	0.3	1.36
birch, river	0.7	50	20.2	20	70	(N/A)	0.7	0.9	5.36
boxelder	1.3	88	43.7	42	131	(N/A)	0.7	1.7	10.07

Table 1. i-Tree Energy Report–Continued

Liberty

Annual Energy Benefits of Public Trees

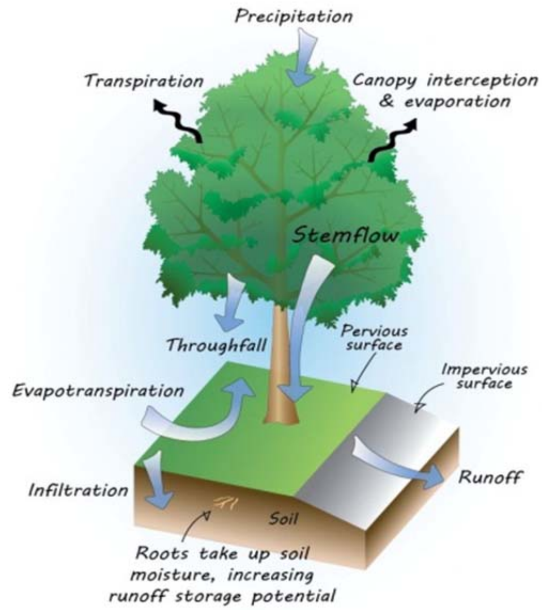
1/17/2014

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
locust, black	0.9	60	25.4	25	85	(N/A)	0.7	1.1	7.08
cherry, Japanese flowerin	0.2	17	3.8	4	20	(N/A)	0.7	0.3	1.71
oak, willow	0.4	25	10.5	10	36	(N/A)	0.6	0.5	3.24
elm, American	1.0	68	13.9	13	81	(N/A)	0.6	1.1	7.37
hornbeam, American	0.1	7	2.0	2	9	(N/A)	0.6	0.1	0.83
maple, amur	0.3	21	10.4	10	31	(N/A)	0.6	0.4	2.84
tulip tree	0.3	23	8.6	8	31	(N/A)	0.6	0.4	3.11
maple, Miyabe	0.0	1	1.0	1	2	(N/A)	0.6	0.0	0.20
sycamore, American	1.1	78	36.1	35	113	(N/A)	0.6	1.5	11.33
honeylocust	0.5	32	-1.9	-2	30	(N/A)	0.5	0.4	3.38
linden, littleleaf	0.1	5	1.3	1	6	(N/A)	0.5	0.1	0.67
serviceberry, downy	0.1	4	0.3	0	5	(N/A)	0.4	0.1	0.59
oak, white swamp	0.3	24	10.1	10	34	(N/A)	0.4	0.4	4.19
planetree, London	0.0	1	0.2	0	1	(N/A)	0.4	0.0	0.13
cedar, spp.	0.1	10	-4.2	-4	6	(N/A)	0.3	0.1	0.93
spruce, blue	0.1	5	-2.3	-2	2	(N/A)	0.3	0.0	0.41
catalpa, northern	0.3	22	9.3	9	32	(N/A)	0.3	0.4	6.32
pear, common	0.1	8	2.4	2	10	(N/A)	0.3	0.1	2.04
European hornbeam	0.0	3	0.7	1	3	(N/A)	0.2	0.0	0.83
dogwood, flowering	0.0	2	0.1	0	2	(N/A)	0.2	0.0	0.59
poplar, white	0.2	15	6.5	6	22	(N/A)	0.2	0.3	5.41
osage-orange	0.0	0	0.1	0	0	(N/A)	0.2	0.0	0.13
pine, Austrian	0.1	7	-2.8	-3	5	(N/A)	0.2	0.1	1.58
oak, white	0.2	13	5.4	5	18	(N/A)	0.2	0.2	5.94
magnolia, sweetbay	0.0	1	0.2	0	1	(N/A)	0.2	0.0	0.44
mulberry, white	0.1	10	3.9	4	14	(N/A)	0.2	0.2	4.62
zelkova, Japanese	0.0	3	0.3	0	3	(N/A)	0.2	0.0	1.01
magnolia, southern	0.0	1	0.0	0	1	(N/A)	0.1	0.0	0.71
pine, eastern white	0.1	6	-0.9	-1	5	(N/A)	0.1	0.1	2.73
cedar, Eastern red	0.0	3	-1.2	-1	2	(N/A)	0.1	0.0	0.87
Goldenrain tree	0.1	6	-0.9	-1	5	(N/A)	0.1	0.1	2.57
oak	0.0	0	0.1	0	0	(N/A)	0.1	0.0	0.20
oak, hybrid	0.0	0	0.2	0	0	(N/A)	0.1	0.0	0.22
cherry, black	0.2	15	7.0	7	22	(N/A)	0.1	0.3	11.00
catalpa, southern	0.0	2	0.3	0	2	(N/A)	0.1	0.0	1.03
buckeye	0.1	4	1.2	1	5	(N/A)	0.1	0.1	5.41
mulberry	0.0	3	1.4	1	5	(N/A)	0.1	0.1	4.56
unknown tree	0.0	1	0.2	0	1	(N/A)	0.1	0.0	0.83
poplar, black	0.0	0	0.0	0	0	(N/A)	0.1	0.0	0.02
larch, American	0.0	1	0.1	0	1	(N/A)	0.1	0.0	0.67
persimmon, common	0.1	4	1.2	1	5	(N/A)	0.1	0.1	5.41
spruce, Norway	0.0	1	-0.5	-1	0	(N/A)	0.1	0.0	0.30
tree-of-heaven	0.1	8	3.5	3	11	(N/A)	0.1	0.1	11.07
Turkish filbert	0.0	1	0.2	0	1	(N/A)	0.1	0.0	0.83
buckeye, Ohio	0.0	1	0.2	0	1	(N/A)	0.1	0.0	0.83
Paperbark maple	0.0	0	0.1	0	0	(N/A)	0.1	0.0	0.33
oak, Shumard	0.0	1	0.5	0	2	(N/A)	0.1	0.0	1.71
pine, scotch	0.1	4	-1.1	-1	3	(N/A)	0.1	0.0	3.13
Kousa dogwood	0.0	1	-0.1	0	1	(N/A)	0.1	0.0	0.85
oak, chinkapin	0.1	8	3.9	4	12	(N/A)	0.1	0.2	12.14
elm, Chinese	0.1	10	2.6	3	12	(N/A)	0.1	0.2	12.22
hickory, spp.	0.1	5	-0.9	-1	4	(N/A)	0.1	0.1	4.44
Total	82.1	5,581	2,020.2	1,966	7,547	(N/A)	100.0	100.0	4.22

Stormwater

Trees intercept rainfall, reducing costs to manage stormwater runoff—Liberty's inventoried trees intercept 3,789,275 gallons of rainfall annually. The estimated average savings for the City in the management of stormwater runoff is $23,494 annually.

Due to its abundance and large canopy, pin oak contributed most to the net annual stormwater benefits, intercepting approximately 918,000 gallons of rainfall. The most dominant species, Callery pear, intercepted an additional 194,000 gallons of rainfall. Large trees with leafy canopies provide the most value, for example, pin oak intercepted 18.2 times more gallons of rainfall than redbud, and silver maple intercepted 10.2 times more gallons than redbud.



- *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 taking up nutrients and other pollutants from soils and water through their roots.*
- *Trees transform pollutants into less harmful substances.*

Social

Aesthetic/Other

Trees provide social benefits in numerous quantifiable ways. These benefits stem, in part, from increases in property and real estate values. Liberty's trees contribute approximately $53,750 worth of Aesthetic/Other Benefits.

Photograph 4. The presence of mature trees in a neighborhood are associated with increased property values, happier people, and decreased crime rates.

Section 2: Tree Inventory Analysis

In December 2013, a Davey Resource Group International Society of Arboriculture Certified Arborist assessed and inventoried trees along the street ROW. Data from a January 2006 inventory conducted by Skip Kincaid and Associates included trees and stumps along the street ROW. These data sets were combined for a total of 1,825 sites. This merged data set consists of: 1789 trees and 36 stumps. Figure 2 provides a detailed breakdown of the number and type of sites inventoried.

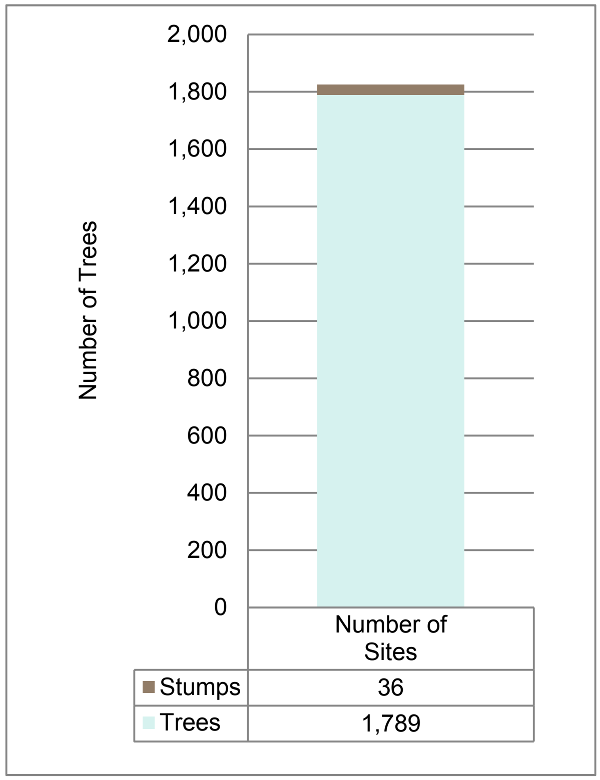


Figure 2. Liberty, Missouri's, combined inventory data from 2006 and 2013

Data Collection Methods

Tree data during the December 2013 inventory were collected using a system developed by Davey Resource Group that utilizes a customized ArcPad® program loaded onto pen-based field computers equipped with geographic information system (GIS). 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, and the site location method is provided in Appendix B. At each site, the following data fields were collected:

aboveground utilities
clearance required
condition
date
diameter
further inspection
hardscape damage
mapping coordinate
notes
observations
other risk factors
primary maintenance need
probability of failure
risk assessment
risk rating
serial number
size of defect
species
staff
stems
target rating
time

Primary and secondary maintenance are based on *ANSI A300 (Part 1)* (2008). Risk assessment and risk ratings during the December 2013 inventory conducted by Davey Resource Group are based on *Best Management Practices: Tree Risk Assessment* (ISA 2011). The January 2006 inventory used *Urban Tree Risk Management* (Pokorny et al. 2003).

The data collected were provided in i-Tree Streets™, ESRI™ shapefile and/or geodatabase, and Microsoft Excel™ and Access™ formats and can be found on the CD-ROM accompanying this plan.

Project Area

The January 2006 inventory consisted primarily of the Downtown Liberty area, while the December 2013 inventory focused on the neighborhoods and primary streets south of S. 291 Highway to South Liberty Parkway between W. Liberty Drive and Birmingham Road. These areas were selected by the City as areas of high importance and to further gain knowledge of their urban forest.

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- and long-term management planning. In this plan, the following criteria and indicators of the inventoried tree population were assessed:

Photograph 5. Davey Resource Group's ISA Certified Arborists inventoried trees along street rights-of-way to collect information about trees that could be used to assess the state of the urban forest.

- Species diversity, the variety of species in a specific population, affects the population's ability to sustain threats from invasive pests and diseases. It also impacts tree maintenance needs and costs, tree planting goals, and canopy continuity.
- Diameter size class distribution data affect the valuation of tree-related benefits as well as the estimation of maintenance needs and costs, planting goals, and canopy continuity. The diameter size class distribution can also be used to indicate relative age of a tree population.
- The general health of a tree population indicates how well trees are performing given their site-specific conditions. General health affects both short- and long-term maintenance needs and costs as well as canopy continuity.
- Analysis of inventory data provides insight into past maintenance practices and growing conditions that may affect future management decisions; other observations are presented for these purposes.

Species Diversity

Species diversity affects canopy continuity, maintenance costs, planting goals, 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. Because of the introduction and spread of Dutch elm disease in the 1930s and its presence today, massive numbers of *Ulmus americana* (American elm), a popular street tree in Midwestern cities and towns, have perished (Karnosky 1979). Many Midwestern communities were stripped of most of their mature shade trees, creating a drastic void in canopy cover. Many communities replanted to replace the lost elm trees. Ash and *Acer* spp. (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 and are a concern for biodiversity. EAB and Asian longhorned beetle (ALB, *Anoplophora glabripennis*) are non-native insect pests that attack some of the most prevalent urban shade trees and some 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 genera no more than 20%, and a single family no more than 30%.

	Callery pear	pin oak	silver maple	red maple	flowering crabapple
CLIENT	12%	11%	7%	6%	6%
10% Rule	10%	10%	10%	10%	10%

Figure 3. Five most abundant species of ROW trees collected in the cumulative inventories.

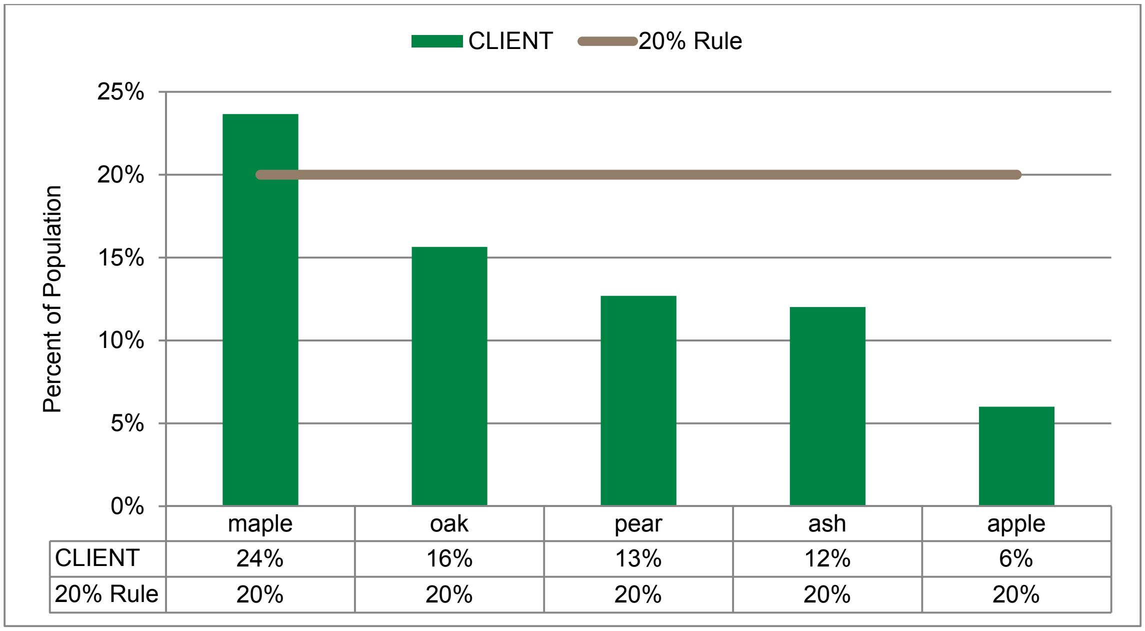


Figure 4. Five most abundant genera of ROW trees in the cumulative inventories.

Findings

Analysis of Liberty's tree inventory data indicated that the population had relatively good diversity, with 40 genera and 74 species represented.

Figure 3 compares the percentages of the most common species identified during the inventory to the 10% Rule. Callery pear and pin oak exceed the recommended 10% maximum for a single species in a population comprising 12% and 11% of the inventoried tree population, respectively.

Figure 4 compares the percentages of the most common genera on the street ROW to the 20% Rule. Maple exceeds the recommended 20% maximum for a single genus in a population comprising 24% of the inventoried tree population.

Discussion/Recommendations

Callery pear dominates the streets. Its abundance in the landscape makes it a concern and a limiting species in terms of biodiversity. Also, it is prone to dropping large limbs in extreme weather due to its poor growing habit and included bark. It is considered an invasive species within Missouri and the rest of the Midwest, and the MDC has recommended that cities and homeowners cease the planting of all cultivars of ornamental pears (Koenig 2011). Having a diverse population of trees is an objective of Liberty that will ensure that its urban forest is sustainable at the street, neighborhood and citywide levels.

Considering the large quantity of ash already present in the population and its susceptibility to EAB, the planting of ash should be stopped to minimize the potential for loss should EAB reach Liberty's urban tree population. See Appendix C for a recommended tree species list for planting.

Diameter Size Class Distribution

Analyzing the diameter size class distribution provides an estimate of the relative age of a tree population and 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 (>24 inches DBH). These categories were chosen so that the population could be analyzed following 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 (<8 inches DBH) with a smaller fraction (approximately 10%) in the large-diameter size class (>24 inches DBH). A tree population with the ideal distribution would have an abundance of newly planted and young trees, with established, maturing, and mature trees present in lower numbers.

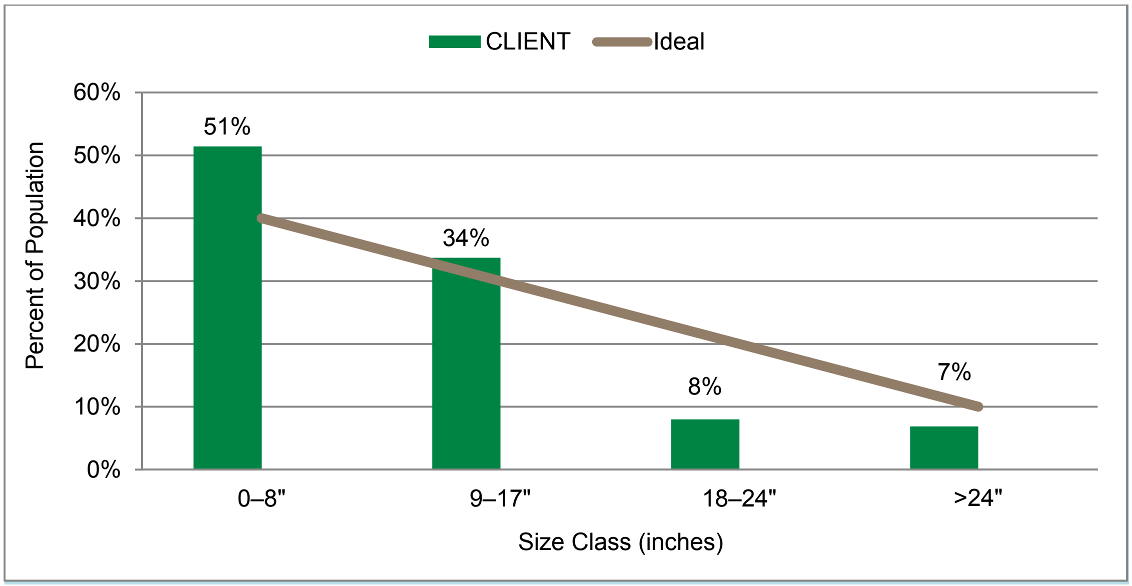


Figure 5. Comparison of diameter size class distribution for ROW trees to the ideal distribution.

Findings

Figure 5 compares Liberty's diameter size class distribution of the inventoried tree population to the ideal proposed by Richards (1983). Liberty's distribution trends toward the ideal; however, young trees outweigh the ideal by over 10% while larger diameter size classes fall short. This may be attributable to the unadjusted DBH's of the trees from the 2006 inventory. These trees have grown and some have likely moved into more mature DBH classes. This may account for the overabundance of young trees in the population.

Discussion/Recommendations

Even though it may appear that Liberty has too many young trees, that is not the case. Actually, Liberty has too few established, maturing, and mature trees and, thus, the distribution is skewed. The City must promote tree preservation and proactive tree care to ensure older trees survive as long as possible. One of Liberty's objectives is to have an uneven-aged distribution of trees at the street, neighborhood and citywide levels. Davey Resource Group recommends that Liberty support a strong planting and maintenance program to ensure that young, healthy trees are in place to fill in gaps in tree canopy and provide for gradual succession of older trees. Tree planting and tree care will allow the distribution to normalize over time.

Planting trees is necessary to increase canopy cover and to 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 finding the best places to create new canopy is critical.

General Health

Davey Resource Group assessed the condition of individual trees based on methods defined by the ISA. Several factors were considered for each tree including root characteristics; branch structure; trunk, canopy, and foliage condition; and the presence of pests. The condition of each inventoried tree was rated Excellent, Very Good, Good, Fair, Poor, Critical, 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 can provide some insight into the stability of the population. In this plan, relative age was based on DBH. 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 relative age: young (0–8 inches DBH), established (9–17 inches DBH), maturing (18–24 inches DBH), and mature (>24 inches DBH).

Figures 6 and 7 illustrate the number of inventoried trees in each condition class and the percent of young, established, mature, and maturing trees relative to their condition.

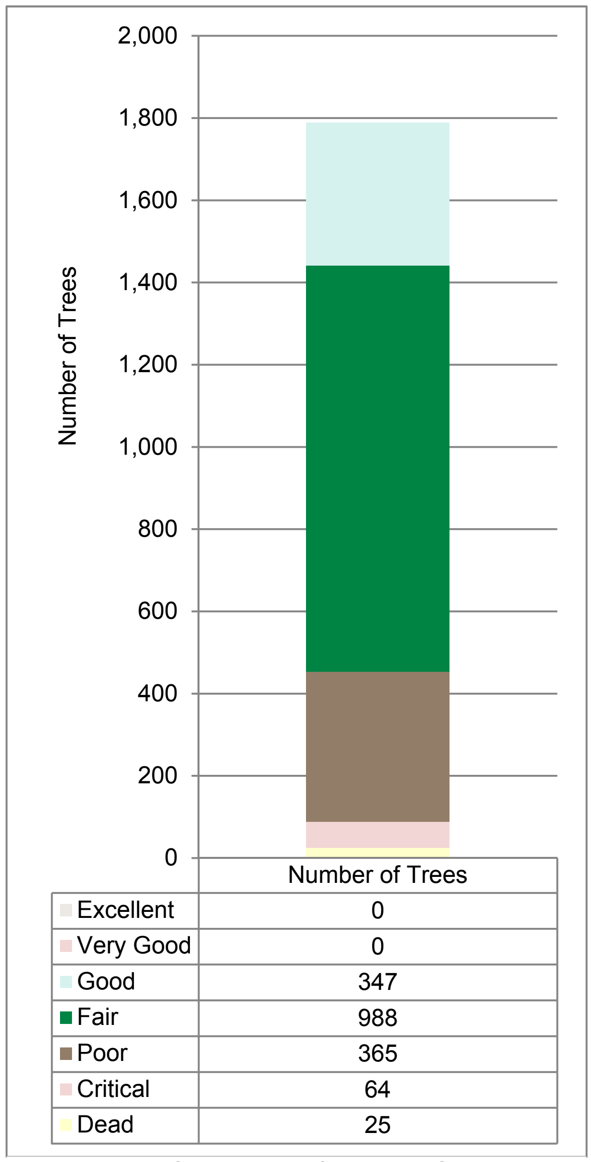


Figure 6. Condition of street ROW trees during the 2006 and 2013 inventories.

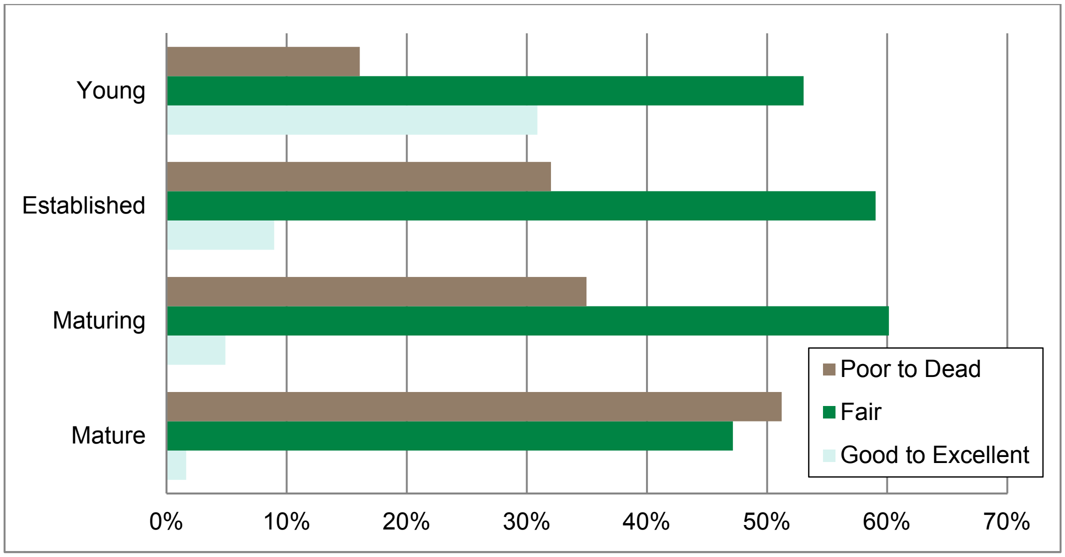


Figure 7. Tree condition by relative age during the 2006 and 2013 inventories.

Findings

The majority (55%) of the inventoried trees were recorded to be in Fair condition, while 19% were found to be in Good condition and 25% were found to be in Poor or worse condition (Figure 6). Based on these data, the general health of the overall inventoried tree population is rated Fair. Figure 7 illustrates that most of the young trees were rated to be in Fair to Good condition while most of the mature trees were rated to be in Fair to Poor condition.

Discussion/Recommendations

Even though the condition of Liberty's inventoried tree population is typical, the conditions found lent some insight into maintenance needs and historical maintenance practices:

- The balanced trend in tree condition across age classes with a higher proportion of young trees in Good condition and a steady increase in Poor to Dead trees as they mature reveals that there are opportunities to improve Liberty's tree care across all age classes and diameters.
- Dead trees and trees in Critical condition should be removed because of their failed health; they most likely will not recover even if care is increased.
- Younger trees rated in Fair or Poor condition may benefit from improvements in structure that in time may improve their health. Pruning should follow *ANSI A300 Standards*.
- Poor condition ratings given to mature trees were generally due to visible signs of decline and stress, including decay, dead limbs, sparse branching, or poor structure. These trees will require corrective pruning, regular inspections, and possible intensive plant health care to improve their health.
- Related to the long-term general health of the urban forest is the need for proper tree care practices. Many of the newly planted trees were improperly mulched, had mechanical damage, or had staking hardware attached to them after it should have been removed. Following guidelines developed by the ISA and those recommended by *ANSI A300 Standards* will ensure that tree maintenance practices will improve the general health of the urban forest.

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 then create risks to public health and safety. Existing or possible conflicts between trees and infrastructure were recorded during the inventory:

- *Clearance Requirements*—The inventory noted trees blocking the visibility of traffic signs or signals, streetlights, or other safety devices. This information should be used to schedule pruning activities.
- *Overhead Utilities*—The presence of overhead utility lines above a tree were noted; it is important to consider these data when planning pruning activities and selecting tree species for planting.
- *Hardscape Damage*—Sometimes trees adversely impact hardscape, which may adversely impact trees. The inventory recorded damage related to trees causing curbs, sidewalks, and other hardscape features to lift. These data should be used to schedule pruning and plan repairs to damaged infrastructure. To limit hardscape damage caused by trees, trees should be planted only in growing spaces where adequate above and belowground space is provided.

Findings

There were 20 trees recorded with some type of clearance issue. Most of those (55%) were related to conflicts with pedestrians using sidewalks. Pedestrian Clearance and conflict was recorded when the bottom of a tree's canopy over the sidewalk was less than 8 feet and likely to encounter a pedestrian's head or face as they used the sidewalk.

There were 104 trees with utilities directly over or passing through the tree canopy. Of those trees, 56% were large- or medium-size trees greater than six inches in diameter.

Hardscape damage was minimal: less than 10% of the tree population raised sidewalk slabs or curbs.

Table 2. Trees Noted to be Conflicting with Infrastructure

Tree and Infrastructure Conflict	Number of Trees	Percent of Population
Pedestrian	11	1%
Vehicles	4	<1%
Building	0	<1%
Signs or Signals	5	<1%
Overhead Utilities	104	6%
Hardscape	177	11%

Discussion/Recommendations

Tree canopy should not interfere with vehicular or pedestrian traffic; rest on buildings; or block signs, signals, or lights. Pruning to avoid clearance issues and to raise tree crowns should be completed in accordance with *ANSI A300 (Part 1)* (2008). Clearance distance guidelines used by Davey Resource Group are: 14 feet over streets; 8 feet over sidewalks; and 5 feet from buildings, signs, signals, or lights.

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

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

Other Observations

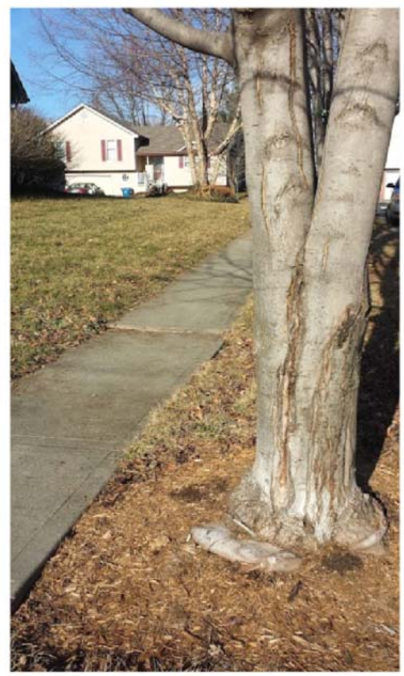
Observations were recorded during the inventory to further describe a tree's health, structure, or location when more detail was needed (Table 3).

Findings

Poor structure and cavity/decay were observed and recorded most often (11.6% and 5.6% of inventoried trees, respectively). Of these 313 trees, 32 were recommended for removal and 43 were rated to be High or Severe Risk trees.

Table 3. Observations Recorded During the Street Tree Inventory

Observation	Number Inventoried	Percent
Poor Structure	211	11.6%
Cavity or Decay	102	5.6%
Remove Hardware	61	3.3%
Other—see notes	282	15.5%
Serious Decline	9	0.5%
Poor Root System	59	3.2%
Poor Location	5	0.1%
Improperly Mulched	56	3.1%
Mechanical Damage	55	3%
Improperly Installed	7	0.4%
Improperly Pruned	24	1.3%
None	954	52.3%
Total	1825	99.9%



Photograph 6. This 13-inch diameter-at-breast-height *Acer rubrum* (red maple) located at 1703 Dunwich Drive has poor structure. With the location of the tree, size of defect, and potential for failure, this tree was recorded as high risk. The installation of a cable or bracing system may provide some structural support and mitigation risk.

Discussion/Recommendations

Trees noted as having poor structure (211 trees) or cavity or decay (102 trees) should be inspected regularly and corrective actions should be taken when warranted. If their condition worsens, removal may be required.

Staking should only be installed when necessary to keep trees from leaning (windy sites) or to prevent damage from pedestrians and/or vandals. Stakes should only be attached to trees with a loose, flexible material. Installed hardware that has been attached to any tree for more than one year and hardware that may no longer be needed for its intended purposes should be inspected and removed as appropriate.

The costs for treating deficient trees must be considered to determine whether removing and replacing the tree is the more viable option.

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

Davey Resource Group recommended four trees for further inspection. It should be noted that all four of the sites listed for further inspection come from the January 2006 inventory. They consist of three *Acer saccharinum* (silver maples) and one *A. platanoides* (Norway maple) that were noted as leaning, having trunk wounds, or poor structure such as co-dominant leaders.

Discussion/Recommendations

An ISA Certified Arborist should perform additional inspections of the four trees.

If it is determined that the silver maple and the Norway maple 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 crucial to ensuring the health and continuity of the street trees. Appendix C provides information about some of the current potential threats to Liberty'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 Missouri (Figure 8). It is important to note that the figure presents data only from the inventoried conducted in 2006 and 2013. Many more trees throughout Liberty, including those on public and private property, may be susceptible to these invasive pests.

Findings

Granulate ambrosia beetle (*Xylosandrus crassiusculus*) and ALB are known threats to a large percentage of the inventoried street trees (65% and 38%, respectively). These pests were not detected in Liberty, but if they were the city could see severe losses in its tree population.

EAB is present in Missouri—In July 2012 an arborist found an infected tree in Platte County near the City of Parkville approximately 10 miles from Liberty. There were 215 ash trees inventoried within Liberty's street ROW, but none showed the tell-tale symptoms. Private trees that were not part of this inventory may already be infected with EAB.

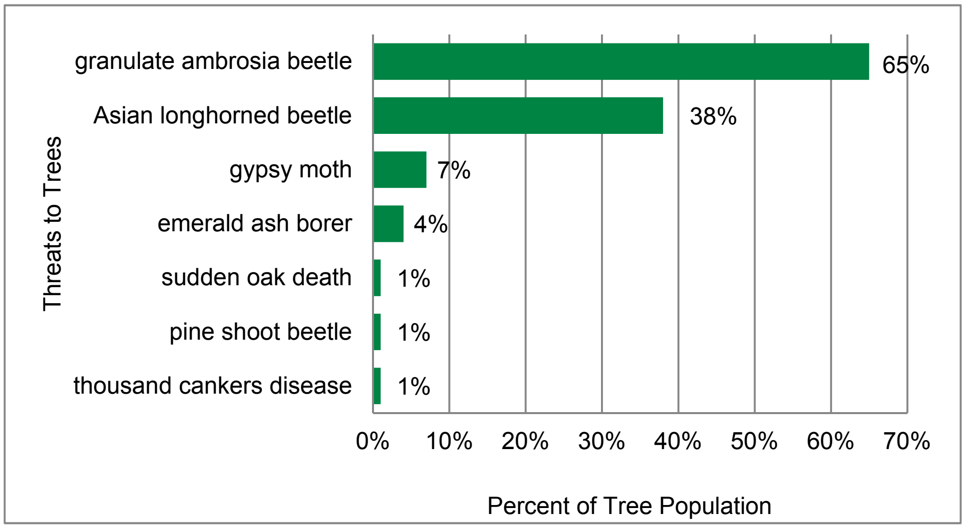


Figure 8. Potential impact of insect and disease threats noted during the 2006 and 2013 inventories.

Discussion/Recommendations

Liberty should be aware of the signs and symptoms of infestations and should be prepared to act if a significant threat is observed in their tree population or in a community nearby. An integrated pest management plan should be established that includes identifying and monitoring threats, understanding the economic threshold, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating results.

Section 3: Tree Management Program

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

Implementing a tree care program is an ongoing process; however, tree work must always be prioritized to reduce public safety risks. Davey Resource Group recommends completing the work identified during the inventory based on the risk rating assigned; however, it is also essential to routinely monitor the tree population to identify other High Risk trees so that they may be systematically alleviated. Pruning cycles and tree planting should be completed regularly; however, priority work (especially trees rated as Severe or High Risk) must at times take precedence to ensure that risk is managed expediently.

How Risk Was Assessed During the Inventory

Every tree has an inherent risk of tree failure or defective tree part failure. During the inventory, Davey Resource Group performed a risk assessment for each tree and assigned a risk rating following protocol based on the *Urban Tree Risk Management* (Pokorny et al. 2003). The probability of failure, size of defective part, probability of target impact, and other risk factors were evaluated for each tree inventoried. Independent point values were assigned and summed to generate the risk rating.

- Probability of Failure (1–4 points). Identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions.
- Size of Defective Part (1–3 points). Rates the size of the part most likely to fail.
- Probability of Target Impact (1–3 points). Rates the use and occupancy of the area that would be struck by the defective part.
- Other Risk Factors (0–2 points). This category is used if professional judgment suggests the need to increase the risk rating. It is especially helpful when growth characteristics become a factor in risk rating. For example, some tree species have growth patterns that make them more vulnerable to certain defects such as weak branch unions and branching shedding.

Once the risk rating is calculated, a level of risk is assigned to each tree based on its risk rating. The assigned risk rating allows for effective prioritization of tree maintenance work.

- *Severe Risk* (rating of 9 or 10): Trees described as Severe Risk have defects that cannot be cost-effectively or practically treated. Most of the trees in this category have multiple or significant defects in the trunk, crown, or critical root zone. Defective trees and/or tree parts are generally larger than 20 inches in diameter and are found in areas of frequent occupation, such as a main thoroughfare, congested street, and/or near a school.
- *High Risk* (rating of 7 or 8): Trees designated as High Risk have defects that may or may not be cost-effectively or practically treated. Most of the trees in this category have multiple or significant defects affecting more than 40% of the trunk, crown, or critical root zone. Defective trees and/or tree parts are generally 4–20 inches in diameter and are found in areas of frequent occupation, such as a main thoroughfare, congested street, and/or near a school.
- *Moderate Risk* (rating of 5 or 6): Trees described as Moderate Risk have defects that may be cost-effectively or practically treated. Most of the trees in this category exhibit several moderate defects affecting less than 40% of a tree's trunk, crown, or critical root zone. These trees may be in high-, moderate-, or low-use areas.
- *Low Risk* (rating of 3 or 4): Trees designated as Low Risk have minor visible structural defects or wounds and are typically found in areas with moderate- to low-use areas.
- *None* (rating of 0): Used for planting sites and stumps.

Trees with elevated (Severe or High) risk levels are usually recommended for removal or for 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, as with a significant or memorial tree or a tree in an historic area, Liberty may decide that cabling, bracing, or moving the target may be the best option for alleviating risk.

Severe 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

Priority and Proactive Maintenance

For many communities, a proactive tree management program is considered to be unfeasible, and 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) (Figure 9). Proactive tree maintenance has many advantages over priority maintenance: the most significant advantage is reduced risk. When trees are assessed and pruned regularly in a proactive program, most defects will be found and eliminated before they escalate to a hazardous situation with an unacceptable level of risk. Other advantages of a proactive program are more predictable budgets and projectable workloads, reduced long-term tree maintenance costs, and increased environmental and economic benefits from trees.

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 7 or greater (High and Severe Risk). Proactive tree maintenance includes pruning of trees with an assessed risk of 6 or less (Moderate or Low Risk) and trees that are young. Tree planting, inspections, and community outreach are also considered proactive maintenance.

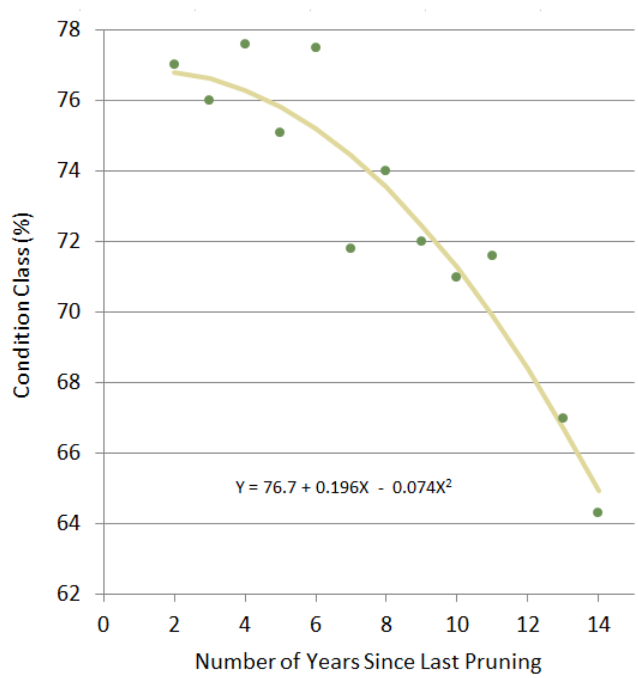


Figure 9. Relationship between average tree condition class and number of years since last pruning (adapted from Miller and Sylvester 1981).

Determination of acceptable risk ultimately lies with the Liberty parks and open space managers along with the Liberty Public Works Department. Trees often have associated risks; the location of a tree is an important factor in the determination and the 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 maintenance needs of a tree population enables tree work to be assigned priority based on observed risk. Once tree work is prioritized, it can be accomplished systematically 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 the potential risks associated with it exceed an acceptable level. Managing trees for risk reduction provides many benefits:

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

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

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

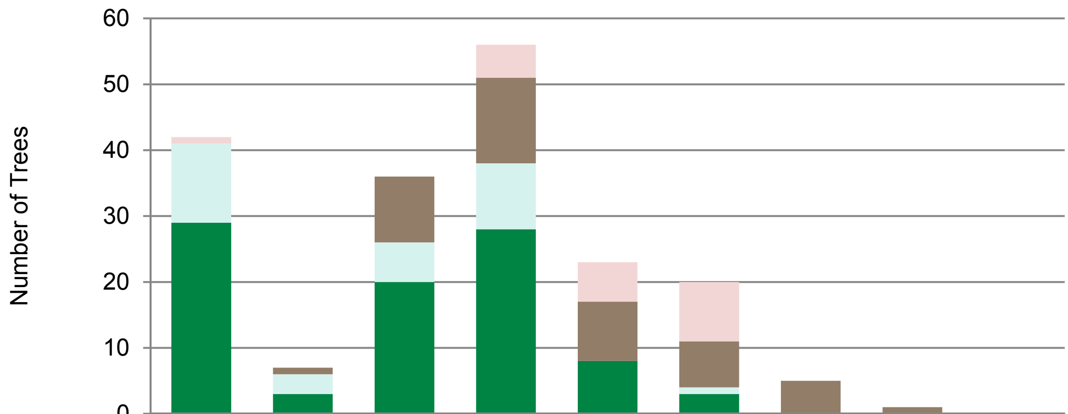
Why Prune Trees on a Cycle?
Miller and Sylvester (1981) examined the frequency of pruning for 40,000 street and boulevard trees in Milwaukee, Wisconsin. They documented a decline in tree health as the length of the pruning cycle increased. When pruning was not completed for more than 10 years, average 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.

Priority Tree Removal

Although tree removal is usually considered a last resort and may sometimes create a reaction from the community, there are circumstances when it 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. Davey Resource Group recommends that trees be removed when corrective pruning will not adequately eliminate the hazard or when it is cost-prohibitive to correct problems. Trees causing obstructions or interfering with power lines or other infrastructure should be removed when their defects cannot be corrected through pruning or other maintenance practices. Nuisance trees and diseased trees also merit removal.

Even though large, short-term expenditures may be required, funding and expediently completing priority tree removals is important to reduce risk and promote public safety.

Figure 10 presents tree removals identified during the inventory by risk rating and diameter size class. The following sections briefly summarize the recommended removals.



	1–3"	4–6"	7–12"	13–18"	19–24"	25–30"	31–36"	37–42"	≥43"
Severe	1	0	0	5	6	9	0	0	0
High	0	1	10	13	9	7	5	1	0
Moderate	12	3	6	10	0	1	0	0	0
Low	29	3	20	28	8	3	0	0	0

Diameter Size Class (inches)

Figure 10. Tree removals by risk rating and diameter size class.

Severe Risk

The inventory identified 21 Severe Risk trees that were recommended for removal. The size of the defect, the probability of failure, or the location of the trees in relation to their surroundings were reasons for Severe Risk ratings. These trees are medium to large in size (16–30 inches DBH) and should be removed immediately to promote public safety. Severe Risk removals can be performed concurrently with Severe Risk pruning.

High Risk

High Risk removals have observable and sizeable defects with elevated probabilities of failure. The location of these trees in relation to their surroundings also increases their risk. The inventory identified 46 High Risk trees recommended for removal. The diameter size classes for these trees ranged from 4–6 inches DBH to 37–42 inches DBH. These trees should be removed immediately because of their assigned risk. Severe and High Risk removals and pruning can be performed concurrently.

Moderate Risk

Tree removals in this category still pose some risk, but have a smaller size of defect and/or less potential for target impact. The inventory identified 32 Moderate Risk trees recommended for removal. Most Moderate Risk trees were smaller than 18 inches DBH. These trees should be removed as soon as possible after all Severe and High Risk removals and pruning have been completed.

Low Risk

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.

The inventory identified 91 Low Risk trees recommended for removal. The majority of these trees were smaller than 18 inches DBH. Most of these trees were young trees planted in recent years that have been damaged or improperly maintained and are in the process of declining steadily. It would be beneficial to the city to remove them and replace them with a healthy tree. All Low Risk trees should be removed when convenient and after all Severe, High, and Moderate Risk removals and pruning have been completed.

Stump Removal

The January 2006 inventory identified 36 stumps recommended for removal. Almost all of these stumps were smaller than 18 inches DBH. The most recent inventory conducted in December 2013 did not collect stumps in the ROW so it is possible that many of these stumps may have already been removed or have decayed to a point where they are no longer locatable.

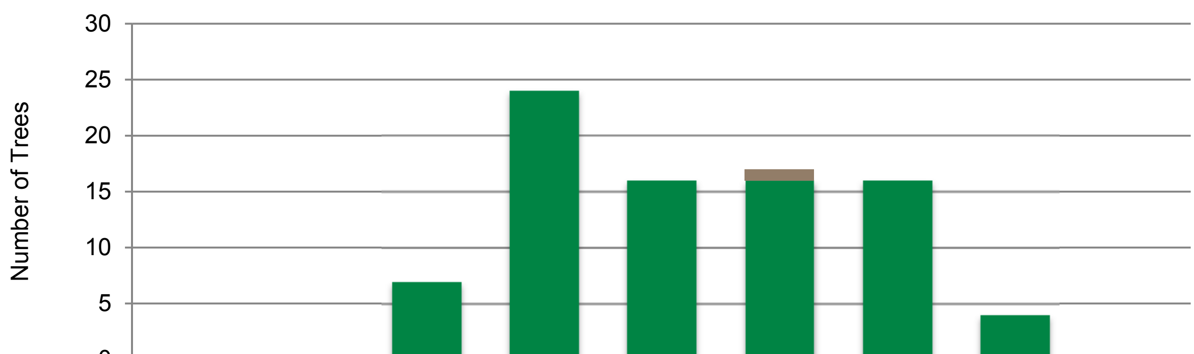
Discussion/Recommendations

Trees noted having poor structure (211 trees) or cavity or decay (102 trees) should be inspected on a regular basis and corrective actions should be taken when warranted. If their condition worsens, removal may be required. Proactive tree maintenance that actively mitigates elevated-risk situations will promote public safety.

Priority Pruning

Priority pruning generally requires cleaning the canopy of both small and large trees to remove hazardous 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 alleviate risk associated with the tree. Priority pruning includes trees with Severe and High Risk.

Figure 11 presents the number of trees recommended for pruning by size class, and the sections that follow briefly summarize the recommendations.



	1–3"	4–6"	7–12"	13–18"	19–24"	25–30"	31–36"	37–42"	≥43"
Severe	0	0	0	0	0	1	0	0	0
High	0	0	7	24	16	16	16	4	0

Figure 11. Tree pruning by risk rating and diameter size class.

Severe Risk

The inventory identified only one Severe Risk trees recommended for pruning. The size of the defect, probability of failure, or location of the tree in relation to its surroundings is the reason for its elevated risk rating. Severe Risk pruning should be performed immediately when the need has been identified and should occur concurrently with Severe Risk removals.

High Risk

High Risk trees recommended for pruning have observable and sizeable defects with elevated probabilities of failure. The location of these trees in relation to their surroundings also increases their risk. The inventory identified 83 High Risk trees recommended for pruning. The diameter size classes for these trees ranged from 7–12 inches DBH to 37–42 inches DBH. This pruning should be performed immediately because of assigned risk and may be done at the same time as other Severe and High Risk removals and pruning.

Proactive Maintenance

Proactive tree maintenance requires that trees are managed and maintained under the responsibility of an individual, department, or agency. Typically, tree work is 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 managed population is visited, assessed, and maintained regularly. Davey Resource Group recommends proactive tree maintenance that includes pruning cycles, inspections, and planned tree planting.

Pruning Cycles

The goals of pruning cycles are to visit, assess, and prune trees on a regular schedule to improve health and reduce risk. Typically, Davey Resource Group recommends that pruning cycles begin after all Severe and High Risk trees are corrected through priority removal or pruning. However, because of the long-term benefit that will come from implementing pruning cycles, Davey Resource Group may recommend it be implemented sooner. To ensure all trees receive the type of pruning they need to mature with better structure and fewer hazards, 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 tree they target, and the length of the cycle.

YTT Cycle

Trees included in the YTT Cycle are generally less than 12 inches DBH. These younger trees sometimes have branch structures that can lead to potential problems as the tree ages: codominant leaders, many 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, with the objective to increase structural integrity by pruning for one dominant leader. Of course, this is species-specific since many trees such as *Betula nigra* (river birch) may naturally have more than one leader. For these trees, YTT pruning is used to develop a strong structural architecture of branches so that future growth will lead to a healthy, structurally sound tree.

Discussion/Recommendations

Davey Resource Group recommends that Liberty implement a three-year YTT Cycle to commence in the first year after all Severe and High Risk trees are removed or pruned. The YTT Cycle will include existing young trees. During the December 2013 inventory, 459 trees smaller than 6 inches DBH were inventoried and recommended for YTT. During the January 2006 inventory there were 105 trees recommended for YTT; however, due to the span in time between these inventories, these 105 trees have been entered as routine prunes in the budget table and associated management plan sections. Since the number of young trees present is relatively few and the benefit of beginning the YTT Cycle is great, Davey Resource Group recommends that 153 trees be structurally pruned each year beginning in Year 1. 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. Table 4 shows the five most populous species requiring a young tree training prune.

Table 4. Top Five Species Recommended for the YTT Cycle

Species	Common Name	Number of Trees
Fraxinus americana	white ash	56
Nyssa sylvatica	blackgum	47
Acer × freemanii	Freeman maple	41
Acer rubrum	red maple	28
Malus spp.	flowering crabapple	26

RP Cycle

The RP Cycle includes medium and large trees (most >12 inches DBH) that need cleaning and crown raising and reducing to remove deadwood and to improve structure. Over time, routine pruning generally improves health and reduces risk as most problems can be corrected before they escalate into more costly priority tree work. Included in this cycle are Moderate and Low Risk trees that require pruning and that pose some risk but have a smaller size of defect and/or less potential for target impact. The hazards 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.

Discussion/Recommendations

Davey Resource Group recommends that the City establish a five-year RP Cycle where approximately one-fifth of the tree population is to be pruned each year. The 2013 and 2006 tree inventory identified approximately 1,056 trees for routine pruning. As soon as the budget allows, Davey Resource Group recommends that the City strive to routinely prune approximately 260 trees per year. Davey Resource Group recommended that the full scale RP Cycle begin in Year 2 of this five-year plan and that it commence after all Severe and High Risk trees are removed or pruned.

The inventory found most trees (59%) on the street ROW needed routine pruning (small and large tree cleaning).

Pruning Cycle Progression

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, thus, eliminated from the RP Cycle.

Inspections

Inspections are essential to unveiling 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 and in parks should be inspected regularly 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 for as appropriate. In addition to locating new hazards, inspections are an opportunity to look for signs and symptoms of pests and diseases. Liberty has a large population of trees susceptible to pests and diseases including ash a target for the EAB; maples which are susceptible to Asian longhorned beetle; and species that fall prey to oak wilt (OW, *Ceratocystis fagacearum*) and gypsy moth. A brief discussion of key pests is found in Appendix D.

Tree Planting

Planting trees is a worthwhile goal as long as trees species are carefully selected and correctly planted. Without upfront 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:

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

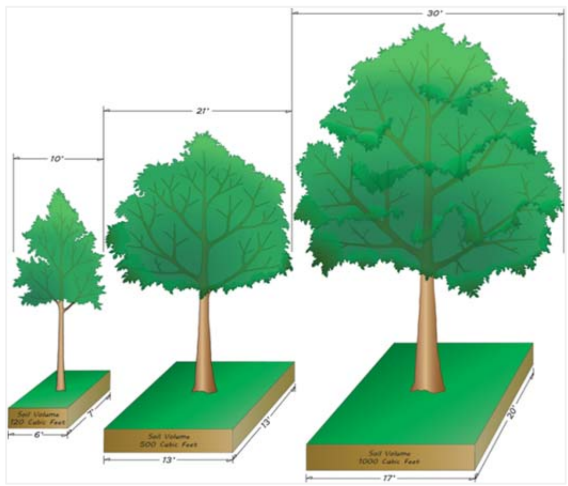


Illustration based on the work of Casey Trees (2008).

Inventoried Street ROW Planting Space

The goal of tree planting is to have a vigorous, healthy tree that lives to the limits of its natural longevity. That can be difficult to achieve in an urban growing environment because the soils can typically be of poor quality and irrigation is limited. However, proper planning, species selection, tree planting techniques, and follow-up tree maintenance will improve the chance of tree planting success.

Findings

The inventory did not collect any data regarding planting sites. But as a general observation and based on discussions with members of Parks and Recreation Department, it is understood that there are ample amounts of sites within tree lawns and other ROW areas to plant a significant amount of young trees ranging in size and species in upcoming years.

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 will be 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, which will reduce the time and money spent to mitigate the problem if such an event were to occur. A wide variety of tree species may help to limit the impacts from physical events such as strong storms, wind, ice, flooding, and drought, as different tree species react differently to stress.

The City of Liberty is located in USDA Hardiness Zone 6a, which identifies a climatic region where the average annual minimum temperature is between -5 and -10 degrees Fahrenheit. Tree species selected for planting in Liberty 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 at maturity, the tree's canopy 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 American sycamore have weak wood and typically drop many small branches during a growing season. Others, such as *Juglans nigra* (black walnut), drop high volumes of fruit. In certain species, such as *Ginkgo biloba* (ginkgo), female trees produce offensive smelling/large fruit; male trees, however, produce no fruit. Furthermore, a few species of trees, including common *Gleditsia tricanthos* (honeylocust) and *Crataegus* spp. (hawthorn), may have substantial thorns. These species should be avoided in high-traffic areas.

Consider seasonal color 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 interest to surrounding landscapes.

Appendix B lists tree species recommended for planting based on inventory findings; this list provides expected height at maturity for each species and is designed to promote species diversity.

Tips for Planting Trees

To ensure a successful tree planting effort:

- 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 threes 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 add soil amendments as appropriate for local conditions. Gently tamp and add water during filling to reduce large air pockets to 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 around the tree moist. Do not allow mulch to touch the trunk.

Photograph 7. Mulch piled too deep and touching the trunk of the tree will harm and may kill the tree. Davey Resource Group suggests that any mulch piled up around a tree should be spread out into a thin layer over the growspace and moved away from the trunk.

Newly Planted and Young Tree Maintenance

Equal in importance to planting trees is caring for them after they are planted. After planting a tree 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 to irrigate trees based on the 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, the tree is protected from mechanical damage, and the growspace is moist. Mulch should be applied in a thin layer, generally one to two inches, and the growing area covered. Mulch should not touch the tree trunk or be piled up around the tree.

Life-Long Tree Care

After the tree is established, it will require routine tree care, which includes inspections, routine pruning and watering, 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 each other; removing limbs that interfere with wires and buildings; pruning tree parts 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 lessen wind resistance and reduce 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 how urgent the removal is. Additionally, an arborist can provide advice and perform 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 concept of preventive maintenance to keep trees in good health, will help a tree better defend itself against insects, disease, and site problems. Arborists can help determine proper plant health so the city's tree population will remain healthy, providing benefits to the community for as long as possible.

Integrated Pest Management is a process involving 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 differ dramatically site by site, individual tree by 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.

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

Educating the community in 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.

Community Outreach

The data that have been 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. Utilized these data to promote the value of the urban forest and the tree management program:

- Tree inventory data can be utilized to justify needed priority and proactive tree maintenance activities as well as tree planting and preservation initiatives.
- Species data can be utilized to guide the development of tree species selection for planting projects with the objective of improving species diversity and limiting the introduction of invasive species.
- Information in this plan can be utilized to advise citizens about the presence of threats to urban trees such as improper maintenance and invasive pests.

Various avenues for outreach exist. 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 developed about trees and the benefits they provide. Arbor Day or Earth Day celebrations can be magnified and signs can be hung from trees to show the contributions trees make to the community. Even contests can be created to make people aware that trees are important. Trees provide oxygen we need to breathe, shade to cool our neighborhoods, and canopies to stand under to get out of the rain.

Liberty has the data to provide solid, meaningful outreach about the urban forest.

Inventory and Plan Updates

Davey Resource Group recommends that the inventory and management plan be updated 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/risk in the inventory database. Update the tree maintenance schedule and acquire the funds needed to promote public safety. Schedule work based on risk.
- Perform routine inspections of public trees as needed. Windshield surveys in line with an *ANSI A300 (Part 1)* (ANSI, 2011) will help City staff stay current regarding changing conditions. Update the tree maintenance schedule and the budget as needed so that identified tree work may be performed efficiently. Schedule 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 as work is performed. Add new tree work to the schedule when work is identified through inspections or a citizen call process.
- Re-inventory the street ROW and parks in five to seven years, updating all data fields.
- Revise the *Tree Management Plan* after five or seven years when the re-inventory has been completed.

Maintenance Schedule

Utilizing data from the 2013 and the 2006 City of Liberty tree inventory, an annual maintenance schedule was developed detailing the number and type of tasks recommended for completion each year. Budget projections were made by Davey Resource Group utilizing industry knowledge and public bid tabulations; actual costs were not specified by the City of Liberty. A summary of the maintenance schedule is presented here and the complete table presented in Appendix D.

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 $71,025 for the first year of implementation and decrease to approximately $37,500 by Year 3. Annual budget funds are needed to ensure that hazard trees are remediated and that critical YTT and RP Cycles can commence. With proper professional tree care, the safety, health, and beauty of the urban forest will improve.

FY 2014 **$71,025**

- **67 Priority Removals**
- **84 Priority Pruning**
- **16 Trees Recommended for Routine Pruning**
- **YTT Cycle; 153 Trees**
- **55 Trees Recommended for Planting and Follow-Up Care**
- **Inclusion of Newly Found Priority Tree Work (Removal or Pruning): Costs To Be Determined**

FY 2015 **$64,755**

- **123 Low- Moderate Risk Removals**
- **36 Stumps Ground**
- **RP Cycle 1/5 of Public Trees Cleaned**
- **YTT Cycle 1/3 of Young Trees Structurally Pruned**
- **55 Trees Recommended for Planting and Follow-Up Care**
- **Inclusion of Newly Found Priority Tree Work (Removal or Pruning): Costs To Be Determined**

FY 2016 **$37,300**

- **RP Cycle 1/5 of Public Trees Cleaned**
- **YTT Cycle 1/3 of Young Trees Structurally Pruned**
- **55 Trees Recommended for Planting and Follow-Up Care**
- **Inclusion of Newly Found Priority Tree Work (Removal or Pruning): Costs To Be Determined**

FY 2017 **$37,625**

- **RP Cycle 1/5 of Public Trees Cleaned**
- **YTT Cycle 1/3 of Young Trees Structurally Pruned**
- **55 Trees Recommended for Planting and Follow-Up Care**
- **Inclusion of Newly Found Priority Tree Work (Removal or Pruning): Costs To Be Determined**

FY2018 **$37,360**

- **RP Cycle 1/5 of Public Trees Cleaned**
- **YTT Cycle 1/3 of Young Trees Structurally Pruned**
- **55 Trees Recommended for Planting and Follow-Up Care**
- **Inclusion of Newly Found Priority Tree Work (Removal or Pruning): Costs To Be Determined**

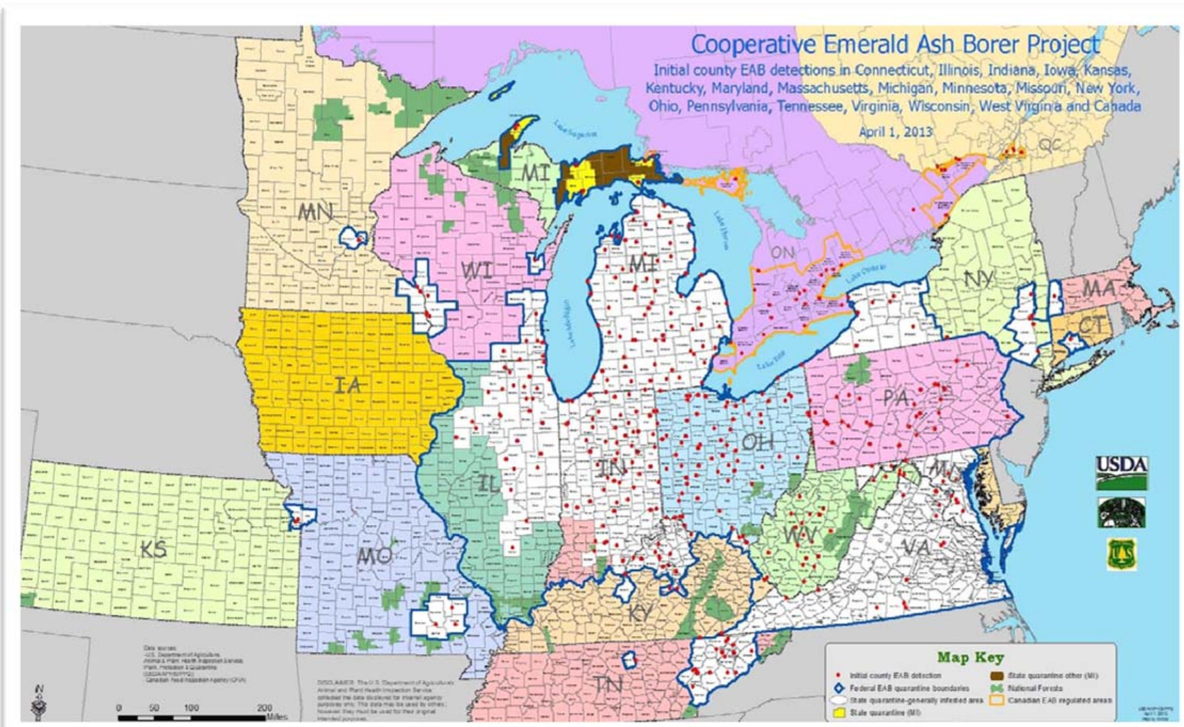
If routing efficiencies and/or contract specifications allow for the accomplishment of more tree work, or if the schedule requires modification to meet budgetary or other needs, then it should be modified accordingly. Unforeseen situations, such as severe weather events, may arise and change the maintenance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

Section 4. Emerald Ash Borer Strategy

Throughout the United States, urban and community forests are under increased pressure from exotic and invasive insects and diseases. Exotic pests that arrive from overseas typically have no natural predators and become invasive when our native trees and shrubs do not have appropriate defense mechanisms to fight them off. Mortality from these pests can range from two weeks with oak wilt, to seven years with EAB or more.

An integral part of tree management is being aware of invasive insects and diseases in the area and how to best manage them. Depending on the tree diversity within Liberty's urban forest, an invasive insect or disease has the potential to negatively impact the tree population.

This chapter provides the different management strategies for dealing with EAB. Included are sections on reforestation and how to effectively monitor EAB, increase public education, handle ash debris, work with stakeholders, and utilize ash wood. Appendix E contains additional EAB reference materials.



Map 1. EAB Detections Throughout North America as of April 2013
(Map Credit http://extension.missouri.edu/emeraldashborer/about.aspx)

Emerald Ash Borer

Emerald ash borer is a small insect native to Asia. In North America, the borer is an invasive species highly destructive to ash trees in its introduced range. The potential damage of EAB rivals that of chestnut blight and Dutch elm disease. Chestnut blight is a fungus that was introduced in North America around 1900, and by 1940, it virtually wiped out most of the mature *Castanea dentate* (American chestnut) population. It is believed that chestnut blight was imported by *Castanea* (chestnut) lumber or through imported chestnut trees. Dutch elm disease is a fungus spread sexually by the elm bark beetle. It was first reported in the United States in 1928 and was believed to have been introduced by imported timber. Since its discovery in the United States, it has killed millions of *Ulmus* (elm) trees. EAB is thought to have been introduced into the United States and Canada in the 1990s but was not positively identified in North America until 2002 in Canton, Michigan. It has now been confirmed in 14 states and has killed at least 50 to 100 million ash trees so far and threatens another 7.5 billion ash trees throughout North America. Missouri's EAB infestation was discovered July 2008 in the campground at the Wappapello Lake U.S. Army Corps of Engineers (USACE) Greenville Recreational Area in Wayne County. The insect has since been found in Reynolds and Madison counties in southeast Missouri and in Platte County near Kansas City. The EAB is a serious pest that threatens the health of all ash tree species in the state. With an estimated 3% of ash trees at risk in Missouri woods—and another 14–30% in cities and towns—the state is committed to early detection and thoughtful management of this pest (Univ. of Missouri Extension 2014). In the United States, EAB has been known to attack all native ash trees, including white, green, blue, and black ash.

EAB has been identified in Missouri and poses a serious threat to the health and condition of Liberty's urban forest.

Photograph 8. EAB adults grow to 5/8 inch in length. (Photograph courtesy of www.wisconsin.gov.)

Photograph 2. EAB larvae. (Photograph courtesy of www.emeraldashborer.info.)

Identification

The adult beetle is elongate, metallic green, and 3⁄8- to 5⁄8-inch long. The adult beetle emerges from late May until early August, feeding on a small amount of foliage. The adult females then lay eggs on the trunk and branches of ash trees and, in about a week, the eggs hatch into larvae, which then bore into the tree. Larvae are creamy white in color, can grow up to an inch long, and are found underneath the bark of the trees. The larvae tunnel and feed on the inner bark and phloem creating winding galleries as they feed. This cuts off the flow of the water and nutrients to the tree causing dieback and death.

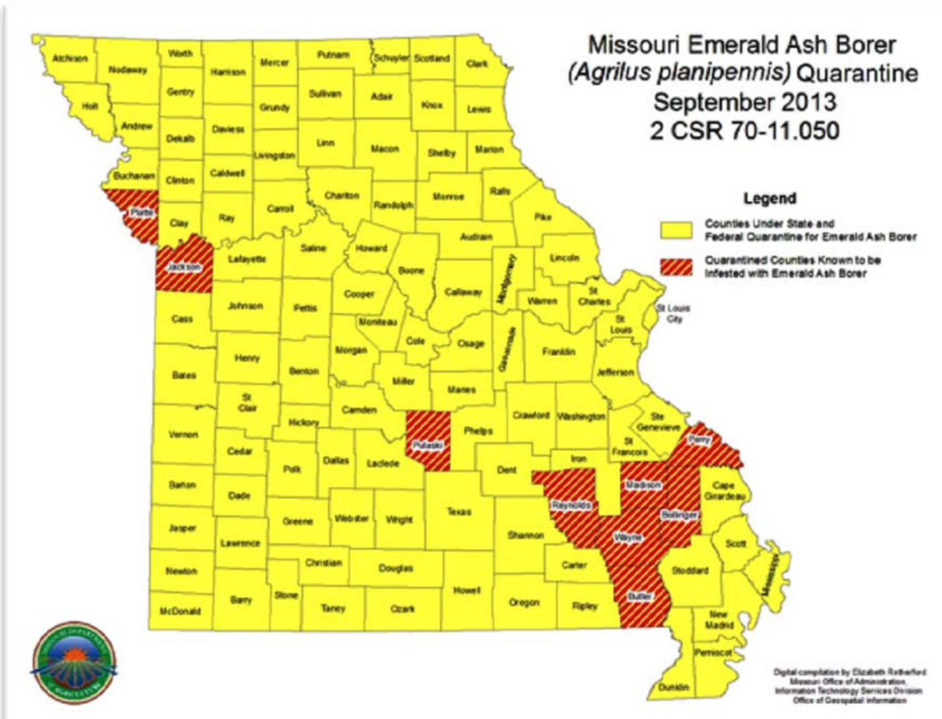
Photograph 3. Stock Photo. Larvae consume the cambium and phloem, effectively girdling the tree and eventually causing death within a few years.

Photograph 4. This ash tree is declining from EAB infestation. The loss of water and nutrients from the intense larvae tunneling can cause the trees to lose between 30% and 50% of their canopies during the first year of infestation. (Photograph courtesy of The Board of Regents of the University of Wisconsin System.)

EAB can be very difficult to detect. Initial symptoms include yellowing and/or thinning of the foliage and longitudinal bark splitting. The entire canopy may die back, or symptoms may be restricted to certain branches. Declining trees may sprout epicormic shoots at the tree base or on branches. Woodpecker injury is often apparent on branches of infested trees, especially in late winter. Removal of bark reveals tissue callusing and frass-filled serpentine tunneling. The S-shaped larval feeding tunnels are about 1⁄4 inch in diameter. Tunneling may occur from upper branches to the trunk and root flare. Adults exit from the trunk and branches in a characteristic D-shaped exit hole that is about 1/8 inch in diameter. The loss of water and nutrients from the intense larvae tunneling can cause trees to lose between 30% and 50% of their canopies during the first year of infestation. Trees often die within two years following infestation.

Missouri/Federal Response

In Missouri, the Missouri Department of Agriculture (MDA) is the lead agency responsible for control of invasive pests. The U.S. Department of Agriculture-Animal and Plant Health Inspection Service (USDA APHIS) federal agency assists with regulatory and control action of invasive pests. The MDA has declared EAB a public nuisance in Missouri and enacted a quarantine restricting the movement of ash trees and non-coniferous firewood (Figure 12). In July 2008, it was reported that EAB had been found in the campground at the Wappapello Lake. In July 2008, further infestations were found in Wayne County. The insect has since been found in Reynolds and Madison Counties in southeast Missouri and in Platte County near Kansas City.



Map 2. ***Current quarantine boundary in Missouri.***
(Map courtesy of Curators of the University of Missouri.)

Federal agencies have been actively researching control measures, including biological controls, developing resistant species, and testing various insecticides. Since 2003, American scientists in conjunction with the Chinese Academy of Forestry have searched for natural enemies of EAB in the wild. This led to the discovery of several parasitoid wasps, namely *Tetrastichus planipennisi*, a gregarious larval endoparasitoid; *Oobius agrili*, a solitary, parthenogenic egg parasitoid; and *Spathius agrili*, a gregarious larval ectoparasitoid. These parasitoid wasps have been released into the Midwest, United States as a possible biological control of EAB. States that released parasitoid wasps include Minnesota, Indiana, and Michigan.

Ash Population

With the threat of EAB nearing Liberty, it is crucial that the City have an action plan. Some of the most important questions to answer will be, "How many ash trees do we have, where are they located, and what actions should we take?" In order to answer these questions, the city needs to maintain an up-to-date inventory, know what resources are available, and understand the City's priorities.

Based on the current public tree inventory, there are 215 ash trees distributed throughout the city. Most of the ash trees were rated in Fair condition. Table 5 compares the diameter class of each ash tree by its condition class. Of the 215 ash trees inventoried, none are currently showing signs and symptoms of EAB.

Table 5. Ash Tree Condition Versus Diameter Class Matrix

		Diameter Class (inches)									
		1–3	4–6	7–12	13–18	19–24	25–30	31–36	37–42	43+	Total
Condition Class	Excellent	0	0	0	0	0	0	0	0	0	0
	Very Good	0	0	0	0	0	0	0	0	0	0
	Good	27	13	3	0	0	0	0	0	0	43
	Fair	12	53	42	22	7	4	3	0	0	143
	Poor	3	2	4	12	2	1	1	0	0	25
	Critical	0	0	1	3	0	0	0	0	0	4
	Dead	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0

Ash Tree Risk Reduction Pruning and Removals

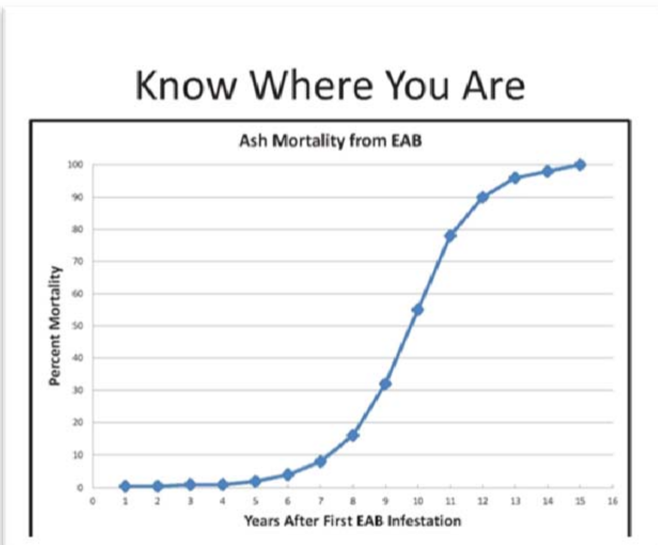
As the infestation of EAB nears Liberty, it becomes the City's highest priority, and it is advisable to refocus budgeted funds and personnel to concentrate more closely on the ash tree population. Davey Resource Group recommends that Liberty perform both treatment and safety related activities on ash trees. This activity will end up saving the City money and increasing productivity. However, it is only recommended due to EAB and the eventual removal of infested ash trees.

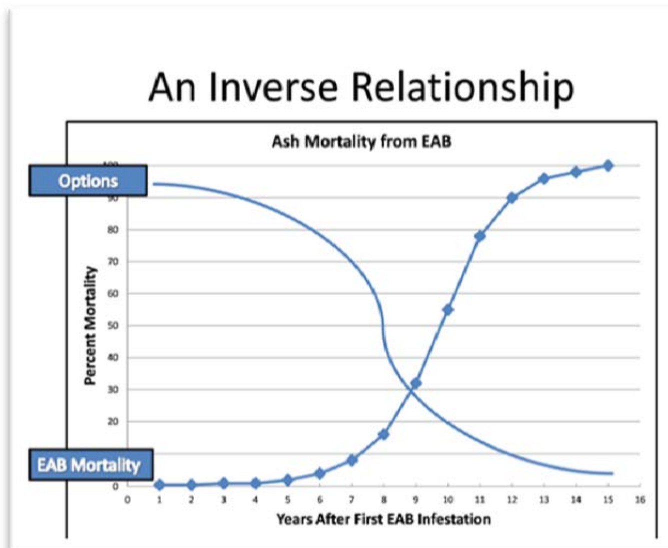
Davey Resource Group also recommends that Liberty proactively remove ash trees during road reconstruction projects and other public works associated activities. By proactively removing ash trees during construction, the cost and impacts should be lower.

In the event that the City decides to proactively remove ash trees, Davey Resource Group recommends that Liberty remove all ash trees less than 7 inches DBH and trees that are rated as Dead, Poor, or Critical condition first. These trees are providing little benefit to the community and the cost for removals should not be significant.

EAB Management Options

Liberty should explore different options for managing EAB. With the City striving to be proactive in EAB management before an infestation occurs, multiple management strategies are available to Liberty. The graphs below present a unique tool and show the possible management options for varying levels of EAB infestations. At this time there has not been any verification of EAB in Liberty and the City can currently be placed at Year 0 on both graphs for year after first EAB infestation. At this position, the City has ample time to prepare as well as select a management option. When infestation occurs, as depicted in the graph, the City's options for management decrease. However EAB has been found and verified within 10 miles of Liberty. It is expected that within the next couple of years Liberty's position on these graphs will change.





Source: Emerald Ash University (www.emeraldashborer.info)

At this time, Liberty has the opportunity to select one of several management types; some of these include removing and replacing all ash, treating all ash, or a combination approach of the removals and treatment. The City should explore all options and develop their strategy based on the benefits to the community. The following are current strategy options for managing EAB and the costs associated with them.

EAB Management

EAB Management Options

With no specific strategy or budget in place for the impending infestation of EAB, Liberty should explore strategies for managing EAB that provide the most economic benefit and increase public safety. These EAB management strategies include do nothing, remove and replace all ash, treat all ash, or a combination of the strategies. The following are current strategies for managing EAB and costs associated with these strategies.

Photograph 12. This is an example of a *do nothing strategy*. These ash trees became infested with EAB and eventually died. They have now become a public safety issue.

EAB Strategy 1: Do Nothing

This means letting EAB run its course and having no strategy for dealing with EAB. This strategy includes not removing and not treating any ash trees. This strategy is economical in the beginning of an infestation because it costs the City no money, but it would become a severe public safety issue within a few years. Davey Resource Group does not recommend this management strategy.

EAB Strategy 2: Remove and Replace all Ash

Remove and replace all 215 ash trees by 2014. This strategy would benefit public safety from the EAB infestation but would have an impact on the City's budget. In order to achieve this strategy and remove all of the ash trees by 2014, the City would most likely have to contract work out. Removing mature ash trees that are in Good and Fair condition would take away all of the valuable benefits that these trees provide to the City. This strategy ultimately benefits the City by increasing public safety but will require a lot of upfront cost. It will be very important to replace all of these ash trees once they have been removed.

The total approximate cost for this strategy would be $100,020; $45,835 would be the approximate cost to remove all ash trees, $6,885 would be the approximate cost to remove all stumps, and $47,300 would be the approximate cost to replace all ash trees (Table 6).

Table 6. Cost to Remove and Replace All Ash

Management Strategy	Management Action	# of Trees	Cost
Remove and Replace All Ash Trees	Removal All	215	$45,835
	Replace All	215	$47,300
	Stump Removal	215	$6,885
	Total		$100,020

EAB Strategy 3: Treat all Ash

Treating all of the ash trees in Liberty could reduce the annual mortality rate, stabilize removals, and would be less expensive than removing and replacing all ash trees. Treating all ash would enable these trees to keep providing Liberty with the monetary benefits that they provide. On the other hand, treating all ash trees is not an ideal practice because some of these ash trees will eventually become infested with EAB, and some of these ash trees are less desirable to retain.

If Liberty wanted to annually treat all of its 215 ash trees that are not recommended for removal, it would cost approximately $109,025 over a five-year period. This means that it would cost the City approximately $21,805 annually to treat all of City's 206 ash trees. The nine ash trees recommended for removal would cost approximately $845 and approximately $300 to remove all stumps. After a five-year treatment period and removing the recommended nine trees, this would cost the City an estimated $110,170 (Table 7).

Table 7. Cost to Treat All Ash

Management Strategy	Management Action	# of Trees	Cost
Treat All Ash Trees	Treat all Ash Trees for Five Years	206	$109,025
	Ash Trees Recommended for removal	9	$845
	Stump Removal	9	$300
	Total		$110,170

EAB Strategy 4: Combination of Removals and Treatment

This strategy is intended to give the City options for a combination of removing and treating ash trees to stabilize annual removals, annual budgets, and prolong the life of ash trees that are Good and Fair condition. Table 8 is an EAB matrix table that is intended to organize trees that should be considered for removal and trees that should be considered for treatment. This EAB matrix table will go into detail about why certain ash trees should be considered for removal and treatment.

Table 8 EAB Matrix Table

		Diameter Class (inches)									
		1–3	4–6	7–12	13–18	19–24	25–30	31–36	37–42	43+	Total
Condition Class	Excellent	0	0	0	0	0	0	0	0	0	0
	Very Good	0	0	0	0	0	0	0	0	0	0
	Good	27	13	3	0	0	0	0	0	0	43
	Fair	12	53	42	22	7	4	3	0	0	143
	Poor	3	2	4	12	2	1	1	0	0	25
	Critical	0	0	1	3	0	0	0	0	0	4
	Dead	0	0	0	0	0	0	0	0	0	0
	Total	42	68	50	37	9	5	4	0	0	215

Based on these numbers, Davey Resource Group makes the following recommendations:

134 Trees to Be Removed

- Trees in the "Poor", "Critical", and "Dead" condition class are recommended for removal. These trees are recommended for removal because they are more susceptible to EAB infestation and if not removed could pose a public safety issue in the future. A total of 29 of these trees are recommended for removal and replacement.
- The remaining 105 trees are 1 to 7 inches DBH and are recommended for removal and replacement. These trees are young and do not provide as many benefits to the community compared to mature ash trees. It would be in the best interest of the City to remove these trees and replace them with a more diversified mix of trees.

78 Candidate Trees for Chemical Treatment (Low–Moderate Priority for Treatment)

- The intent here is to defer removal of a large block of trees within the matrix of "Fair" condition class between 7 and 43+ inches DBH. These 78 trees are considered to be "low-moderate priority" for chemical treatment. Eventually a lot of these trees can become infested with EAB and will have to be removed in a timely manner. However, treating these trees could stabilize annual budgets and removals each year. Treatment can be economically beneficial and reduce the chance for a public safety issue in the near future.

3 Candidate Trees for Chemical Treatment (High Priority for Treatment)

- Candidates for chemical treatment will exhibit "Fair" condition or better, have no more than 30% dieback, and be located in an appropriate site (i.e., not under overhead utilities). Treating these 3 ash trees will help to keep these trees around for a long time and the City will profit from the monetary benefits these ash trees provide.

Private Trees

In addition to ash trees located on public property, EAB will impact trees located on private property. The number of private ash trees is unknown but it could be equal to or greater than the ash trees located on public property. During the inventory, it was evident to the inventory arborists that there was an abundance of ash trees located on private properties. The cost to remove ash trees will be higher on private property because of the greater inaccessibility to these areas. It is crucial that the City promote public education about EAB so that it can reduce the potential of City involvement with regulating tree removals on private properties. The public education section will explain more on how to minimize anxiety from private homeowners and gives examples on how to go about informing the public about managing their ash trees.

Photograph 13. Hangers will help make private homeowners aware of the management options available for EAB.

Dying and infested ash trees on private property will pose a threat to human and public safety. In the event that City officials have to get involved with private property owners about a potential infested ash tree, Liberty should consider utilizing the current Liberty tree and landscape ordinance. Liberty should consider amending *Section 28A-8* of the ordinance so that EAB is acknowledged as a public nuisance and treated in similar fashion as Dutch elm disease and other insect pests or plant diseases.

Photograph 14. Posting information about EAB on ash trees around the City could promote private homeowners to become more proactive in managing their ash trees.

Public Education

It is crucial for Liberty property owners to be well informed about EAB. Their assistance and cooperation will be vital in helping to detect EAB, managing ash trees on private property, and the reforestation process that will come from the removal of ash trees. Liberty should inform the public that EAB has been discovered nearby. If the public is well informed, then they are more likely to accept what is happening without panicking and cooperate with the City's requests. The following are examples of how Liberty should go about informing the public:

- New releases
- City newsletter articles
- Radio programs
- Post information about EAB on the City's website

It is vital for Liberty to enlighten the public on how to detect EAB, become informed about treatment options, and the importance for reforestation. If the public is advised on how to detect for EAB, then they can make proactive choices about managing infested ash trees. This could help ease the burden on the City by not having as many private trees becoming a public safety issue. Encourage property owners that want to keep their ash trees because of the benefits they receive from them to regularly inspect their ash.

The City should provide information about treatment options so that their trees can last for years to come. It will be important for the City to inform the public on reforestation and explain the important benefits that trees provide to neighborhoods and how trees increase real estate value. This can help fund and promote neighborhood tree plantings. The following are examples of ways the City can inform the public about these issues.

- Display information packets at public buildings
- Postcard mailings to ash tree owners
- Distribute door hangers explaining maintenance options
- Presentations to community groups
- Post information about EAB on the City's website
- Tie ribbons around ash trees and place tags on the trees with information about EAB

Reforestation

As the ash tree population is being reduced in Liberty, the City will need to come up with a plan to replant where ash trees have been removed. The City could potentially lose over 6% of its tree population due to EAB. It will be vital for a prompt reforestation in Liberty because of the numerous benefits that the ash trees provide the community. Some of the benefits that these ash trees provide to the City include, but are not limited to, removing pollutants from the air, helping improve summer temperatures, reducing storm water runoff, and providing social and psychological benefits.

If the City is to replace all the ash trees, it will cost approximately $100,020. This would be a huge financial burden on the City, but it will be important that these trees be replaced. The cost of replanting ash trees could be spread out over multiple years by establishing a goal that a certain amount of trees need to be planted each year. If the City was to plant 22 trees a year, then Liberty could replace all of the ash trees within 10 years. This cost could be reduced if the City comes up with a plan to work with volunteers and private property owners. This could include giving private property owners the option of paying for the tree and getting to pick the tree they want from a list of 10 species. Liberty should also explore grants for reforestation. Organizing volunteer groups to participate in planting trees could help decrease the cost for planting trees.

It is important to consider diversification when replacing ash trees. Without diversification, a community is much more vulnerable to catastrophic losses that impact budgets and community appearance. Davey Resource Group recommends that no one species represents 10% and that no one genus comprises more than 15% of the total public tree population. Since EAB has hit local communities, there might be a possibility that local nurseries have a shortage of trees. Liberty might want to consider nurseries in other regions for trees.

Conclusions

Managing trees in urban areas is often complicated. Dealing with the recommendations of experts, the needs of residents, the pressures of local economics and politics, the concerns for public safety and liability issues, the physical aspects of trees, the forces of nature and severe weather events, and the expectation for all of these issues to be met at the same time is a considerable challenge. The city should prepare an EAB Management Plan.

The City must carefully consider each specific issue and balance these pressures with a knowledgeable understanding of trees and their needs. If balance is achieved, Liberty's beauty will flourish and the health and safety of its trees and citizens will be maintained.

Glossary

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

address number (data field): The address number was recorded based on the visual observation by the Davey Resource Group arborist at the time of the inventory of the actual address number posted on a building at the inventoried site. In instances where there was no posted address number on a building or sites were located by vacant lots with no GIS parcel addressing data available, the address number assigned was matched as closely as possible to opposite or adjacent addresses by the arborist(s) and an "X" was added to the number in the database to indicate that the address number was assigned.

Aesthetic/Other Report: The i-Tree Streets Aesthetic/Other Report presents the tangible and intangible benefits of trees reflected in increases in property values in dollars ($).

Air Quality Report: The i-Tree Streets 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 Standards**:** 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.

Benefit-Cost Ratio (BCR): The i-Tree Streets (BCR) is the ratio of the cumulative benefits provided by the landscape trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms.

Carbon Dioxide Report: The i-Tree Streets 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.

clean (primary maintenance need): Based on *ANSI A300 Standards*, selective removal of dead, dying, broken, and/or diseased wood to minimize potential risk.

clearance requirements (data field): Illustrates the need for pruning to meet clearance standards over streets and sidewalks, or where branches are considered to be interfering with the movement of vehicles or pedestrians or where they are obstructing signs and street or traffic lights.

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: Excellent (100%), Very Good (90%), Good (80%), Fair (60%), Poor, (40%), Critical (20%), Dead (0%).

cycle: Planned length of time between vegetation maintenance activities.

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

diameter: See **tree size**.

Energy Report: The i-Tree Streets 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).

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 give you 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.

hardscape damage (data field): Indicates trees damaged by hardscape or hardscape damaged by trees (for example, damage to curbs, cracking, lifting of sidewalk pavement one inch or more).

High Risk tree: Tree that cannot be cost-effectively or practically treated. Most High Risk trees have multiple or significant defects affecting less than 40% of the trunk, crown, or critical root zone. Defective trees and/or tree parts are most likely between 4–20 inches in diameter and can be found in areas of frequent occupation, such as a main thoroughfare, congested streets, and/or near schools.

Importance Values: A calculation in i-Tree Streets. Importance Values (IV) are displayed in table form for all species that make up more than 1% of the population. The Streets IV is the mean of three relative values (percentage of total trees, percentage of total leaf area, and percentage of canopy cover) and can range from 0 to 100 with an IV of 100 suggesting total reliance on one species. IVs offer valuable information about a community's reliance on certain species to provide functional benefits. For example, a species might represent 10% of a population, but have an IV of 25% because of its great size, indicating that the loss of those trees due to pests or disease would be more significant than their numbers suggest.

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.

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

Low Risk tree: Tree with minor visible structural defects or wounds in areas with moderate to low public access.

Management Costs: Used in i-Tree Streets, they are the expenditures associated with street tree management presented in total dollars, dollars per tree, and dollars per capita.

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

Moderate Risk tree: Tree with defects that may be cost-effectively or practically treated. Most of the trees in this category exhibit several moderate defects affecting more than 40% of a tree's trunk, crown, or critical root zone.

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

Net Annual Benefits: Specific data field for i-Tree Streets. Citywide benefits and costs are calculated according to category and summed. Net benefits are calculated as benefits minus costs.

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

none (risk rating): Equal to zero. It is used only for planting sites and stumps.

notes (data field): Describes additional pertinent information.

observations (data field): When conditions with a specific tree warrant recognition, it was described in this data field. Observations include cavity decay, grate guard, improperly installed, improperly mulched, improperly pruned, mechanical damage, memorial tree, nutrient deficiency, pest problem, poor location, poor root system, poor structure, remove hardware, serious decline, and signs of stress.

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): The risk assessment is a point-based assessment of each tree by an arborist using a protocol based on the US Forest Service Community Tree Risk Rating System. In the field, the probability of tree or tree part failure is assigned 1–4 points (identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions), the size of defective tree part is assigned 1–3 points (rates the size of the part most likely to fail), the probability of target impact by the tree or tree part is assigned 1–3 points (rates the use and occupancy of the area that would be struck by the defective part), and other risk factors are assigned 0–2 points (used if professional judgment suggests the need to increase the risk rating). The data from the risk assessment is used to calculate the risk rating that is ultimately assigned to the tree.

risk rating: Calculated from the field risk assessment data (see **risk assessment**), this is the sum of total risk assessment values. Risk ratings range from 3–10, with 3 being the lowest risk and 10 being the highest risk. In this Plan, the risk rating was used to identify the severity of risk assigned to a tree and to prioritize tree maintenance needs. The following categories were used:

- risk rating of 9 or 10 = Severe Risk tree
- risk rating of 7 or 8 = High Risk tree
- risk rating of 5 or 6 = Moderate Risk tree
- risk rating of 3 or 4 = Low Risk tree
- risk rating of 0 = no risk (used only for planting sites and stumps)

Severe Risk tree: Tree rated to be Severe Risk cannot be cost-effectively or practically treated. Most Severe Risk trees have multiple and significant defects present in the trunk, crown, or critical root zone. Defective trees and/or tree parts are most likely larger than 20 inches in diameter and can be found in areas of frequent occupation, such as a main thoroughfare, congested streets, and/or near schools.

site number (data field): All sites at an address are assigned a *site number*. Sites numbers are not unique; they are sequential to the side of the address only (the only unique number is the tree identification number assigned to each site). Site numbers are collected in the direction of vehicular traffic flow. The only exception is a one-way street. Site numbers along a one-way street are collected as if the street were actually a two-way street, so some site numbers will oppose traffic.

species: 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.

stems (data field): Identifies the number of stems or trunks splitting less than one foot above ground level.

Stored Carbon Report: Whereas, the i-Tree Streets Carbon Dioxide Report quantifies annual CO_2 reductions, and the i-Tree Streets Stored Carbon Report tallies all of the Carbon (C) stored in the urban forest over the life of the trees as a result of sequestration measured in pounds as the CO_2 equivalent.

Stormwater Report: A report generated by i-Tree Streets 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.

stump removal (primary maintenance need): Indicates a stump that should be removed.

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.

Summary Report: The i-Tree Streets Summary report presents the annual total of energy, stormwater, air quality, carbon dioxide, and aesthetic/other benefits. Values are dollars per tree or total dollars.

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

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

tree 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 one-inch size classes at 4.5 feet above ground, also known as diameter at breast height (DBH) or diameter.

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.

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.

Volatile Organic Compounds (VOCs): Hydrocarbon compounds that exist in the ambient air and are by-products of energy used to heat and cool buildings. Volatile organic compounds contribute to the formation of smog and/or are toxic. Examples of VOCs are gasoline, alcohol, and solvents used in paints.

young tree train (primary maintenance need): Data field based on *ANSI A300 Standards*, pruning of young trees to correct or eliminate weak, interfering, or objectionable branches to improve structure. These trees, up to 20 feet in height, can be worked with a pole pruner by a person standing on the ground.

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Appendix A
Site Location Methods

Equipment and Base Maps

Inventory arborists use a CF-19 Panasonic Toughbook® unit.

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

Base Map Layers Utilized for Inventory

Imagery/Data Source	Date	Projection
City of Liberty GIS Dept. (Cynthia Matley)	Most Current (2012)	NAD 1983 StatePlane Missouri West ft

Street ROW Site Location

Individual street ROW sites (trees and stumps) were located using a methodology developed by Davey Resource Group that identifies sites by *address number*, *street name*, *side*, *and site number*. This methodology allows for 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 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 address number assigned was matched as closely as possible to opposite or adjacent addresses by the arborist and an "X" was added to the number in the database to indicate that it was assigned (for example, "37X Choice Avenue").

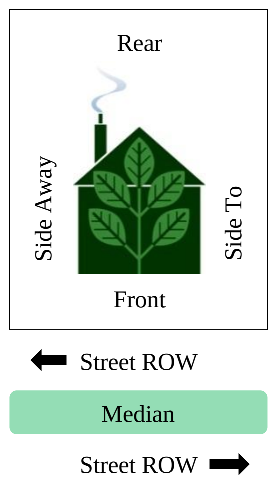


Figure 1. Side values for street ROW sites.

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 given its own assigned address.

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

Side Value and Site Number

Each site was assigned a *side value* and *site number*. Side values include: *front*, *side to*, *side away*, *median* (includes islands), or *rear* based on the site's location in relation the lot's street frontage (Figure 1). The *front side* is the side that faces the address street. *Side to* is the name of the street the arborist is walking towards as data are being collected. The *side from* is the name of the street the arborist is walking away from while collecting data. *Median* indicates a median or island. The *rear* is the side of the lot opposite of the front.

All sites at an address are assigned a *site number*. Sites numbers are not unique; they are sequential to the side of the address only (the only unique number is the tree identification number assigned to each site). Site numbers are collected in the direction of vehicular traffic flow. The only exception is a one-way street. Site numbers along a one-way street are collected as if the street was a two-way street; thus, some site numbers will oppose traffic.

A separate site number sequence is used for each side value of the address (front, side to, side away, median, or rear). For example, trees at the front of an address may have site numbers from 1 through 999 and, if trees are located on the side to, side away, median, or rear of that same address, each side will also be numbered consecutively beginning with the number 1.

Site Location Examples

Figure 2. The tree trimming crew in the truck traveling westbound on E Mac Arthur Street is trying to locate an inventoried tree with the following location information:

Address/Street Name:	226 E. Mac Arthur Street
Side:	Side To
Site Number:	1
On Street:	Davis Street

The tree site circled in red is the site the crew is looking for. 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. Moving with the flow of traffic, the from street is Taft Street, and the to street is East Mac Arthur Street.

Figure 3. Location information collected for inventoried trees at Corner Lot A and Corner Lot B.

Corner Lot A

Address/Street Name: 205 Hoover St.
Side/Site Number: Side To / 1
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side/Site Number: Side To / 2
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side/Site Number: Side To / 3
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side/Site Number: Front / 1
On Street: Hoover St.

Corner Lot B

Address/Street Name: 226 E Mac Arthur St.
Side/Site Number: Side To / 1
On Street: Davis St.

Address/Street Name: 226 E Mac Arthur St.
Side/Site Number: Front / 1
On Street: E Mac Arthur St.

Address/Street Name: 226 E Mac Arthur St.
Side/Site Number: Front / 2
On Street: E Mac Arthur 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 (USDA Zones 5 and 6) conditions found throughout Missouri.

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

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

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

Medium Trees: 31–45 Feet in Height at Maturity

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

Small Trees: 15–30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
*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: 31–45 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: 15–30 Feet in Height at Maturity

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

This suggested species list was compiled through the use of the excellent references *Dirr's Hardy Trees and Shrubs* (Dirr 2003) and *Manual of Woody Landscape Plants (5th Edition)* (Dirr 1998). Cultivar selections are recommendations only and are based on Davey Resource Group's experience; tree availability will vary by nursery.

Appendix C
Invasive Pests and Diseases That Affect Trees

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

Once here, 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. Following are 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 you can to 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

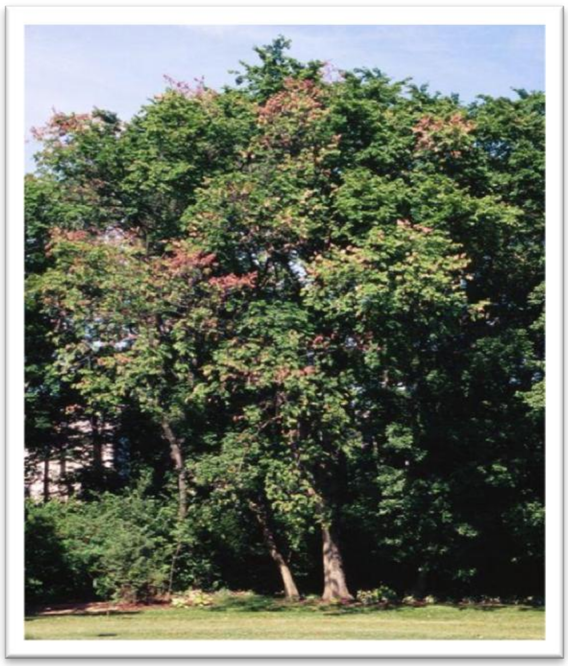
Asian Longhorned Beetle

The Asian longhorned beetle (ALB, *Anoplophora glabripennis*) is an exotic pest threatening a wide variety of hardwood trees in North America. The beetle was introduced in New York City, Chicago, and New Jersey 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 the *Acer platanoides* (Norway maple), sugar maple, *A. saccharinum* (silver maple), red maple, *A. negundo* (box elder), *Aesculus glabra* (buckeye), *A. hippocastanum* (horsechestnut), *Betula* (birch), *Platanus* × *acerifolia* (London planetree), *Salix* (willow), and *Ulmus* (elm).

Dutch Elm Disease



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).

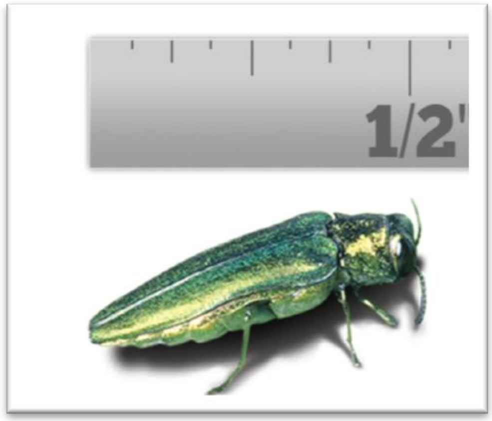
Considered by many to be one of the most destructive, invasive diseases of shade trees in the United States, Dutch elm disease (DED) was first found in Ohio in 1930 and by 1933 it was in several East Coast cities. By 1959, it had killed thousands of elms. Today, DED covers about two-thirds of the eastern 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.

There are two closely related fungi that are collectively referred to as DED. The most common is *Ophiostoma novo-ulmi*, and 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: the native elm bark beetle (*Hylurgopinus rufipes*) and the European elm bark beetle (*Scolytus multistriatus*).

Trees most affected by DED are the *Ulmus americana* (American elm).

Emerald Ash Borer

The 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, it has been found in China, Korea, Japan, Mongolia, Taiwan, and eastern Russia. 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 tree species preferred as hosts by the EAB are in the genus *Fraxinus* (ash).

Gypsy Moth

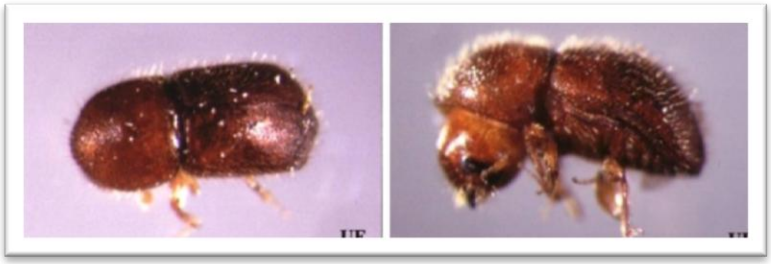
The gypsy moth (GM, *Lymantria dispar*) is native to Europe and first arrived in the United States in Massachusetts in 1869. This moth is a significant pest because its caterpillars have voracious appetites for more than 300 species of trees and shrubs. GM caterpillars defoliate trees leaving them vulnerable 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 GM prefers approximately 150 primary hosts but feeds 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).

Granulate Ambrosia Beetle



Adult granulate ambrosia beetle.

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

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

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

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

Oak Wilt

Oak wilt symptoms on red and white oak leaves.

Photograph courtesy USDA Forest Service (2011a).

Oak wilt was first identified in 1944 and is caused by the fungus *Ceratocystis fagacearum*. While considered an invasive and aggressive disease, its status as an exotic pest is debated since the fungus has not been reported in any other part of the world. This disease affects the oak genus, and is most devastating to those in the red oak subgenus, such as *Q. 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.

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 more commonly the disease is spread through root grafts. Oak species within the same subgenus (white or red) will form root colonies with grafted roots that allow the disease to move readily from one tree to another.

Pine Shoot Beetle

Mined shoots on Scotch pine. Photo courtesy USDA Forest Service (1993).

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

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

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

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

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 and, thus, 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 woodwasp 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 3-6 months following attack. Infested trees may have resin beads or dribbles at the egg laying sites which are more common at the mid-bole level. Larval galleries are tightly packed with very fine sawdust. As adults emerge, they chew round exit holes that vary from 1/8 to 3/8 inch in diameter.

Southern Pine Beetle

Adult southern pine beetles. Photograph courtesy of Forest Encyclopedia Network (2012).

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

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

Thousand Cankers Disease


Walnut twig beetle, side view. Photograph courtesy of USDA Forest Service (2011b).

A disease complex referred to as thousand cankers disease (TCD) was first observed in Colorado in 2008 and is now thought to have been existence 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 resulted 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 D
Estimated Costs for the City of Liberty's Five-Year Tree Management Program

Estimated Costs for Each Activity			2014		2015		2016		2017		2018		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	
Severe-Risk Removal	1-3"	$25	1	$25	0	$0	0	$0	0	$0	0	$0	$25
	4-6"	$105	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$220	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	13-18"	$355	5	$1,775	0	$0	0	$0	0	$0	0	$0	$1,775
	19-24"	$525	6	$3,150	0	$0	0	$0	0	$0	0	$0	$3,150
	25-30"	$845	9	$7,605	0	$0	0	$0	0	$0	0	$0	$7,605
	31-36"	$1,140	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$1,470	0	$0	0	$0		$0	0	$0	0	$0	$0
	43"+	$1,850	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**21**	**$12,555**	0	$0	0	$0	0	$0	0	$0	**$12,555**
High-Risk Removal	1-3"	$25	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$105	1	$105	0	$0	0	$0	0	$0	0	$0	$105
	7-12"	$220	10	$2,200	0	$0	0	$0	0	$0	0	$0	$2,200
	13-18"	$355	13	$4,615	0	$0	0	$0	0	$0	0	$0	$4,615
	19-24"	$525	9	$4,725	0	$0	0	$0	0	$0	0	$0	$4,725
	25-30"	$845	7	$5,915	0	$0	0	$0	0	$0	0	$0	$5,915
	31-36"	$1,140	5	$5,700	0	$0	0	$0	0	$0	0	$0	$5,700
	37-42"	$1,470	1	$1,470	0	$0	0	$0	0	$0	0	$0	$1,470
	43"+	$1,850	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**46**	**$24,730**	0	$0	0	$0	0	$0	0	$0	**$24,730**
Moderate-Risk Removal	1-3"	$25	0	$0	12	$300	0	$0	0	$0	0	$0	$300
	4-6"	$105	0	$0	3	$315	0	$0	0	$0	0	$0	$315
	7-12"	$220	0	$0	6	$1,320	0	$0	0	$0	0	$0	$1,320
	13-18"	$355	0	$0	10	$3,550	0	$0	0	$0	0	$0	$3,550
	19-24"	$525	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	25-30"	$845	0	$0	1	$845	0	$0	0	$0	0	$0	$845
	31-36"	$1,140	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$1,470	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$1,850	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	**32**	**$6,330**	0	$0	0	$0	0	$0	**$6,330**
Low-Risk Removal	1-3"	$25	0	$0	29	$725	0	$0	0	$0	0	$0	$725
	4-6"	$105	0	$0	3	$315	0	$0	0	$0	0	$0	$315
	7-12"	$220	0	$0	20	$4,400	0	$0	0	$0	0	$0	$4,400
	13-18"	$355	0	$0	28	$9,940	0	$0	0	$0	0	$0	$9,940
	19-24"	$525	0	$0	8	$4,200	0	$0	0	$0	0	$0	$4,200
	25-30"	$845	0	$0	3	$2,535	0	$0	0	$0	0	$0	$2,535
	31-36"	$1,140	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$1,470	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$1,850	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	**91**	**$22,115**	0	$0	0	$0	0	$0	**$22,115**
Stump Removal	1-3"	$25	0	$0	14	$350	0	$0	0	$0	0	$0	$350
	4-6"	$25	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$25	0	$0	12	$300	0	$0	0	$0	0	$0	$300
	13-18"	$40	0	$0	9	$360	0	$0	0	$0	0	$0	$360
	19-24"	$60	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	25-30"	$85	0	$0	1	$85	0	$0	0	$0	0	$0	$85
	31-36"	$110	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$130	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$160	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	**36**	**$1,095**	0	$0	0	$0	0	$0	**$1,095**
Remove this Row section	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	13-18"	$120	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	19-24"	$170	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	25-30"	$225	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	31-36"	$305	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$380	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$590	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	0	$0	0	$0	0	$0	0	$0	$0
Severe and High-Risk Prune	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$75	7	$525	0	$0	0	$0	0	$0	0	$0	$525
	13-18"	$120	24	$2,880	0	$0	0	$0	0	$0	0	$0	$2,880
	19-24"	$170	16	$2,720	0	$0	0	$0	0	$0	0	$0	$2,720
	25-30"	$225	17	$3,825	0	$0	0	$0	0	$0	0	$0	$3,825
	31-36"	$305	16	$4,880	0	$0	0	$0	0	$0	0	$0	$4,880
	37-42"	$380	4	$1,520	0	$0	0	$0	0	$0	0	$0	$1,520
	43"+	$590	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**84**	**$16,350**	0	$0	0	$0	0	$0	0	$0	**$16,350**
Routine Pruning	1-3"	$20	3	$60	78	$1,560	78	$1,560	78	$1,560	80	$1,600	$6,340
	4-6"	$30	1	$30	11	$330	11	$330	11	$330	11	$330	$1,350
	7-12"	$75	4	$300	79	$5,925	79	$5,925	80	$6,000	80	$6,000	$24,150
	13-18"	$120	5	$600	55	$6,600	55	$6,600	55	$6,600	55	$6,600	$27,000
	19-24"	$170	1	$170	21	$3,570	21	$3,570	22	$3,740	22	$3,740	$14,790
	25-30"	$225	2	$450	12	$2,700	13	$2,925	12	$2,700	12	$2,700	$11,475
	31-36"	$305	0	$0	2	$610	2	$610	3	$915	2	$610	$2,745
	37-42"	$380	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$590	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**16**	**$1,610**	**258**	**$21,295**	**259**	**$21,520**	**261**	**$21,845**	**262**	**$21,580**	**$87,850**
Young Tree Training Pruning	1-3"	$20	91	$1,820	91	$1,820	91	$1,820	91	$1,820	91	$1,820	$9,100
	4-6"	$30	62	$1,860	62	$0	62	$1,860	62	$1,860	62	$1,860	$7,440
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			**153**	**$3,680**	**153**	**$1,820**	**153**	**$3,680**	**153**	**$3,680**	**153**	**$3,680**	**$16,540**
Tree Planting	Purchasing	$110	55	$6,050	55	$6,050	55	$6,050	55	$6,050	55	$6,050	$30,250
	Planting	$110	55	$6,050	55	$6,050	55	$6,050	55	$6,050	55	$6,050	$30,250
Activity Total(s)			**110**	**$12,100**	**110**	**$12,100**	**110**	**$12,100**	**110**	**$12,100**	**110**	**$12,100**	**$60,500**
Young Tree Maintenance	Mulching	$100	55		55		55		55		55		$0
	Watering	$100	55		55		55		55		55		$0
Activity Total(s)			**110**		**110**		**110**		**110**		**110**		$0
To Be Determined	TBD		0	$0	0	$0	0	$0	0	$0	0	$0	$0
	TBD		0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Grand Total			**430**		**680**		**522**		**524**		**525**		**$2,681**
Cost Grand Total				**$71,025**		**$64,755**		**$37,300**		**$37,625**		**$37,360**	**$248,065**

Appendix E
Emerald Ash Borer Information

In addition to the information provided there several websites to find additional information:

- http://extension.missouri.edu/emeraldashborer/pdf/EABCSI.pdf
- http://mdc.mo.gov/discover-nature/field-guide/emerald-ash-borer
- http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/survey_guidelines.pdf
- http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/index.shtml
- http://www.emeraldashborer.info/map.cfm#sthash.P0XWEJ8v.dpbs

www.emeraldashborer.info

Insecticide Options for Protecting Ash Trees From Emerald Ash Borer

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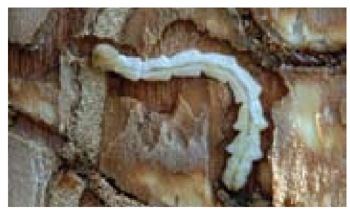
Emerald ash borer (*Agrilus planipennis* Fairmaire), an invasive insect native to Asia, has killed tens of millions of ash trees in urban, rural and forested settings. This beetle was first discovered in 2002 in southeast Michigan and Windsor, Ontario. As of May 2009, emerald ash borer (EAB) infestations were known to be present in 11 states and two Canadian provinces. Many homeowners, arborists and tree care professionals want to protect valuable ash trees from EAB. Scientists have learned much about this insect and methods to protect ash trees since 2002. This bulletin is designed to answer frequently asked questions and provide the most current information on insecticide options for controlling EAB.



EAB larvae damage the vascular system of the tree as they feed, which interferes with movement of systemic insecticides in the tree.

EAB adults must feed on foliage before they become reproductively mature.

Answers to Frequently Asked Questions

What options do I have for treating my ash trees?

If you elect to treat your ash trees, there are several insecticide options available and research has shown that treatments can be effective. Keep in mind, however, that controlling insects that feed under the bark with insecticides has always been difficult. This is especially true with EAB because our native North American ash trees have little natural resistance to this pest. In university trials, some insecticide treatments were effective in some sites, but the same treatments failed in other sites. Furthermore, in some studies conducted over multiple years, EAB densities continued to increase in individual trees despite annual treatment. Some arborists have combined treatments to increase the odds of success (e.g., combining a cover spray with a systemic treatment).

Healthy ash trees that have been protected with insecticides growing next to untreated ash trees killed by EAB.

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Our understanding of how EAB can be managed successfully with insecticides has increased substantially in recent years. The current state of this understanding is detailed in the bulletin. It is important to note that research on management of EAB remains a work in progress. Scientists from universities, government agencies and companies continue to conduct intensive studies to understand how and when insecticide treatments will be most effective.

I know my tree is already infested with EAB. Will insecticides still be effective?

If a tree has lost more than 50 percent of its canopy, it is probably too late to save the tree. Studies have shown that it is best to begin using insecticides while ash trees are still relatively healthy. This is because most of the insecticides used for EAB control act systemically — the insecticide must be transported within the tree. In other words, a tree must be healthy enough to carry a systemic insecticide up the trunk and into the branches and canopy. When EAB larvae feed, their galleries injure the phloem and xylem that make up the plant's circulatory system. This interferes with the ability of the tree to transport nutrients and water, as well as insecticides. As a tree becomes more and more infested, the injury becomes more severe. Large branches or even the trunk can be girdled by the larval galleries.

Studies have also shown that if the canopy of a tree is already declining when insecticide treatments are initiated, the condition of the tree may continue to deteriorate during the first year of treatment. In many cases, the tree canopy will begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the EAB infestation has been reduced.

My ash tree looks fine but my county is quarantined for EAB. Should I start treating my tree?

Scientists have learned that ash trees with low densities of EAB often have few or no external symptoms of infestation. Therefore, if your property is within a county that has been quarantined for EAB, your ash trees are probably at risk. Similarly, if your trees are outside a quarantined county but are still within 10-15 miles of a known EAB infestation, they may be at risk. If your ash trees are more than 15 miles beyond this range, it is probably too early to begin insecticide treatments. Treatment programs that begin too early are a waste of money. Remember, however, that new EAB infestations have been discovered every year since 2002 and existing EAB populations will build and spread over time. Stay up to date with current EAB quarantine maps and related information at **www.emeraldashborer.info**. You can use the links in this Web site to access specific information for individual states. When an EAB infestation is detected in a state or county for the first time, it will be added to these maps. Note, however, that once an area has been quarantined, EAB surveys generally stop, and further spread of EAB in that area will not be reflected on future maps.

I realize that I will have to protect my ash trees from EAB for several years. Is it worth it?

The economics of treating ash trees with insecticides for EAB protection are complicated. Factors that can be considered include the cost of the insecticide and expense of application, the size of the trees, the likelihood of success, and potential costs of removing and replacing the trees. Until recently, insecticide products had to be applied every year. A new product that is effective for two years or even longer (emamectin benzoate) has altered the economics of treating ash trees. As research progresses, costs and methods of treating trees will continue to change and it will be important to stay up to date on treatment options.

Benefits of treating trees can be more difficult to quantify than costs. Landscape trees typically increase property values, provide shade and cooling, and contribute to the quality of life in a neighborhood. Many people are sentimental about their trees. These intangible qualities are important and should be part of any decision to invest in an EAB management program.

It is also worth noting that the size of EAB populations in a specific area will change over time. Populations initially build very slowly, but later increase rapidly as more trees become infested. As EAB populations reach their peak, many trees will decline and die within one or two years. As untreated ash trees in the area succumb, however, the local EAB population will decrease substantially. Scientists do not yet have enough experience with EAB to know what will happen over time to trees that survive the initial wave of EAB. Ash seedlings and saplings are common in forests, woodlots, and right-of-ways, however, and it is unlikely that

EAB will ever completely disappear from an area. That means that ash trees may always be at some risk of being attacked by EAB, but it seems reasonable to expect that treatment costs could eventually decrease as pest pressure declines after the EAB wave has passed.

Insecticide Options for Controlling EAB

Insecticides that can effectively control EAB fall into four categories: (1) systemic insecticides that are applied as soil injections or drenches; (2) systemic insecticides applied as trunk injections; (3) systemic insecticides applied as lower trunk sprays; and (4) protective cover sprays that are applied to the trunk, main branches, and (depending on the label) foliage.

Insecticide formulations and application methods that have been evaluated for control of EAB are listed in Table 1. Some are marketed for use by homeowners while others are intended for use only by professional applicators. The "active ingredient" refers to the compound in the product that is actually toxic to the insect.

Formulations included in Table 1 have been evaluated in multiple field trials conducted by the authors. Inclusion of a product in Table 1 does not imply that it is endorsed by the authors or has been consistently effective for EAB control. Please see the following sections for specific information about results from these trials. Results of some tests have also been posted on **www.emeraldashborer.info**.

Strategies for the most effective use of these insecticide products are described below. It is important to note that pesticide labels and registrations change constantly and vary from state to state. It is the legal responsibility of the pesticide applicator to read, understand and follow all current label directions for the specific pesticide product being used.

Table 1. Insecticide options for professionals and homeowners for controlling EAB that have been tested in multiple university trials. Some products may not be labeled for use in all states. Some of the listed products failed to protect ash trees when they were applied at labeled rates. Inclusion of a product in this table does not imply that it is endorsed by the authors or has been consistently effective for EAB control. See text for details regarding effectiveness.

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
		Professional Use Products	
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
IMA-jet®	Imidacloprid	Trunk injection	Early May to mid-June
Imicide®	Imidacloprid	Trunk injection	Early May to mid-June
Pointer™	Imidacloprid	Trunk injection	Early May to mid-June
TREE-äge™	Emamectin benzoate	Trunk injection	Early May to mid-June
Inject-A-Cide B®	Bidrin®	Trunk injection	Early May to mid-June
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Early May to mid-June
Astro®	Permethrin	Preventive bark and foliage cover sprays	2 applications at 4-week intervals; first spray should occur when black locust is blooming (early May in southern Ohio to early June in mid-Michigan)
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
		Homeowner Formulation	
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Mid-fall or mid- to late spring

Using Insecticides to Control EAB

Soil-Applied Systemic Insecticides

Systemic insecticides applied to the soil are taken up by the roots and translocated throughout the tree. The most widely tested soil-applied systemic insecticide for control of EAB is imidacloprid, which is available under several brand names for use by professional applicators and homeowners (see Table 1). All imidacloprid formulations can be applied as a drench by mixing the product with water, then pouring the solution directly on the soil around the base of the trunk. Dinotefuran is also labeled for use as a soil treatment, but to date it has been tested only as a basal trunk spray (discussed below). Studies to test its effectiveness as a soil treatment are currently underway.

Imidacloprid soil applications should be made when the soil is moist but not saturated. Application to water-logged soil can result in poor uptake if the insecticide becomes excessively diluted and can also result in puddles of insecticide that could wash away, potentially contaminating surface waters and storm sewers. Insecticide uptake will also be limited when soil is excessively dry. Irrigating the soil surrounding the base of the tree before the insecticide application can improve uptake.

The application rates for the homeowner product (Bayer Advanced™ Tree & Shrub Insect Control) and professional formulations of imidacloprid are very similar. Homeowners apply the same amount of active ingredient that professionals apply. However, there are certain restrictions on the use of homeowner formulations that do not apply to professional formulations. Homeowner formulations of imidacloprid can be applied only as a drench. It is not legal to inject these products into the soil, although some companies have marketed devices to homeowners specifically for this purpose. Homeowners are also restricted to making only one application per year. Several generic products containing imidacloprid are available to homeowners, but the formulations vary and the effectiveness of these products has not yet been evaluated in university tests.

Soil drenches offer the advantage of requiring no special equipment for application other than a bucket or watering can. However, imidacloprid can bind to surface layers of organic matter, such as mulch or leaf litter, which can reduce uptake by the tree. Before applying soil drenches, it is important to remove, rake or pull away any mulch or dead leaves so the insecticide solution is poured directly on the mineral soil.

Imidacloprid formulations labeled for use by professionals can be applied as a soil drench or as soil injections. Soil injections require specialized equipment, but offer the advantage of placing the insecticide under mulch or turf and directly into the root zone. This also can help to prevent runoff on sloped surfaces. Injections should be made just deep enough to place the insecticide beneath the soil surface (2-4 inches). Soil injections should be made within 18 inches of the trunk where the density of fine roots is highest. As you move away from the tree, large radial roots diverge like spokes on a wheel and studies have shown that uptake is higher when the product is applied at the base of the trunk. There are no studies that show that applying fertilizer with imidacloprid enhances uptake or effectiveness of the insecticide.

Optimal timing for imidacloprid soil injections and drenches is mid-April to mid-May, depending on your region. Allow four to six weeks for uptake and distribution of the insecticide within the tree. In southern Ohio, for example, you would apply the product by mid-April; in southern Michigan, you should apply the product by early to mid-May. When treating larger trees (e.g., with trunks larger than 12 inches in diameter), treat on the earlier side of the recommended timing. Large trees will require more time for uptake and transportation of the insecticide than will small trees. Recent tests show that imidacloprid soil treatments can also be successful when applied in the fall.

Trunk-Injected Systemic Insecticides

Several systemic insecticide products can be injected directly into the trunk of the tree including formulations of imidacloprid and emamectin benzoate (see Table 1). An advantage of trunk injections is that they can be used on sites where soil treatments may not be practical or effective, including trees growing on excessively wet, compacted or restricted soil environments. However, trunk injections do wound the trunk, which may cause long-term damage, especially if treatments are applied annually.

Products applied as trunk injections are typically absorbed and transported within the tree more quickly than soil applications. Allow three to four weeks for most trunk-injected products to move through the tree. Optimal timing of trunk injections occurs after trees have leafed out in spring but before EAB eggs have hatched, or generally between mid-May and mid-June. Uptake of trunk-injected insecticides will be most efficient when trees are actively transpiring. Best results are usually obtained by injecting trees in the morning when soil is moist but not saturated. Uptake will be slowed by hot afternoon temperatures and dry soil conditions.

Noninvasive, Systemic Basal Trunk Sprays

Dinotefuran is labeled for application as a noninvasive, systemic bark spray for EAB control. It belongs to the same chemical class as imidacloprid (neonicotinoids) but is much more soluble. The formulated insecticide is sprayed on the lower five to six feet of the trunk using a common garden sprayer and low pressure. Research has shown that the insecticide penetrates the bark and moves systemically throughout the rest of the tree. Dinotefuran can be mixed with surfactants that may facilitate its movement into the tree, particularly on large trees with thick bark. However, in field trials, adding a surfactant did not consistently increase the amount of insecticide recovered from the leaves of treated trees.

The basal trunk spray offers the advantage of being quick and easy to apply and requires no special equipment other than a garden sprayer. This application technique does not wound the tree, and when applied correctly, the insecticide does not enter the soil.

Protective Cover Sprays

Insecticides can be sprayed on the trunk, branches and (depending on the label) foliage to kill adult EAB beetles as they feed on ash leaves, and newly hatched larvae as they chew through the bark. Thorough coverage is essential for best results. Products that have been evaluated as cover sprays for control of EAB include some specific formulations of permethrin, bifenthrin, cyfluthrin and carbaryl (see Table 1).

Protective cover sprays are designed to prevent EAB from entering the tree and will have no effect on larvae feeding under the bark. Cover sprays should be timed to occur when most adult beetles are feeding and beginning to lay eggs. Adult activity can be difficult to monitor because there are no effective pheromone traps for EAB. However, first emergence of EAB adults generally occurs between 450-550 degree days (starting date of January 1, base temperature of 50˚F), which corresponds closely with full bloom of black locust (*Robinia pseudoacacia*). For best results, consider two applications, one at 500 DD_{50} (as black locust approaches full bloom) and a second spray four weeks later.

How Effective Are Insecticides for Control of EAB?

Extensive testing of insecticides for control of EAB has been conducted by researchers at Michigan State University (MSU) and The Ohio State University (OSU). Results of some of the MSU trials are available at **www.emeraldashborer.info**.

Soil-Applied Systemic Insecticides

Efficacy of imidacloprid soil injections for controlling EAB has been inconsistent; in some trials EAB control was excellent, while others yielded poor results. Differences in application protocols and conditions of the trials have varied considerably, making it difficult to reach firm conclusions about sources of variation in efficacy. For example, an MSU study found that low-volume soil injections of imidacloprid applied to small trees averaging 4 inches in DBH (diameter of the trunk at breast height) using the Kioritz applicator (a hand-held device for making low-volume injections) provided good control at one site. However, control was poor at another site where the same application protocols were used to treat larger trees (13-inch DBH). Imidacloprid levels may have been too low in the larger trees to provide adequate control. Higher pest pressure at the second site also may have contributed to poor control in the large trees.

In the same trials, high-pressure soil injections of imidacloprid (applied in two concentric rings, with one at the base of the tree and the other halfway to the drip line of the canopy) provided excellent control at one site. At another site, however, soil injections applied using the same rate, timing and application method were completely ineffective, even though tree size and infestation pressure were very similar. It should be noted that recent studies have shown that imidacloprid soil injections made at the base of the trunk result in more effective uptake than applications made on grid or circular patterns under the canopy.

Imidacloprid soil drenches have also generated mixed results. In some studies conducted by MSU and OSU researchers, imidacloprid soil drenches have provided excellent control of EAB. However, in other studies, control has been inconsistent. Experience and research indicate that imidacloprid soil drenches are most effective on smaller trees and control of EAB on trees with a DBH that exceeds 15 inches is less consistent.

This inconsistency may be due to the fact that application rates for systemic insecticides are based on amount of product per inch of trunk diameter or circumference. As the DBH of a tree increases, the amount of vascular tissue, leaf area and biomass that must be protected by the insecticide increases exponentially. Consequently, for a particular application rate, the amount of insecticide applied as a function of tree size is proportionally decreased as trunk diameter increases. Hence, the DBH-based application rates that effectively protect relatively small trees can be too low to effectively protect large trees. Some systemic insecticide products address this issue by increasing the application rate for large trees.

In an OSU study with larger trees (15- to 22-inch DBH), Xytect™ (imidacloprid) soil drenches provided most consistent control of EAB when applied experimentally at twice the rate that was allowed at that time. Recently, the Xytect™ label was modified to allow the use of this higher rate, which we now recommend when treating trees larger than 15-inch DBH. Merit® imidacloprid formulations, however, are not labeled for application at this high rate. Therefore, when treating trees greater than 15-inch DBH with Merit® soil treatments, two applications are recommended, either in the fall and again in the spring, or twice in the spring, about four weeks apart (for example in late April and again in late May). This is not an option for Bayer Advanced™ Tree and Shrub Insect Control and other homeowner formulations of imidacloprid, which are limited by the label to one application per year. Homeowners wishing to protect trees larger than 15-inch DBH should consider having their trees professionally treated.

All treatment programs must comply with the limits specified on the label regarding the maximum amount of insecticide that can be applied per acre during a given year.

Trunk-Injected Systemic Insecticides

Emamectin benzoate

In several intensive studies conducted by MSU and OSU researchers, a single injection of emamectin benzoate in mid-May or early June provided excellent control of EAB for at least two years, even under high pest pressure. For example, in a highly-replicated study conducted on trees ranging in size from 5- to 20-inch DBH at three sites in Michigan, untreated trees had an average of 68 to 132 EAB larvae per m^2 of bark surface, which represents high pest pressure. In contrast, trees treated with emamectin benzoate had, on average, only 0.2 larvae per m^2, a reduction of > 99 percent. When additional trees were felled and debarked two years after the emamectin benzoate injection, there were still virtually no larvae in the treated trees, while adjacent, untreated trees at the same sites had hundreds of larvae.

In two OSU studies conducted in Toledo with street trees ranging in size from 15- to 25-inch DBH, a single application of emamectin benzoate also provided excellent control for two years. There was no sign of canopy decline in treated trees and very few emergence holes, while the canopies of adjacent, untreated trees exhibited severe decline and extremely high numbers of emergence holes.

One study suggests that a single injection of emamectin benzoate may even control EAB for three years. Additional studies to further evaluate the long-term effectiveness of emamectin benzoate are underway. To date, this is the only product that controls EAB for more than one year with a single application. In addition, in side-by-side comparisons with other systemic products (neonicotinoids), emamectin benzoate was more effective.

Imidacloprid

Trunk injections with imidacloprid products have provided varying degrees of EAB control in trials conducted at different sites in Ohio and Michigan. In an MSU study, larval density in trees treated with Imicide® injections were reduced by 60 percent to 96 percent, compared to untreated controls. There was no apparent relationship between efficacy and trunk diameter or infestation pressure. In another MSU trial, imidacloprid trunk injections made in late May were more effective than those made in mid-July, and IMA-jet® injections provided higher levels of control than did Imicide®, perhaps because the IMA-jet® label calls for a greater amount of active ingredient to be applied on large trees. In an OSU study in Toledo, IMA-jet® provided excellent control of EAB on 15- to 25-inch trees under high pest pressure when trees were injected annually. However, trees that were injected every other year were not consistently protected.

In a discouraging study conducted in Michigan, ash trees continued to decline from one year to the next despite being treated in both years with either imidacloprid (Imicide®, Pointer™) or Bidrin (Inject-A-Cide B®) trunk injections. Imicide®, Pointer™ and Inject-A-Cide B® trunk injections all suppressed EAB infestation levels in both years, with Imicide® generally providing best control under high pest pressure in both small (six-inch DBH) and larger (16-inch DBH) caliper trees. However, larval density increased in treated and untreated trees from one year to the next. Furthermore, canopy dieback increased by at least 67 percent in all treated trees (although this was substantially less than the amount of dieback observed in untreated trees). Although untreated trees were more severely impacted, these results indicate that even consecutive years of treatment with these trunk-injection treatments may only slow or delay ash decline when pest pressure is severe.

In three other side-by-side comparisons, Imicide® consistently provided higher levels of control than did Pointer™. In another MSU study, ACECAP® trunk implants (active ingredient is acephate) were not effective under high pest pressure.

Noninvasive Basal Trunk Sprays with Dinotefuran

Studies to date indicate that systemic basal trunk sprays with dinotefuran are about as effective as imidacloprid treatments. MSU and OSU studies have evaluated residues in leaves from trees treated with the basal trunk spray. Results show that the dinotefuran effectively moved into the trees and was translocated to the canopy at rates similar to those of other trunk-injected insecticides, and faster than other soil-applied neonicotinoid products.

As with imidacloprid treatments, control of EAB with dinotefuran has been variable in research trials. In an MSU study conducted in 2007 and 2008, dinotefuran trunk sprays reduced EAB larval density by approximately 30 percent to 60 percent compared to the heavily infested untreated trees. The treatment was effective for only one year and would have to be applied annually. In general, control is better and more consistent in smaller trees than in large trees, but more research is needed with larger trees. Studies to address the long-term effectiveness of annual dinotefuran applications for control of EAB are underway.

Protective Cover Sprays

MSU studies have shown that applications of Onyx™, Tempo® and Sevin® SL provided good control of EAB, especially when the insecticides were applied in late May and again in early July. Acephate sprays were less effective. BotaniGard® (*Beauvaria bassiana*) was also ineffective under high pest pressure. Astro® (permethrin) was not evaluated against EAB in these tests, but has been effective for controlling other species of wood borers and bark beetles.

In another MSU study, spraying Tempo® just on the foliage and upper branches or spraying the entire tree were more effective than simply spraying just the trunk and large branches. This suggests that some cover sprays may be especially effective for controlling EAB adults as they feed on leaves in the canopy. A single, well-timed spray was also found to provide good control of EAB, although two sprays may provide extra assurance given the long period of adult EAB activity.

It should be noted that spraying large trees is likely to result in a considerable amount of insecticide drift, even when conditions are ideal. Drift and potential effects of insecticides on non-target organisms should be considered when selecting options for EAB control.

Key Points and Summary Recommendations

- Insecticides can effectively protect ash trees from EAB.
- Unnecessary insecticide applications waste money. If EAB has not been detected within 10-15 miles, your trees are at low risk. Be aware of the status of EAB in your location. Current maps of known EAB populations can be found at **www.emeraldashborer.info**. Remember, however, that once a county is quarantined, maps for that county are no longer updated.
- Trees that are already infested and showing signs of canopy decline when treatments are initiated may continue to decline in the first year after treatment, and then begin to show improvement in the second year due to time lag associated with vascular healing. Trees exhibiting more than 50 percent canopy decline are unlikely to recover even if treated.
- Emamectin benzoate is the only product tested to date that controls EAB for more than one year with a single application. It also provided a higher level of control than other products in side-by-side studies.
- Soil drenches and injections are most effective when made at the base of the trunk. Imidacloprid applications made in the spring or the fall have been shown to be equally effective.
- Soil injections should be no more than 2-4 inches deep, to avoid placing the insecticide beneath feeder roots.
- To facilitate uptake, systemic trunk and soil insecticides should be applied when the soil is moist but not saturated or excessively dry.
- Research and experience suggest that effectiveness of insecticides has been less consistent on larger trees. Research has not been conducted on trees larger than 25-inch DBH. When treating very large trees under high pest pressure, it may be necessary to consider combining two treatment strategies.
- Xytect™ soil treatments are labeled for application at a higher maximum rate than other imidacloprid formulations, and we recommend that trees larger than 15-inch DBH be treated using the highest labeled rate. Merit® imidacloprid formulations are not labeled for use at this higher rate. When treating larger trees with Merit® soil treatments, best results will be obtained with two applications per year. Imidacloprid formulations for homeowners (Bayer Advanced™ Tree & Shrub Insect Control and other generic formulations) can be applied only once per year.
- Homeowners wishing to protect trees larger than 15-inch DBH should consider having their trees professionally treated.
- All treatment programs must comply with label restrictions on the amount of insecticide that can be applied per acre in a given year.

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BEFORE THE BUG COMES TO TOWN

Developing a State or Regional Readiness and Response Plan for Exotic Invasive Insects

PLAN DEVELOPMENT

An invasive pest can be a huge threat to the balance of the urban ecosystem. Managing an infestation – all the essential education, administration, information, communication, and regulation issues that need to be coordinated – is a staggering task for any agency. The main purpose for undertaking readiness planning *before* the bug comes to town is to learn as much as possible ahead of time, collaborate to share resources and information, and create a network to strengthen a coordinated response. **The primary goal is to protect the resource** to the extent possible.

1. BUILDING A TEAM - Bringing together stakeholders

A team approach is essential to tackle the imposing threat of an exotic species invasion. A strong and diverse team can be much more effective through collaboration, than any one organization can be alone. Members of the team should bring useful and important knowledge and experience to the planning effort. The team itself creates a critical network for information sharing and dissemination and supports and energizes individual member organizations in preparedness activities. A team working to plan for protection of the urban and community forest should include the following partners:

Regulatory agencies
- USDA APHIS-PPQ*
- State Department of Agriculture

Supporting agencies
- USDA* Forest Service – State and Private Forestry
- State Department of Natural Resources

Researchers
- Universities/Colleges
- USDA Forest Service – Research
- State Natural History Survey

Educators
- Arboreta and Botanic Gardens
- Non-profit organizations related to tree/forest issues

Resource managers
- Municipal Foresters Associations
- Local, County, Regional, and State Park Agencies
- Parks and Recreation Associations
- Forest Preserves
- Consulting Foresters Associations

Industry
- Arborist Associations
- Landscape Contractors Associations
- Nursery/Growers Associations
- Wood Products Associations
- Forestry Councils
- Golf Course Superintendent Associations

Municipalities
- Regional Councils of Governments
- Mayors & Managers Associations
- Individual Municipalities
- County and Township Agencies

Organizations/Agencies involved in outbreaks in other states

2. WHAT IS AT RISK? - Calculating consequences of infestation

In order to garner support, interest, and collaboration for readiness planning, it is important to determine the following:

- What is the extent of the resource at risk?
  (e.g. 6% of the forest cover is ash, 19% of all public trees are ash, and 35% of the public canopy cover is ash)
  - Research FIA* data for rural forests
  - State natural resources department
  - Survey of city foresters for urban forest data

- What consequences could arise from the infestation?
  (e.g. loss of canopy and resulting economic and environmental impacts such as increase in stormwater runoff; expenses associated with removal and replanting; visual/aesthetic impacts; property loss, hazardous conditions with dead standing trees; private homeowner assistance needs – be specific!)
  - Readiness planning team members can contribute from various perspectives
  - Research consequences of infestation in other states

3. WHAT IS ALREADY BEING DONE? – Coordinate with existing plans

APHIS* is directing all states to develop "Plant Resource Emergency Response Guidelines." These guidelines outline the legal authority, roles and responsibilities of various agencies and organizations, and a system for rapid response to an insect, disease, or weed that impacts plants. These general guidelines may be useful in developing a species-specific preparedness/response plan. For information about the status of your state's guidelines, contact your State Plant Health Director or State Plant Regulatory Official (visit the following websites for directories by state):

- State Plant Regulatory Officials
  http://nationalplantboard.org/member/index.html

- State Plant Health Directors
  http://ceris.purdue.edu/napis/names/sphdXstate.html

Look to management plans from other state. APHIS PPQ develops manuals and guidelines for all kinds of introduced pests. Review relevant manuals (e.g. New Pest Response Guidelines Asian Longhorned Beetle) to glean ideas for regional readiness.

- APHIS manuals for introduced pests
  http://www.aphis.usda.gov/ppq/manuals/online_manuals.html

Utilize the resources of the National Invasive Species Information Center, an interdepartmental coordinating council of federal agencies that compiles numerous model management and control plans into a Manager's Toolkit.

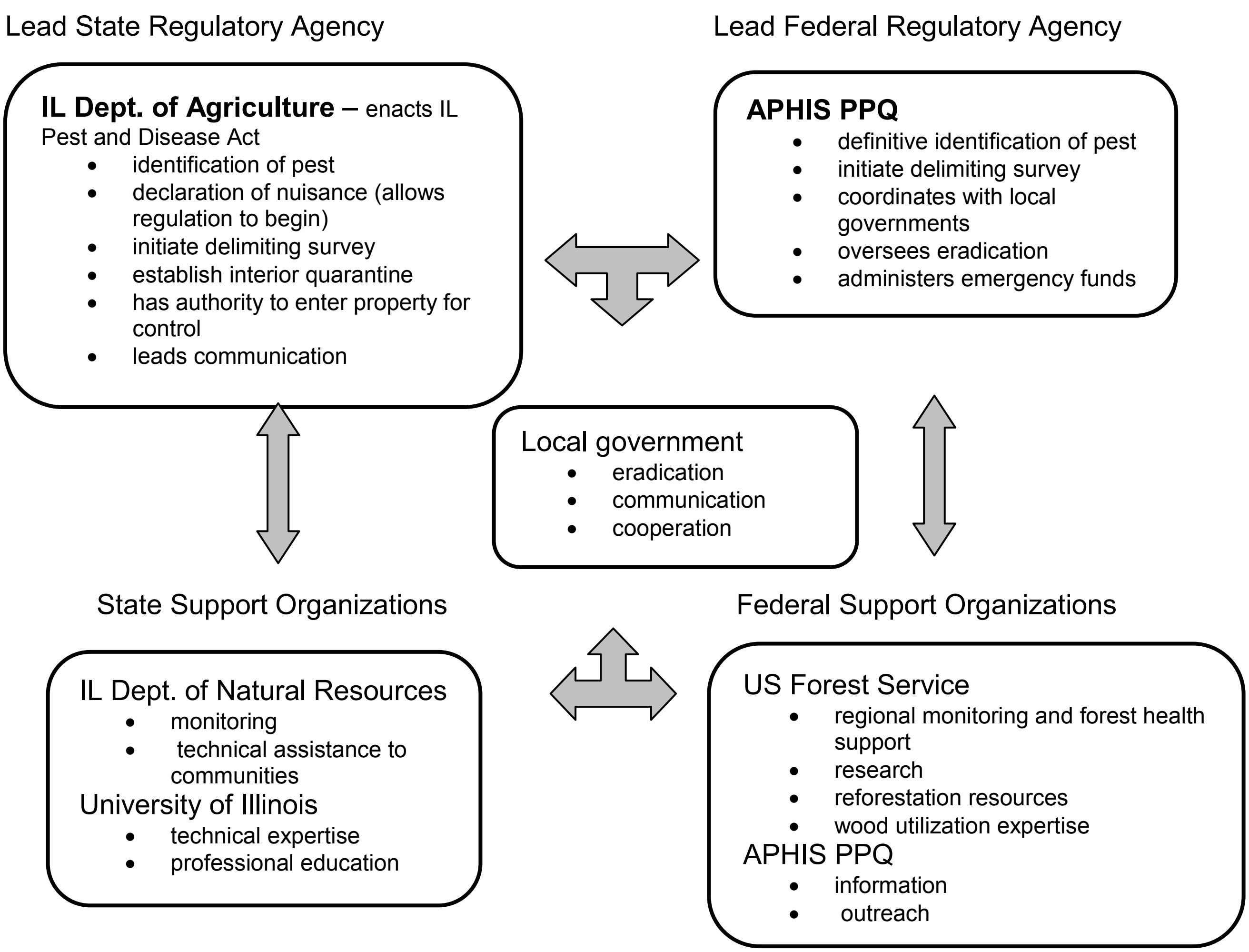
- Invasive Species Manager's Toolkit
  http://www.invasivespecies.gov/toolkit/main.shtml

4. WHAT HAVE YOU GOT? Identifying strengths, capacity, resources, and programs

- Determine who has authority and responsibility
- Inventory existing programs and efforts to educate, monitor and reduce risk

- Identify strengths
  (e.g. strong green industry professional networks to educate and disseminate information, previous ALB experience had success with public awareness and support)
- Find mechanisms to distribute information
- Locate expertise in team organizations
  (e.g. where are the entomologists, foresters, communications specialists, and lobbyists?)
- Look for sources of funds
  (e.g. US Forest Service Forest Health Program, APHIS, State Department of Agriculture, professional organizations, State Urban Forestry Grants, Councils of Governments, state and federal legislature)

Example: Illinois Authorities and Resources



5. WHERE ARE THE GAPS? - Identifying needs, shortages, and hindrances

- Are the public agencies adequately staffed and supported?
- Are all at-risk land managers engaged?
- What information do we need to know before we can plan?
- Are there any policies, attitudes or programs that would be obstacles to readiness?
  (e.g. Do state regulatory statutes allow for rapid response? Is there political support?)

6. WILL IT HAPPEN TO YOU? - Determining vulnerability

- What geographic area is at highest risk?

(e.g. most of the ash forests are in the Northeast part of the state--Windham, Olmsted, Orleans, and Lawrence Counties, most of the public ash trees are located in the highly populous areas of the Chicago metro)

- Where is the most probable source of an infestation?
  (e.g. human movement such as nursery stock, wood products and firewood transfer from out-of-state infested site)
- Where is the most probable port of entry into the state?
  (e.g. 1. urban areas with newly planted ash (from nursery stock),
  2. recreation areas like campgrounds from firewood transfer,
  3. Chicago due to its large population and proximity to Michigan and Indiana; because it is a major port for foreign shipments; there is a high concentration of industry and because there are multiple ports of entry via train, auto, and ship)

7. DRAFT A PLAN. - With consensus from major stakeholders draft a plan to guide planning and prioritize action.

8. MAINTAIN READINESS.

- Share evolving issues, actions, information and technology with team members.
- Collaborate with team member to act on key steps in the readiness plan.
  (e.g. Collaborate with land owners and universities to conduct a detection survey.)
- Inform stakeholders and constituents of plan and state of readiness.
- Communicate with the media about the plan and achievements to foster public cooperation and confidence.

PLAN COMPONENTS

This is an example of a plan developed in Illinois to prepare for the emerald ash borer (EAB):

1. Readiness- reduce risk, minimize impact, and respond more effectively to a possible infestation and work towards overall health and sustainability of the urban forest in Illinois and northeast Indiana

A. Administrative Readiness
  1) Establish a network of agencies and organizations to be affected by EAB
    a. Statutory Administrative Team – lead regulatory agencies
    b. Technical and Administrative Team
    b. Education and Communication Team
  2) Finalize Develop an EAB Readiness Plan
  3) Identify resources and needs
  4) Take proactive steps to speed administrative processes i.e., shorten time required to establish quarantine
  5) Educate the media and assure accuracy of information

B. Technical Readiness
  1) Review and distribute federal scientific guidelines to advise actions
  2) Advocate for continued research for greater understanding of EAB and management options
  3) Transfer technology

2. **Prevention infestation** – to assure that all means of introduction are known and blocked, whenever possible
   A. Assess Risk
      1) Identify possible sources of EAB importation (i.e., firewood and nursery stock from Michigan)
      2) Assess the scope of the resource at risk (number of ash trees)
      3) Track spread of EAB and distribute to Readiness Team
   B. Reduce Risk
      1) Advocate for appointment of vital vacant positions
      2) Raise public awareness about risk from firewood importation
      3) Track nursery stock, ash lumber and ash firewood importation in recent past
      4) Educate industries about risk of ash importation
      5) Assure plantings selections contribute to a diverse and sustainable urban forest
      6) Seek legislative support to reduce risk

3) **Identification** – minimize the spread and improve odds of containing an infestation
   A. Survey urban ash populations to quickly find, or rule out the presence of EAB
   B. Offer training and outreach to landscapers, arborists, nurserymen and other green industry workers to accurately identify EAB
   C. Educate general public about ash health and EAB
   D. Establish a hotline and a website
   E. Support full staffing of IDA Inspectors to respond quickly to possible sightings

4) **Response** - contain infestation and manage the EAB population
   A. Implement coordinated effort to contain the infestation
   B. Provide accurate information to the media through EAB Teams
   C. Communicate with public and industry professionals to foster cooperation to maximize effective response
   D. Reforest

*ACRONYMS

Federal Organizations:
APHIS – Animal and Plant Health Inspection Service
PPQ – Plant Protection and Quarantine (Under APHIS)
FEMA – Federal Emergency Management Agency
USDA – United States Department of Agriculture
FS – Forest Service

State Organizations:
DNR – State Department of Natural Resources
DA – State Department of Agriculture
EMA – State Emergency Management Agency
FHP – Forest Health Program

Other:
FIA – Forest Inventory and Analysis (program of the USDA Forest Service)
ALB – Asian longhorned beetle
EAB - emerald ash borer

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