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Executive Summary

Overview

This plan was developed to assist the City of Lehigh with managing its urban forest, including budgeting and future planning. Trees can provide a multitude of benefits to the community, and sound management allows a community to best take advantage of these benefits. Management is especially important considering the serious threats posed by forest pests such as the emerald ash borer (EAB). EAB is an invasive insect imported from Eastern Asia on wood shipping crates that kills all species of ash trees (this does not include mountain ash). There is a strong possibility that about 15% of Lehigh's city owned trees (ash) will die once EAB becomes established in the community, unless preventative treatment is used. With proper planning and management, the costs of removing dead and dying trees can be extended over years, mitigating public safety issues.

Inventory and Results

In 2018, a tree inventory was conducted using Global Positioning System (GPS) data collectors. The inventory was a complete inventory of street and park trees. Below are some key findings of the 213 trees inventoried.

- Lehigh's trees provide \$39,251 of benefits annually, an average of \$184 per tree
- There are over 20 species of trees
- The top three genera are: Elm 21%, Ash 15%, and Oak 15%
- 87% of trees are in need of some type of management
- 30 trees are recommended for removal

Recommendations

The core recommendations are detailed in the Recommendations Section. The Emerald Ash Borer Plan includes management recommendations as well. Below are some key recommendations.

- Of the 30 trees suggested for removal, 6 trees are over 18 inches in diameter at 4.5 ft. and should be addressed as soon as possible [*City ownership of the trees recommended for removal should be verified prior to any removal*](#)
- 4 of the 31 ash trees should be carefully examined, as they have one or more symptoms that could be related to an EAB infestation
- All trees should be pruned on a routine schedule- one third of the city every other year
- Plant a diverse mix of trees that do not include: ash, maple, cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut
- Check ash trees with a visual survey yearly
- With an annual budget of \$2,000 it could take more than 12 years to remove ash – Suggestion: request a budget increase to \$3,000 annually and apply for grants to plant replacement trees

Introduction

This plan was developed to assist Lehigh with the management, budgeting and future planning of their urban forest. Across the state, forestry budgets continue to decrease with more and more of that money spent on tree removal. With the anticipated arrival of Emerald Ash Borer (EAB), an invasive pest that kills native ash trees, it is time to prepare for the increased costs of tree removal or treatment and replacement planting. With proper planning and management of the current canopy in Lehigh, these costs can be extended over years and public safety issues from dead and dying ash trees mitigated.

Trees are an important component of Lehigh's infrastructure and one of the greatest assets to the community. The benefits of trees are immense. Trees provide the community with improved air quality, stormwater runoff interception, energy conservation, lower traffic speeds, increased property values, reduced crime, improved mental health and create a desirable place to live, to name just a few benefits. It is essential that these benefits be maintained for the people of Lehigh and future generations through good urban forestry management.

Good urban forestry management involves setting goals and developing management strategies to achieve these goals. An essential part of developing management strategies is a comprehensive public tree inventory. The inventory supplies information that will be used for maintenance, removal schedules, tree planting and budgeting. Basing actions on this information will help meet Lehigh's urban forestry goals.

Inventory

In 2018, a tree inventory was conducted that included 100% of city-owned park and street trees. The tree data was collected using a handheld Global Positioning System (GPS) receiver. The data collector gives Geographic Information Systems (GIS) coordinates with an accuracy of 3 meters, which can be used in Arc GIS as an active GIS data layer. Because the inventory is a digital document the data can be updated with new information and become a working document.

The programming used to collect tree information on the data collectors was written to be compatible with a state-of-the-art software suite called i-Tree. i-Tree was developed by the USDA Forest Service to quantify the structure of community trees and the environmental services that trees provide. The i-Tree suite is a public domain which can be accessed for free.

To quantify the urban forest structure and benefits, specific data is collected for each tree. This data includes: location, land use, species, diameter at 4.5 ft., recommended maintenance, priority of that maintenance, leaf health, and wood condition. Additionally, signs and symptoms associated with EAB were noted for all ash trees. The signs and symptoms noted were canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Inventory Results

The data collected for the 213 city trees was entered into the USDA Forest service program Street Tree Resource Analysis Tool for Urban forestry Management as part of the i-Tree suite. The following are results from the i-Tree STREETS analysis.

Annual Benefits

Annual Energy Benefits

Trees conserve energy by shading buildings and blocking winds. Lehigh's trees reduce energy related costs by approximately \$10,683 annually (Appendix A, Table 1). These savings are both in Electricity (50.8 MWh) and in Natural Gas (6,964.7 Therms).

Annual Stormwater Benefits

Lehigh's trees intercept about 588,597 gallons of rainfall or snow melt a year (Appendix A, Table 2). This interception provides \$15,951 of benefits to the city.

Annual Air Quality Benefits

Air quality is a persistent public health issue in Iowa. The urban forest improves air quality by removing pollutants, lowering air temperature, and reducing energy consumption, which in turn reduces emissions from power plants, and emitting volatile organic matter (ozone). In Lehigh, it is estimated that trees remove 676.4 lbs. of air pollution (ozone (O₃), particulate matter less than 10 microns (PM₁₀), carbon monoxide (CO), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂)) per year with a net value of \$1,926 (Appendix A, Table 3).

Annual Carbon Benefits

Carbon sequestration and storage reduce the amount of carbon in the atmosphere, mitigating climate change. In Lehigh, trees sequester about 107,909 lbs. of carbon a year with an associated value of \$809 (Appendix A, Table 5). In addition, the trees store 2,526,394 lbs. of carbon, with a yearly benefit of \$18,948 (Appendix A, Table 4).

Annual Aesthetics Benefits

Social benefits of trees are hard to capture. The analysis does have a calculation for this area that includes: aesthetic value, property values, lowered rates of mental illness and crime, city livability and much more. Lehigh receives \$9,339 in annual social benefits from trees (Appendix A, Table 6).

Financial Summary of all Benefits

According to the USDA Forest Service i-Tree STREETS analysis, Lehigh's trees provide \$39,251 of benefits annually. Benefits of individual trees vary based on size, species, health and location, but on average each of the 213 trees in Lehigh provide approximately \$184 annually (Appendix A, Table 7).

Forest Structure

Species Distribution

Lehigh has over 20 different tree species along city streets and in parks (Appendix A, Figure 1). The distribution of trees by genera is as follows:

Elm	45	21.1%
Ash	31	14.6%
Oak	31	14.6%
Black Walnut	26	12.2%
Hackberry	22	10.3%
Maple	20	9.4%
Spruce	11	5.2%
Apple	9	4.2%
Eastern Redcedar	3	1.4%
Black Locust	2	<1%
Hickory	2	<1%
Honeylocust	2	<1%
Scotch Pine	2	<1%
Willow	2	<1%
Northern White Cedar	1	<1%
Broadleaf Deciduous Md	3	1.4%
Broadleaf Deciduous Lg	1	<1%

Age Class

Nearly half of Lehigh's trees (47%) are between 12 and 30 inches in diameter at 4.5 ft. (Appendix A, Figure 2). For age, it is preferred that the highest amounts of trees are in the smallest size category (a downward slope) to prepare for natural mortality and to maintain canopy cover. Lehigh's size curve is on the medium side, indicating a relatively average-aged tree canopy.

Condition: Wood and Foliage

Both wood condition and leaf condition are good indicators of the overall health of the urban forest. The foliage condition results for Lehigh indicate that 95% of trees are in fair or good health, with only 5% of foliage in poor health, dead or dying (Appendix A, Figure 3 & Appendix B, Figure 3). Similarly, 89% of Lehigh's trees are in fair or good health for wood condition (appendix A, Figure 4 & Appendix B, Figure 3). Wood condition that is in poor health, dead or dying is about 11% of the population. This 11% is an estimate of trees that need management follow up.

Management Needs

The following outlines the specific management needs of the street and park trees by number of trees and percent of canopy (Appendix B, Figure 3).

Crown Cleaning	120	56%
Tree Removal	30	14%
Crown Reduction	21	10%
Raising	14	7%
Staking/Training	2	<1%

Canopy Cover

The total canopy with both private and public trees is 0.4% of total land area. The canopy cover included in the Lehigh inventory includes approximately 5.93 acres (Appendix A, Figure 4).

Land Use and Location

The majority of Lehigh’s city and park trees are in front yards in single family residential neighborhoods (Appendix A, Figure 6 & Appendix A, Figure7). The following describes the land use and locations for the street and park trees.

<u>Land Use</u>	
Single family residential	59%
Park/vacant/other	40%
Multifamily residential	1%
<u>Location</u>	
Front Yard	95%
Planting Strip	3%
Cutout (surrounded by pavement)	2%

Recommendations

Risk Management

Hazardous trees can be a significant threat to both people and property. Trees that are dead or dying, or that have large issues such as trunk cracks longer than 18 inches should be removed. Broken branches and branches that interfere with motorist’s vision of pedestrians, vehicles, traffic signs and signals, etc. should be removed.

Hazardous trees

Lehigh has 6 trees that should be removed as soon as possible. These trees can be seen on the Location of Trees with Recommended Maintenance map (Appendix B, Figure 4). It is recommended to start with large diameter trees first. There are 4 trees over 24 inches in diameter at 4.5 ft. that should be removed first. Please refer to the six year maintenance plan at the end of this section. After all six of these trees are addressed, there should be follow up on the trees marked as needing maintenance. There are 180 additional trees that require varying degrees of maintenance, most of which is NOT immediate.

Poor tree species

After removal of the aforementioned trees, ash trees in poor health should be assessed for removal (Appendix B, Figure 3 & Appendix B, Figure 4). Of these 6 removals, only one is an ash tree. Three

additional ash tree show signs and symptoms associated with EAB, and another two trees display poor wood or leaf health. [*City ownership of the trees recommended for removal should be verified prior to any removal*](#)

Pruning Cycle

Proper pruning can extend the life and good health of trees, as well as reduce public safety issues. In the Management Needs section of the Findings there are four main maintenance issues to be addressed: routine pruning, crown cleaning, crown raising, and crown reduction. Crown cleaning removes dead, diseased, and damaged limbs. Crown raising is the removal of lower branches that are 2 inches in diameter or larger in the case of providing clearance for pedestrians or vehicles. Crown reduction is removing individual limbs from structures or utility wires. It is recommended that all trees be pruned on a routine schedule every five to seven years. Please refer to the six year maintenance plan for further information.

Planting

Most of the planting over the next 5 years will replace the trees that are removed. It is recommended to plant 1.2 trees for every tree removed, since survival rates will not be 100%. Please refer to the six year maintenance plan at the end of this section. It is not essential that the new trees be planted in the same location of the trees being removed. However, maintaining the same number of trees helps ensure continuation of the benefits of the existing forest in Lehigh.

It is important to plant a diverse mix of species in the urban forest to maintain canopy health, since most insects and diseases target a genus (ash) or species (green ash) of trees. Current diversity recommendations advise that a genus (i.e. maple, oak) not make up more than 20% of the urban forest and a single species (i.e. silver maple, sugar maple, white oak, bur oak) not make up more than 10% of the total urban forest. Presently, the forest is heavily planted with maple (14.5%) (Appendix A, Figure 1). Maples should not be planted until this percentage can be lowered. Also, ash trees have not been recommended since 2002, due to the threat of EAB. Other species to avoid because they are public nuisances include: cottonwood, poplar, box elder, Chinese elm, evergreen, willow and black walnut.

Continual Monitoring

Due to the threat of EAB, it is important to continuously check the health of ash trees. It is recommended that ash trees be checked with a visual survey every year for tree decline and for the following signs and symptoms: canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Six Year Maintenance Plan with No Additional Funding

Year 1

- Removal: 2 largest trees requiring immediate attention, including one ash tree
- Planting and Replacement: 3 trees to be planted in open locations
- Young Tree Pruning & Maintenance:
- Visual Survey for signs and symptoms of EAB

Year 2

- Removal: 2 largest remaining trees requiring immediate attention
- *Or saving for ash tree treatment and/or future ash removal

Planting and Replacement: 1 tree in open locations
Young Tree Pruning & Maintenance:
Routine trimming: Contract to trim 1/3 of the city trees
Visual Survey for signs and symptoms of EAB

Year 3

Removal: 2 final trees requiring immediate attention
*Or saving for ash tree treatment and/or future ash removal
Planting and Replacement: 2 trees to be planted in open locations and locations from previous removals
Young Tree Pruning & Maintenance:
Visual Survey for signs and symptoms of EAB

Year 4

Removal: 1 tree - removal of new critical concern tree and/or ash in poor health
*Or saving for ash tree treatment and/or future ash removal
Planting and Replacement: 6 trees in open locations from previous removals
Routine trimming: Contract to trim 1/3 of the city trees
Young Tree Pruning & Maintenance:
Visual Survey for signs and symptoms of EAB

Year 5

Removal: 2 trees - removal of new critical concern trees and/or ash in poor health
*Or saving for ash tree treatment and/or future ash removal
Planting and Replacement: 3 trees to be planted in open locations and locations from previous removals
Young Tree Pruning & Maintenance:
Visual Survey for signs and symptoms of EAB

Year 6

Removal: 2 tree - removal of new critical concern trees and/or ash in poor health
*Or saving for ash tree treatment and/or future ash removal
Routine trimming: Contract to trim 1/3 of the city trees
Young Tree Pruning & Maintenance:
Visual Survey for signs and symptoms of EAB

*Reduction of ash over 6 years: Approximately 15 ash trees removed (approximately 48% of ash). It will take more than 12 years to remove all ash with a budget of \$2,000 per year. EAB could potentially kill all ash within 4 to 15 years of its arrival.

**To remove all ash trees within 6 years, the budget would need to be more than \$4,000 per year.

Emerald Ash Borer Plan

Ash Tree Removal

Tree removal will be prioritized with dead, dying, hazardous trees to be removed first (Appendix B, Figure 4). Next will be all ash in poor condition and displaying signs and symptoms of EAB (Appendix B, Figure 2 & Appendix B, Figure 3). **City ownership of the tree recommended for removal should be verified prior to any removal**

Treatment of Ash Trees

Chemical treatment can be effective tool for communities to spread removal costs out over several years while allowing trees to continue to provide benefits. However, treatment is not recommended if EAB is more than 15 miles away from the community. For more information on the cost of treatment strategies visit <http://extension.entm.purdue.edu/treecomputer/>

EAB Quarantines

EAB is an extremely destructive plant pest and it is responsible for the death and decline of millions of ash trees. Ash in both forested and urban settings constitute a significant portion of the canopy cover in the United States. Current tools to detect, control, suppress and eradicate this pest are not as robust as the USDA would desire. In order to stay ahead of this hard to detect beetle, the USDA is attempting to contain the beetle before it spreads beyond its known positions by regulating articles.

A regulated article under the USDA's quarantine includes any of the following items:

- emerald ash borer
- firewood of all hardwood species (for example ash, oak, maple and hickory)
- nursery stock and green lumber of ash
- any other ash material, whether living, dead, cut or fallen, including logs, stumps, roots, branches, as well as composted and not composted chips of the genus ash (Mountain ash is not included)

In addition, any other article, product or means of conveyance not listed above may be designated as a regulated article if a USDA inspector determines that it presents a risk of spreading EAB once a quarantine is in effect for your county.

Wood Disposal

A very important aspect of planning is determining how wood infested with EAB will be handled, keeping in mind that quarantines will restrict its movement. Consider who will cut and haul the dead and dying trees? Is there an accessible, secured site big enough to store and sort the hundreds of trees and the associated brush and chips? How will wood be disposed of or utilized? Do you have equipment capable of handling the amount and size of ash trees your tree inventory has identified? Once your county is under quarantine for EAB, contact USDA-APHIS-PPQ at 515-251-4083 or visit the website http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/regulatory.shtml. Wood waste can be disposed of as you normally would if your county is not part of a quarantine.

Canopy Replacement

As budget permits, all removed trees will be replaced. All trees will meet the restrictions set forth in the Lehigh city ordinance.

Postponed Work

While finances, staffing and equipment are focused on the management of ash, usual services may be delayed. Tree removal requests on genera other than ash will be prioritized by hazardous or emergency situations only.

Monitoring

It is recommended that ash trees be checked with a visual survey every year for tree death and for the following signs and symptoms: canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Private Ash Trees

****It is strongly recommended that private property owners start removing ash trees on their property upon arrival of EAB if preventative treatments are not being used.****

Budget

Current Budget

Total \$12,000 over 6 years (\$2,000/year)

FY 2020 Budget

Removal: \$1,600

*Or saving for ash tree treatment and/or future ash removal

Planting: \$300

Watering & Maintenance: \$100

FY 2021 Budget

Removal: \$1,600

*Or saving for ash tree treatment and/or future ash removal

Planting: \$100

Routine trimming: \$200

Watering & Maintenance: \$100

FY 2021 Budget

Removal: \$1,600

*Or saving for ash tree treatment and/or future ash removal

Planting: \$200

Watering & Maintenance: \$200

FY 2023 Budget

Removal: \$800

*Or saving for ash tree treatment and/or future ash removal

Planting: \$600

Routine trimming: \$200

Watering & Maintenance: \$200

FY 2024 Budget

Removal: \$1,600

*Or saving for ash tree treatment and/or future ash removal

Planting: \$300

Watering & Maintenance: \$200

FY 2025 Budget

Removal: \$1,600

*Or saving for ash tree treatment and/or future ash removal

Routine trimming: \$200

Watering & Maintenance: \$300

***Reduction of ash over 6 years: approximately 15 ash trees removed (approximately 48% of ash). It will take approximately 13 years to remove all ash with the current budget.**

Purposed Budget Increase

EAB could potentially kill all ash trees in Lehigh within 4 years of its arrival. To remove all ash trees within 6 years the budget would need to be increased to more than \$4,000 a year. Additionally, it is recommended that Lehigh apply for grants to fund replacement trees. Utility Company grants are usually between \$500 and \$10,000 for community-based, tree-planting projects that include parks, gateways, cemeteries, nature trails, libraries, nursing homes, and schools.

Another option being considered by many communities is treating a number of selected trees, either to maintain those trees in the landscape or to delay their removal – to spread out the costs and number of trees needing removed all at once. Trunk injection is administered every two years for the life of the tree. If treatment is discontinued, the tree dies. For instance, in this treatment scenario, the average ash diameter is 18 inches and at \$15 per inch, about 6 trees could be treated per year (every other year treatment). This would be 12 trees selected for treatment, and Lehigh would still need to find \$20,000 for removal. Alternatively, if there are 4 treatable trees, it would cost approximately \$540 a year for treatment and leave \$1,460 for removal. These are alternatives to straight removal of ash trees. However, whether or not the treatment option is selected, there will be an increased cost of dealing with ash trees if EAB is found in Lehigh. It is suggested to consider increasing the budget to plan for this.

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Appendix A: i-Tree Data

Table 1: Annual Energy Benefits

Lehigh

Annual Energy Benefits of Public Trees

3/25/2018

Species	Total Electricity (MWh)	Electricity (\$)	Total Natural Gas (Therms)	Natural Gas (\$)	Total Standard (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Elm	12.0	914	1,631.0	1,598	2,512	(N/A)	21.1	23.5	55.83
Green ash	6.3	478	883.2	865	1,343	(N/A)	14.1	12.6	44.77
Bur oak	11.0	834	1,500.0	1,470	2,304	(N/A)	13.1	21.6	82.28
Black walnut	4.6	348	581.6	570	918	(N/A)	12.2	8.6	35.31
Northern hackberry	3.8	290	550.1	539	830	(N/A)	10.3	7.8	37.70
Silver maple	3.4	259	452.9	444	703	(N/A)	4.2	6.6	78.13
Apple	1.7	133	263.7	258	391	(N/A)	4.2	3.7	43.47
Blue spruce	0.6	46	80.1	79	125	(N/A)	2.8	1.2	20.82
Spruce	0.5	37	62.5	61	98	(N/A)	2.3	0.9	19.59
Boxelder	0.7	54	99.8	98	152	(N/A)	1.4	1.4	50.75
Black maple	0.9	65	119.7	117	182	(N/A)	1.4	1.7	60.68
Eastern red cedar	0.3	25	49.3	48	74	(N/A)	1.4	0.7	24.57
Norway maple	0.2	18	30.3	30	48	(N/A)	0.9	0.4	23.94
Scotch pine	0.2	14	24.1	24	38	(N/A)	0.9	0.4	18.86
Black locust	0.6	42	76.9	75	118	(N/A)	0.9	1.1	58.81
Willow	0.6	49	94.8	93	142	(N/A)	0.9	1.3	70.84
UNKNOWN	0.0	0	0.0	0	0	(N/A)	0.9	0.0	0.00
Honeylocust	0.7	51	89.7	88	139	(N/A)	0.9	1.3	69.53
Broadleaf Deciduous Small	0.3	21	44.5	44	64	(N/A)	0.9	0.6	32.17
Hickory	0.2	14	27.5	27	41	(N/A)	0.9	0.4	20.64
White oak	0.8	62	110.0	108	170	(N/A)	0.9	1.6	84.77
Ash	0.3	20	39.6	39	59	(N/A)	0.5	0.5	58.69
Sugar maple	0.3	20	36.7	36	56	(N/A)	0.5	0.5	55.65
Northern white cedar	0.1	10	14.6	14	24	(N/A)	0.5	0.2	24.14
Amur maple	0.2	15	31.6	31	46	(N/A)	0.5	0.4	46.14
Northern red oak	0.2	16	30.6	30	46	(N/A)	0.5	0.4	46.28
Red maple	0.3	22	39.9	39	61	(N/A)	0.5	0.6	60.68
Total	50.8	3,857	6,964.7	6,825	10,683	(N/A)	100.0	100.0	50.15

Table 2: Annual Stormwater Benefits

Lehigh

Annual Stormwater Benefits of Public Trees

3/25/2018

Species	Total rainfall interception (Gal)	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Elm	141,682	3,840	(N/A)	21.1	24.1	85.32
Green ash	68,032	1,844	(N/A)	14.1	11.6	61.46
Bur oak	159,852	4,332	(N/A)	13.1	27.2	154.71
Black walnut	39,161	1,061	(N/A)	12.2	6.7	40.82
Northern hackberry	29,668	804	(N/A)	10.3	5.0	36.55
Silver maple	52,806	1,431	(N/A)	4.2	9.0	159.01
Apple	9,044	245	(N/A)	4.2	1.5	27.23
Blue spruce	7,957	216	(N/A)	2.8	1.4	35.94
Spruce	6,855	186	(N/A)	2.3	1.2	37.15
Boxelder	9,788	265	(N/A)	1.4	1.7	88.42
Black maple	8,601	233	(N/A)	1.4	1.5	77.70
Eastern red cedar	4,904	133	(N/A)	1.4	0.8	44.30
Norway maple	1,421	39	(N/A)	0.9	0.2	19.26
Scotch pine	2,134	58	(N/A)	0.9	0.4	28.92
Black locust	5,173	140	(N/A)	0.9	0.9	70.10
Willow	7,529	204	(N/A)	0.9	1.3	102.01
UNKNOWN	0	0	(N/A)	0.9	0.0	0.00
Honeylocust	7,590	206	(N/A)	0.9	1.3	102.84
Broadleaf Deciduous Small	1,439	39	(N/A)	0.9	0.2	19.49
Hickory	1,216	33	(N/A)	0.9	0.2	16.47
White oak	11,182	303	(N/A)	0.9	1.9	151.51
Ash	2,479	67	(N/A)	0.5	0.4	67.19
Sugar maple	2,466	67	(N/A)	0.5	0.4	66.84
Northern white cedar	1,539	42	(N/A)	0.5	0.3	41.70
Amur maple	1,174	32	(N/A)	0.5	0.2	31.82
Northern red oak	2,039	55	(N/A)	0.5	0.3	55.25
Red maple	2,867	78	(N/A)	0.5	0.5	77.70
Citywide total	588,597	15,951	(N/A)	100.0	100.0	74.89

Table 3: Annual Air Quality Benefits

Lehigh

Annual Air Quality Benefits of Public Trees

3/25/2018

Species	Deposition (lb)				Total Depos. (\$)	Avoided (lb)				Total Avoided (\$)	BVOC Emissions (lb)	BVOC Emissions (\$)	Total (lb)	Total Standard (\$ Error)	% of Total Trees	Avg. \$/tree
	O ₃	NO ₂	PM ₁₀	SO ₂		NO ₂	PM ₁₀	VOC	SO ₂							
Elm	19.9	3.2	9.3	0.9	105	57.3	8.4	8.0	54.6	358	0.0	0	161.5	463 (N/A)	21.1	10.28
Green ash	8.0	1.3	3.9	0.4	43	30.2	4.4	4.2	28.5	188	0.0	0	80.8	231 (N/A)	14.1	7.69
Bur oak	24.7	3.9	11.0	1.1	129	52.4	7.6	7.3	49.8	327	0.0	0	157.9	456 (N/A)	13.1	16.28
Black walnut	4.0	0.6	2.1	0.2	22	21.5	3.2	3.0	20.8	135	0.0	0	55.4	157 (N/A)	12.2	6.03
Northern hackberry	4.4	0.8	2.3	0.2	24	18.5	2.7	2.6	17.4	115	0.0	0	48.7	139 (N/A)	10.3	6.31
Silver maple	9.8	1.7	4.7	0.4	53	16.1	2.4	2.3	15.5	101	-5.1	-19	47.8	135 (N/A)	4.2	14.96
Apple	3.2	0.5	1.5	0.1	17	8.6	1.2	1.2	7.9	53	0.0	0	24.2	70 (N/A)	4.2	7.75
Blue spruce	1.0	0.2	0.9	0.1	7	2.9	0.4	0.4	2.8	18	-2.9	-11	5.8	14 (N/A)	2.8	2.34
Spruce	0.7	0.1	0.6	0.1	5	2.3	0.3	0.3	2.2	14	-2.7	-10	4.0	9 (N/A)	2.3	1.82
Boxelder	1.4	0.2	0.6	0.1	8	3.4	0.5	0.5	3.2	21	-0.4	-1	9.7	27 (N/A)	1.4	9.16
Black maple	2.2	0.4	1.0	0.1	12	4.1	0.6	0.6	3.9	25	-0.7	-3	12.1	35 (N/A)	1.4	11.54
Eastern red cedar	1.0	0.2	0.8	0.1	7	1.6	0.2	0.2	1.5	10	-2.7	-10	3.1	7 (N/A)	1.4	2.19
Norway maple	0.2	0.0	0.1	0.0	1	1.1	0.2	0.2	1.1	7	-0.1	0	2.9	8 (N/A)	0.9	4.03
Scotch pine	0.2	0.0	0.2	0.0	2	0.9	0.1	0.1	0.8	5	-0.7	-3	1.7	4 (N/A)	0.9	2.15
Black locust	1.1	0.2	0.5	0.0	6	2.7	0.4	0.4	2.5	17	-0.3	-1	7.5	21 (N/A)	0.9	10.75
Willow	1.7	0.3	0.8	0.1	9	3.1	0.5	0.4	2.9	19	-0.4	-1	9.5	27 (N/A)	0.9	13.58
UNKNOWN	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0 (N/A)	0.9	0.00
Honeylocust	1.5	0.2	0.7	0.1	8	3.2	0.5	0.4	3.0	20	-1.1	-4	8.5	23 (N/A)	0.9	11.74
Broadleaf Deciduous Small	0.5	0.1	0.2	0.0	3	1.4	0.2	0.2	1.2	8	0.0	0	3.8	11 (N/A)	0.9	5.45
Hickory	0.0	0.0	0.0	0.0	0	0.9	0.1	0.1	0.9	6	0.0	0	2.1	6 (N/A)	0.9	2.99
White oak	2.1	0.3	0.9	0.1	11	3.9	0.6	0.5	3.7	24	0.0	0	12.1	35 (N/A)	0.9	17.51
Ash	0.5	0.1	0.2	0.0	3	1.3	0.2	0.2	1.2	8	-0.1	0	3.6	10 (N/A)	0.5	10.16
Sugar maple	0.3	0.0	0.2	0.0	2	1.2	0.2	0.2	1.2	8	-0.2	-1	3.0	8 (N/A)	0.5	8.46
Northern white cedar	0.2	0.0	0.1	0.0	1	0.6	0.1	0.1	0.6	4	-0.5	-2	1.2	3 (N/A)	0.5	2.82
Amur maple	0.4	0.1	0.2	0.0	2	1.0	0.1	0.1	0.9	6	0.0	0	2.9	8 (N/A)	0.5	8.35
Northern red oak	0.4	0.1	0.2	0.0	2	1.0	0.1	0.1	1.0	6	-0.6	-2	2.4	7 (N/A)	0.5	6.50
Red maple	0.7	0.1	0.3	0.0	4	1.4	0.2	0.2	1.3	8	-0.2	-1	4.0	12 (N/A)	0.5	11.54
Citywide total	90.4	14.8	43.7	4.3	484	242.7	35.3	33.7	230.3	1,512	-18.7	-70	676.4	1,926 (N/A)	100.0	9.04

**Table 4: Annual Carbon Stored
Lehigh**

Stored CO2 Benefits of Public Trees

3/25/2018

Species	Total Stored CO2 (lbs)	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Elm	668,278	5,012	(N/A)	21.1	26.5	111.38
Green ash	260,827	1,956	(N/A)	14.1	10.3	65.21
Bur oak	825,886	6,194	(N/A)	13.1	32.7	221.22
Black walnut	135,176	1,014	(N/A)	12.2	5.4	38.99
Northern hackberry	67,208	504	(N/A)	10.3	2.7	22.91
Silver maple	230,447	1,728	(N/A)	4.2	9.1	192.04
Apple	49,568	372	(N/A)	4.2	2.0	41.31
Blue spruce	6,343	48	(N/A)	2.8	0.3	7.93
Spruce	5,978	45	(N/A)	2.3	0.2	8.97
Boxelder	57,581	432	(N/A)	1.4	2.3	143.95
Black maple	23,836	179	(N/A)	1.4	0.9	59.59
Eastern red cedar	3,306	25	(N/A)	1.4	0.1	8.27
Norway maple	3,641	27	(N/A)	0.9	0.1	13.65
Scotch pine	1,427	11	(N/A)	0.9	0.1	5.35
Black locust	17,904	134	(N/A)	0.9	0.7	67.14
Willow	28,560	214	(N/A)	0.9	1.1	107.10
UNKNOWN	0	0	(N/A)	0.9	0.0	0.00
Honeylocust	18,988	142	(N/A)	0.9	0.8	71.20
Broadleaf Deciduous	7,651	57	(N/A)	0.9	0.3	28.69
Hickory	2,069	16	(N/A)	0.9	0.1	7.76
White oak	71,755	538	(N/A)	0.9	2.8	269.08
Ash	7,945	60	(N/A)	0.5	0.3	59.59
Sugar maple	7,945	60	(N/A)	0.5	0.3	59.59
Northern white cedar	1,170	9	(N/A)	0.5	0.0	8.78
Amur maple	6,743	51	(N/A)	0.5	0.3	50.57
Northern red oak	8,218	62	(N/A)	0.5	0.3	61.63
Red maple	7,945	60	(N/A)	0.5	0.3	59.59
Citywide total	2,526,394	18,948	(N/A)	100.0	100.0	88.96

Table 5: Annual Carbon Sequestered

Lehigh

Annual CO₂ Benefits of Public Trees

3/25/2018

Species	Sequestered (lb)	Sequestered (\$)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released (\$)	Avoided (lb)	Avoided (\$)	Net Total (lb)	Total Standard (\$ Error)	% of Total Trees	% of Total \$	Avg. \$/tree
Elm	25,820	194	-3,208	-130	-25	20,197	151	42,680	320 (N/A)	21.1	23.7	7.11
Green ash	15,233	114	-1,252	-68	-10	10,555	79	24,468	184 (N/A)	14.1	13.6	6.12
Bur oak	24,255	182	-3,964	-123	-31	18,428	138	38,596	289 (N/A)	13.1	21.4	10.34
Black walnut	9,600	72	-649	-45	-5	7,691	58	16,598	124 (N/A)	12.2	9.2	4.79
Northern hackberry	3,869	29	-324	-37	-3	6,418	48	9,926	74 (N/A)	10.3	5.5	3.38
Silver maple	15,743	118	-1,106	-39	-9	5,732	43	20,329	152 (N/A)	4.2	11.3	16.94
Apple	1,760	13	-238	-25	-2	2,934	22	4,431	33 (N/A)	4.2	2.5	3.69
Blue spruce	470	4	-30	-10	0	1,026	8	1,455	11 (N/A)	2.8	0.8	1.82
Spruce	489	4	-29	-8	0	812	6	1,264	9 (N/A)	2.3	0.7	1.90
Boxelder	3,507	26	-276	-11	-2	1,202	9	4,423	33 (N/A)	1.4	2.5	11.06
Black maple	0	0	-114	-8	-1	1,431	11	1,308	10 (N/A)	1.4	0.7	3.27
Eastern red cedar	43	0	-16	-6	0	561	4	582	4 (N/A)	1.4	0.3	1.45
Norway maple	391	3	-18	-2	0	402	3	774	6 (N/A)	0.9	0.4	2.90
Scotch pine	168	1	-7	-3	0	311	2	469	4 (N/A)	0.9	0.3	1.76
Black locust	386	3	-86	-6	-1	934	7	1,227	9 (N/A)	0.9	0.7	4.60
Willow	0	0	-137	-9	-1	1,077	8	932	7 (N/A)	0.9	0.5	3.49
UNKNOWN	0	0	0	0	0	0	0	0	0 (N/A)	0.9	0.0	0.00
Honeylocust	936	7	-91	-5	-1	1,130	8	1,970	15 (N/A)	0.9	1.1	7.39
Broadleaf Deciduous Smal	592	4	-37	-4	0	459	3	1,011	8 (N/A)	0.9	0.6	3.79
Hickory	418	3	-10	-2	0	318	2	723	5 (N/A)	0.9	0.4	2.71
White oak	1,336	10	-344	-9	-3	1,365	10	2,347	18 (N/A)	0.9	1.3	8.80
Ash	470	4	-38	-3	0	440	3	869	7 (N/A)	0.5	0.5	6.52
Sugar maple	523	4	-38	-3	0	435	3	917	7 (N/A)	0.5	0.5	6.88
Northern white cedar	116	1	-6	-2	0	216	2	324	2 (N/A)	0.5	0.2	2.43
Amur maple	478	4	-32	-3	0	335	3	778	6 (N/A)	0.5	0.4	5.84
Northern red oak	382	3	-39	-3	0	360	3	700	5 (N/A)	0.5	0.4	5.25
Red maple	923	7	-38	-3	0	477	4	1,359	10 (N/A)	0.5	0.8	10.20
Citywide total	107,909	809	-12,129	-568	-95	85,246	639	180,459	1,353 (N/A)	100.0	100.0	6.35

Table 6: Annual Social and Aesthetic Benefits

Lehigh

Annual Aesthetic/Other Benefits of Public Trees

3/25/2018

Species	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Elm	2,141	(N/A)	21.1	22.9	47.57
Green ash	1,340	(N/A)	14.1	14.3	44.65
Bur oak	1,681	(N/A)	13.1	18.0	60.02
Black walnut	948	(N/A)	12.2	10.2	36.47
Northern hackberry	680	(N/A)	10.3	7.3	30.90
Silver maple	1,159	(N/A)	4.2	12.4	128.75
Apple	104	(N/A)	4.2	1.1	11.56
Blue spruce	129	(N/A)	2.8	1.4	21.51
Spruce	134	(N/A)	2.3	1.4	26.79
Boxelder	201	(N/A)	1.4	2.2	66.99
Black maple	0	(N/A)	1.4	0.0	0.00
Eastern red cedar	14	(N/A)	1.4	0.1	4.56
Norway maple	42	(N/A)	0.9	0.4	20.95
Scotch pine	48	(N/A)	0.9	0.5	23.87
Black locust	39	(N/A)	0.9	0.4	19.58
Willow	0	(N/A)	0.9	0.0	0.00
UNKNOWN	0	(N/A)	0.9	0.0	0.00
Honeylocust	195	(N/A)	0.9	2.1	97.30
Broadleaf Deciduous Small	35	(N/A)	0.9	0.4	17.60
Hickory	57	(N/A)	0.9	0.6	28.56
White oak	94	(N/A)	0.9	1.0	47.08
Ash	43	(N/A)	0.5	0.5	43.05
Sugar maple	59	(N/A)	0.5	0.6	58.58
Northern white cedar	32	(N/A)	0.5	0.3	32.32
Amur maple	29	(N/A)	0.5	0.3	28.80
Northern red oak	27	(N/A)	0.5	0.3	27.47
Red maple	109	(N/A)	0.5	1.2	109.08
Citywide total	9,339	(N/A)	100.0	100.0	43.84

Table 7: Summary of Benefits in Dollars

Lehigh

Total Annual Benefits of Public Trees by Species (\$)

3/25/2018

Species	Energy	CO ₂	Air Quality	Stormwater	Aesthetic/Other	Total (\$)	Standard Error	% of Total \$
Elm	2,512	320	463	3,840	2,141	9,275	(N/A)	23.6
Green ash	1,343	184	231	1,844	1,340	4,940	(N/A)	12.6
Bur oak	2,304	289	456	4,332	1,681	9,062	(N/A)	23.1
Black walnut	918	124	157	1,061	948	3,209	(N/A)	8.2
Northern hackberry	830	74	139	804	680	2,527	(N/A)	6.4
Silver maple	703	152	135	1,431	1,159	3,580	(N/A)	9.1
Apple	391	33	70	245	104	843	(N/A)	2.1
Blue spruce	125	11	14	216	129	495	(N/A)	1.3
Spruce	98	9	9	186	134	436	(N/A)	1.1
Boxelder	152	33	27	265	201	679	(N/A)	1.7
Black maple	182	10	35	233	0	460	(N/A)	1.2
Eastern red cedar	74	4	7	133	14	231	(N/A)	0.6
Norway maple	48	6	8	39	42	142	(N/A)	0.4
Scotch pine	38	4	4	58	48	151	(N/A)	0.4
Black locust	118	9	21	140	39	328	(N/A)	0.8
Willow	142	7	27	204	0	380	(N/A)	1.0
UNKNOWN	0	0	0	0	0	0	(N/A)	0.0
Honeylocust	139	15	23	206	195	578	(N/A)	1.5
Broadleaf Deciduous Sn	64	8	11	39	35	157	(N/A)	0.4
Hickory	41	5	6	33	57	143	(N/A)	0.4
White oak	170	18	35	303	94	619	(N/A)	1.6
Ash	59	7	10	67	43	186	(N/A)	0.5
Sugar maple	56	7	8	67	59	196	(N/A)	0.5
Northern white cedar	24	2	3	42	32	103	(N/A)	0.3
Amur maple	46	6	8	32	29	121	(N/A)	0.3
Northern red oak	46	5	7	55	27	141	(N/A)	0.4
Red maple	61	10	12	78	109	269	(N/A)	0.7
Citywide Total	10,683	1,353	1,926	15,951	9,339	39,251	(N/A)	100.0

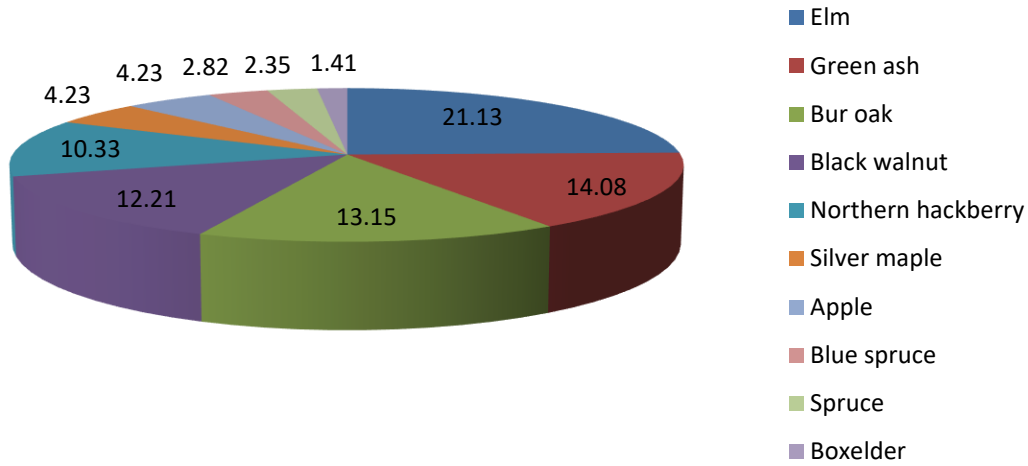


Figure 1: Species Distribution

Relative Age Distribution of Top 10 Public Tree Species (%)

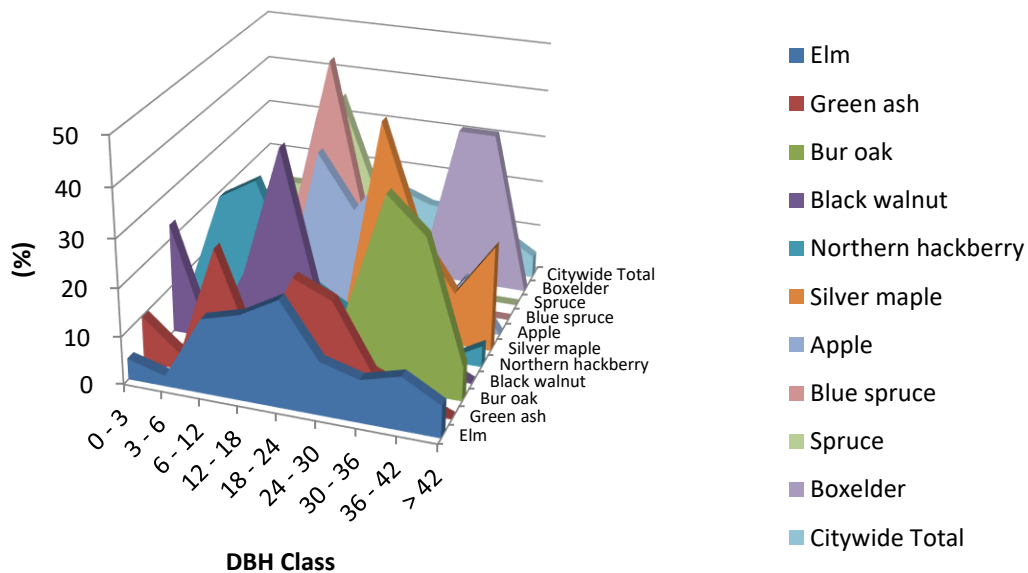


Figure 2: Relative Age Class

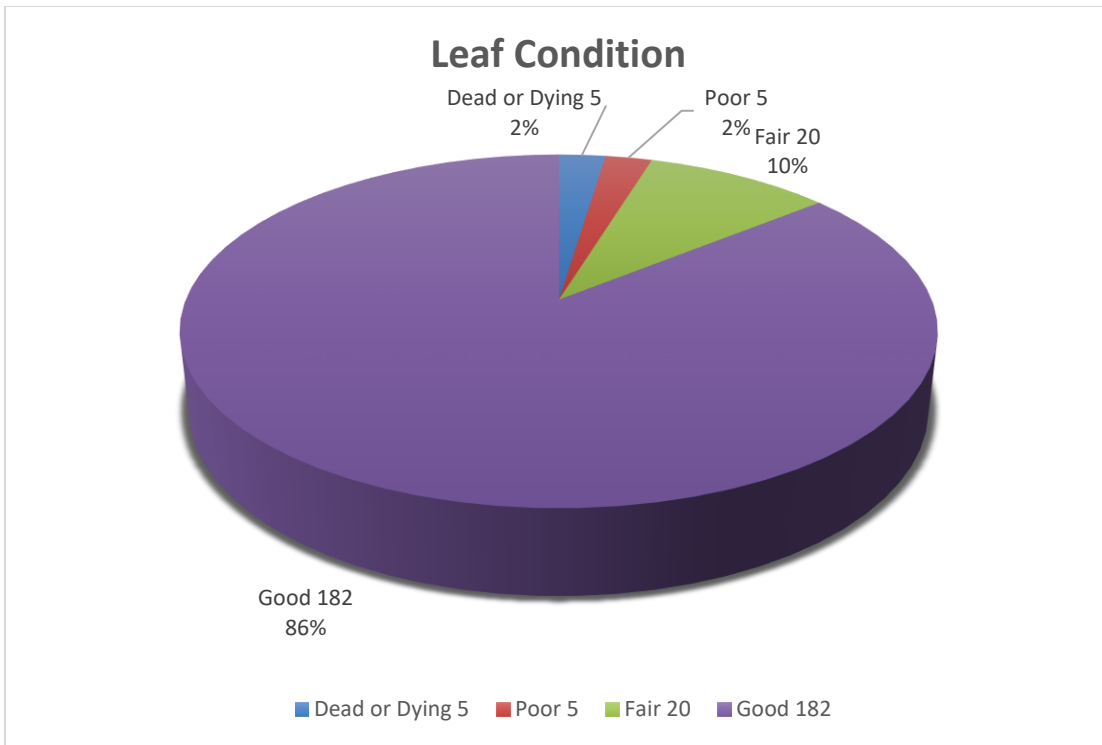


Figure 3: Foliage Condition

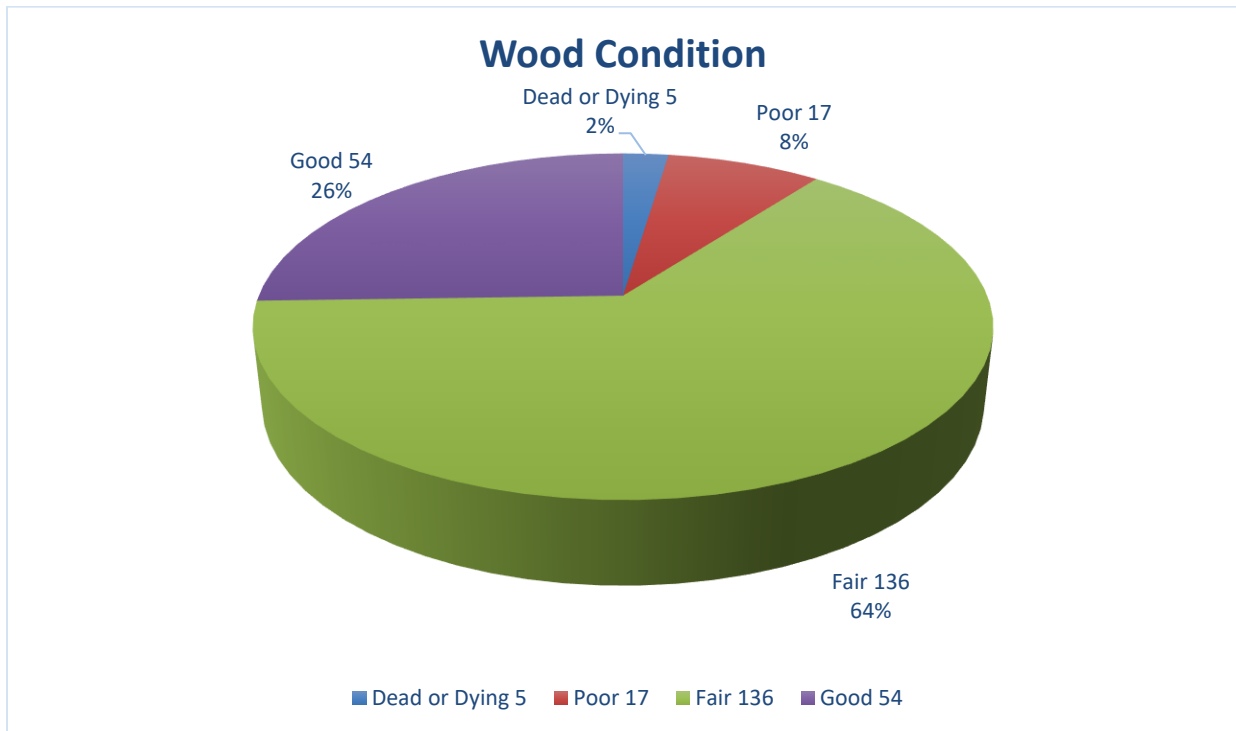


Figure 4: Wood Condition

Canopy Cover of Public Trees (Acres)

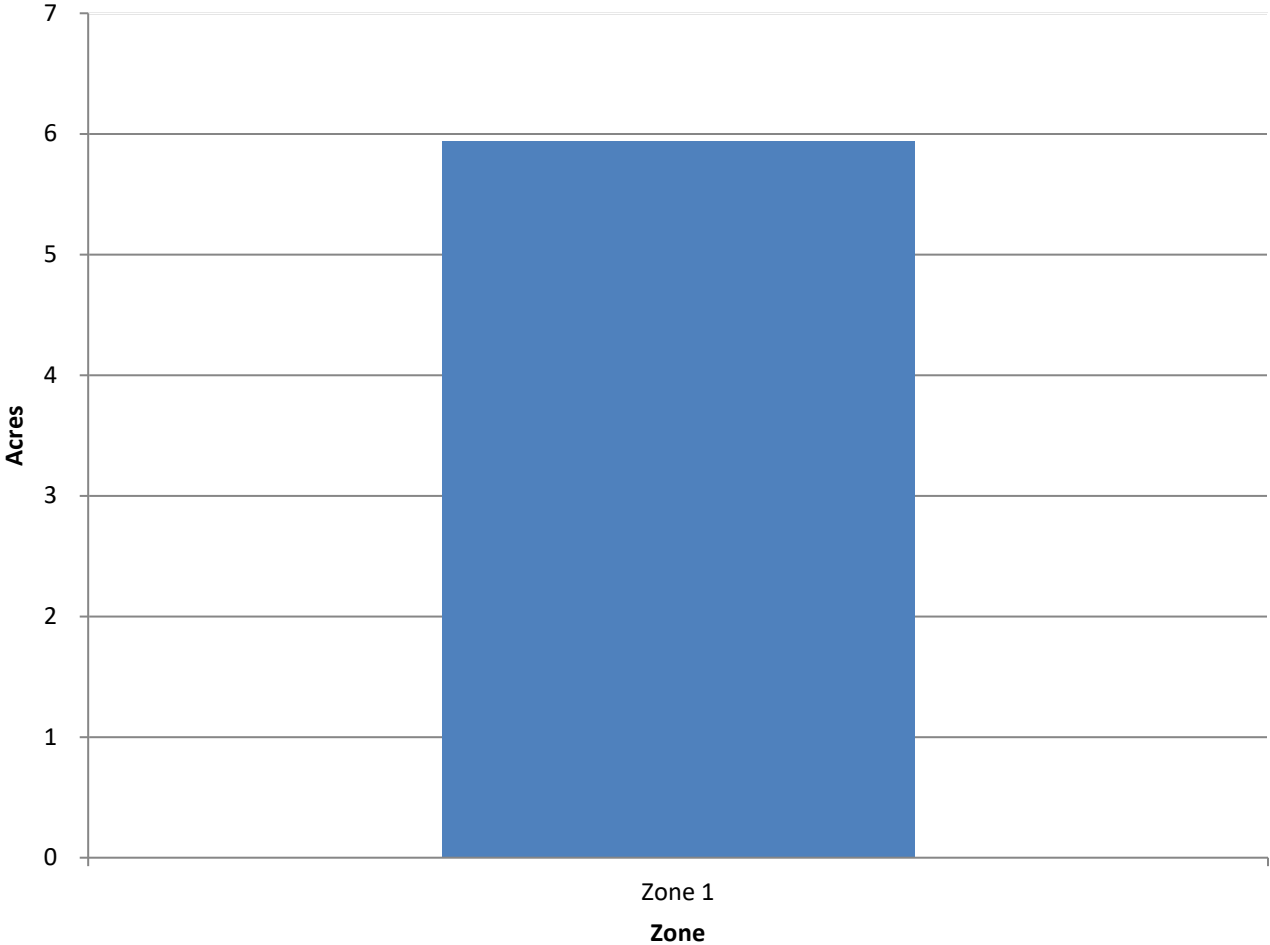


Figure 5: Canopy Cover in Acres

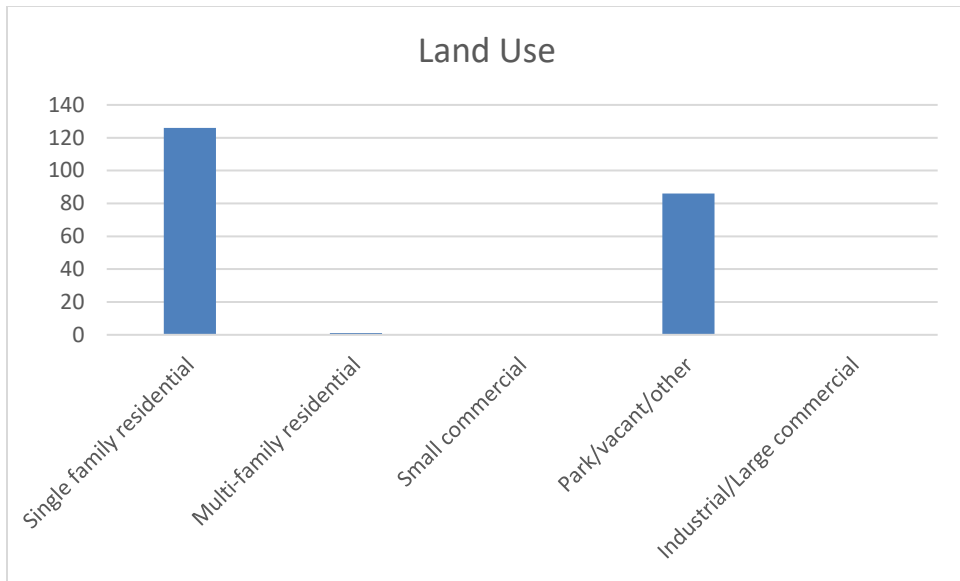


Figure 6: Land Use of city/park trees

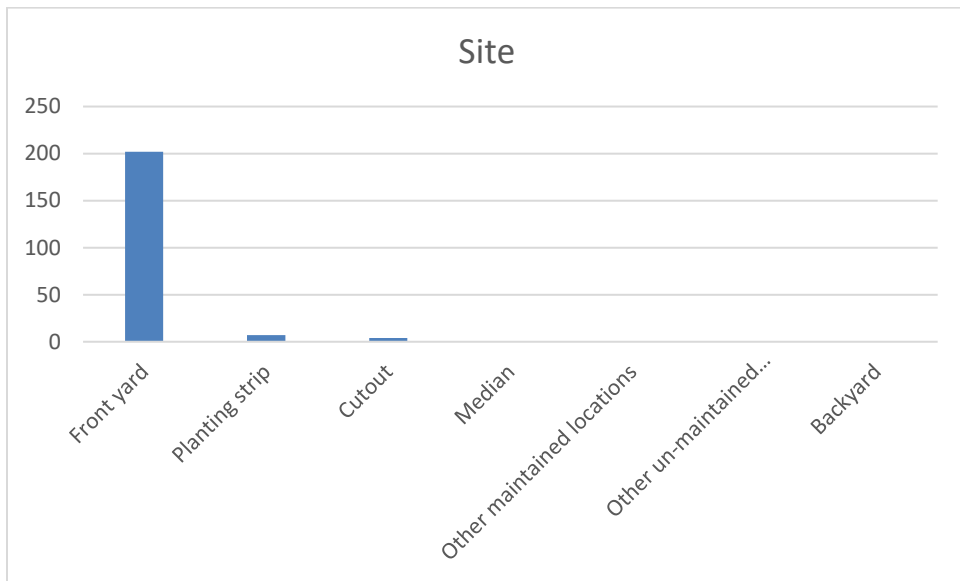


Figure 7: Site Type



Figure 3: Location of Poor Condition Trees



Figure 4: Location of Trees with Recommended Maintenance

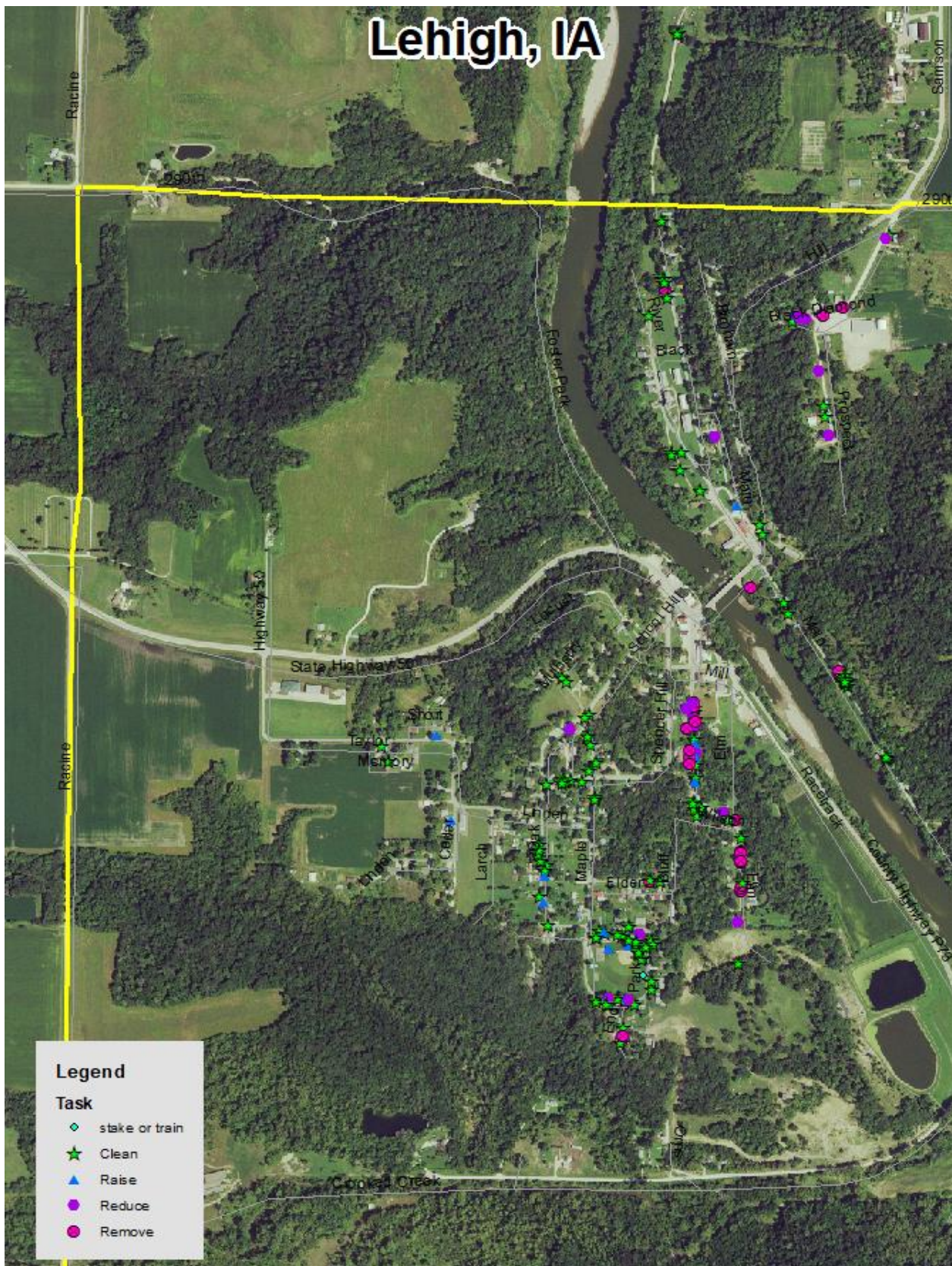


Figure 5: Maintenance Tasks *City ownership of the trees recommended for removal should be verified prior to any removal*

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