

TREE INVENTORY ANALYSIS & MAINTENANCE STRATEGY PREPARED FOR THE

# City of Muskegon, MI

November 2025



## Prepared By:

**Tommy Flynn**  
Inventory Arborist, Site Manager  
Davey Resource Group, Inc.  
24301 Catherine Industrial Dr  
Suite #124  
Novi, MI 48375  
Cell: (513) 948210  
E-mail: [thomas.flynn@davey.com](mailto:thomas.flynn@davey.com)



# Table of Contents

Acknowledgments.....	4
Executive Summary.....	5
Inventory Analysis Summary.....	6
Recommended Maintenance.....	7
Introduction.....	8
Section 1: Structure and Composition.....	11
SPECIES & GENUS DIVERSITY.....	13
Species & Genus Diversity Recommendations.....	14
PEST SUSCEPTIBILITY.....	15
Pest/Disease Susceptibility Recommendations.....	15
CONDITION.....	16
Condition Recommendations.....	16
RELATIVE AGE DISTRIBUTION.....	17
Relative Age Recommendations.....	18
DEFECT OBSERVATIONS.....	19
Defect Observation Recommendations.....	19
INFRASTRUCTURE AND GROWING SPACE.....	20
Infrastructure Recommendations.....	21
Growing Space Recommendations.....	21
Section 2: Functions and Benefits.....	24
I-TREE RESULTS.....	25
ANNUAL BENEFITS.....	25
IMPROVING AIR QUALITY.....	26
SEQUESTERING AND STORING CARBON.....	27
CONTROLLING STORMWATER.....	27
REPLACEMENT VALUE.....	27
Tree Benefit Recommendations.....	28
Section 3: Recommended Maintenance.....	30
RISK MANAGEMENT AND RECOMMENDED MAINTENANCE.....	31
PRIORITY MAINTENANCE (PRUNING & REMOVAL).....	31
1. Priority Maintenance Needs – High-risk Pruning & Removals.....	31
Priority Maintenance Recommendations.....	32
2. Moderate-Risk Pruning & Removals.....	32
Moderate and Low Risk Pruning & Removal Recommendations.....	32

ROUTINE PRUNING CYCLE (RPC) PROACTIVE PRUNING & DISCRETIONARY MAINTENANCE.....	34
Routine Pruning Cycle (RPC) Recommendations .....	34
YOUNG TREE TRAINING (YTT) CYCLE.....	35
Young Tree Training (YTT) Cycle Recommendations .....	36
ROUTINE INSPECTIONS, INVENTORY UPDATES & FURTHER INSPECTIONS.....	36
Routine Inspections & Inventory Update Recommendations.....	36
Further Inspections.....	37
Further Inspection Recommendations .....	37
TREE PLANTING & STUMP REMOVAL.....	37
Tree Planting & Stump Removal Recommendations .....	37
MAINTENANCE STRATEGY AND EXAMPLE BUDGET.....	38
Conclusion .....	43
EVALUATING AND UPDATING THIS PLAN.....	43
References.....	45
Appendix A Summary of Recommendations .....	47
STUMP REMOVAL & TREE PLANTING.....	51
Appendix B Study Area and Data Collection.....	52
STUDY AREA.....	52
Appendix C Risk Assessment .....	55

# Acknowledgments

This project supports Muskegon's vision to promote and enhance community well-being through tree conservation efforts and improved forestry management practices. This Tree Inventory Analysis & Maintenance Strategy (TIAMS) offers expert recommendations to preserve and expand the urban forest. Here we aim to maximize the environmental, economic, and social benefits provided by trees today and for future generations in Muskegon.



Muskegon, MI received grant funding from the Michigan Department of Natural Resources (MDNR) in cooperation with U.S. Forest Service at the West Michigan Shoreline Regional Development Commission (WMSRDC). These funds came through the Urban and Community Forestry Inflation Reduction Act (UCF IRA) Grant Program. The UCF IRA provides funds to communities to create and support sustainable urban forestry programs throughout the United States.

Muskegon, MI recognizes the support of:

*Erin Kuhn, Executive Director, West Michigan Shoreline Regional Development Commission*

*Fallon Chabala, Program Manager, West Michigan Shoreline Regional Development Commission*

*Dave Bailey, Park Maintenance, City of Muskegon*

Notice of Disclaimer: Inventory data provided by Davey Resource Group, Inc. (DRG) are based on visual recordings at the time of inspection. Visual records do not include individual testing or analysis, nor do they include aerial or subterranean inspection. DRG is not responsible for the discovery or identification of hidden or otherwise non-observable hazards. Records may not remain accurate after inspection due to the variable deterioration of inventoried material. DRG provides no warranty with respect to the fitness of the urban forest for any use or purpose whatsoever. Clients may choose to accept or disregard DRG 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

From June to August of 2025, DRG took inventory of Muskegon's public trees.

Sites point data of trees and non-trees sites that we collected during the inventory. We assessed and recorded location, tree and risk data. 'Sites' refer to any data we collected as part of the inventory including tree- and non-trees.

- Also known as: inventoried trees, public trees, community trees, assessed tree population, tree population of interest, inventory data

Trees: existing sites that have a known species.

*Non-trees* Vacant (planting sites), stumps, and unknown/dead trees.

After the inventory, we compiled this Inventory Analysis & Maintenance Strategy (IAMS). Here you will find data summarized by species, size, defect, condition and maintenance. We also include the estimated ecological benefits provided by Muskegon's existing trees.

i-Tree is software used to calculate the ecological benefits associated with inventoried trees. iTree reports values in US dollars for each category of environmental benefits: stormwater and air pollution reduction and carbon sequestration.

Muskegon's inventoried trees have an estimated replacement value of over \$60.7 million and provide \$212,600 annually in stormwater, air quality, and carbon benefits each year.

Funding and support for Muskegon's public trees is crucial for maximizing tree benefits, reducing tree care costs over time, and increasing the value of the urban forest. While other municipal infrastructure loses value over time (depreciates), the value of public trees increases (appreciates).

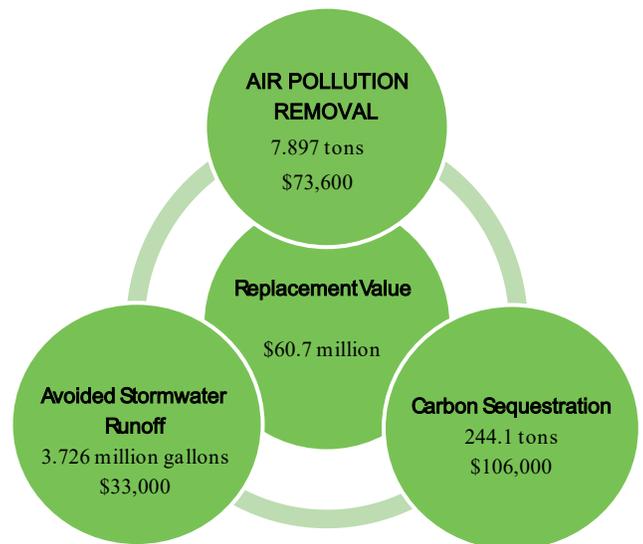
In the final section we provide a sample budget and maintenance schedule (Table 7). High priority tree removal and pruning make up a significant portion of the Year 1 budget. Tree maintenance costs will generally decrease and become more stable in later years. We focus on a proactive tree maintenance strategy to eliminate hazardous tree conditions as soon as possible and prevent minor tree defects from deteriorating.

## Calculating Tree Benefits

The benefits of Muskegon's inventoried trees presented in this plan are calculated using i-Tree Eco

i-Tree is the industry recognized suite of tools used to measure and quantify the ecosystem benefits that trees provide.

i-Tree is a partnership between the USDA Forest Service, The Davey Tree Expert Company, the Arbor Day Foundation, the International Society of Arboriculture, Society of Municipal Arborists, Casey Tree and SUNY College of Environmental Science and Forestry. It was released in 2006, and its models are updated regularly based on the latest science and research.



# Inventory Analysis Summary

## Inventoried Sites

Total Sites= 14436

**\*\* Stumps = 198\*\***

**\*\* Unknown / dead = 55\*\***

TreeSites=14183

## Stocking Level

“Stocking level” refers to the ratio of sites in the right-of-way (ROW) occupied by trees to the total street ROW sites suitable for trees. This is not applicable to Muskegon. We did not collect vacant planting sites during this inventory.

## Annual Benefits

Avoided Stormwater Runoff = ~~33~~ 38,000

Air Pollution Removal = ~~73~~ 600

Carbon Sequestration = ~~106~~ 100,000

## Top 5 Inventoried Species

Species	% UF
Red maple	10.4
Norway maple	9.8
Silver maple	8.8
Freeman maple	8.6
Northern red oak	7.0

More than 10% of one species in a tree population exceeds industry recommendations.

## Top 5 Inventoried Genera

Genus	% UF
Maple	41.3
Oak	18.7
Elm	4.6
Apple	3.1
Pine	3.1

More than 20% of one genus in a tree population exceeds industry recommendations.

**We excluded **\*\*non-tree sites\*\*** to calculate the percentages on this page.**

## Relative Age Distribution

We approximate the ages of trees using their diameter in inches at breast height (DBH). The relative ages of trees in Muskegon:

- 27.9% young (0-8”). Industry guidelines: 40%
- 22.6% established (9-17”). Industry guidelines: 30%
- 19.5% maturing (18-24”). Industry guidelines: 20%
- 29.9% mature (>24”). Industry guidelines: 10%

## Infrastructure Conflicts

Of the 14,183 tree sites, we found and recorded:

- 16.7% with overhead utilities.
- 11.0% conflicting with overhead utilities, meaning the tree was:
  - In contact with communication lines
  - 10’ or less from electrical lines. This is the minimum approach distance for working around power lines.

## Growing Space

- 20.7% of sites had nearby hardscape damage.

## Pest Susceptibility

The following insects and diseases pose the greatest threat to Muskegon’s urban forest (% of tree population at risk):

- Spotted lanternfly (70.8%)
- Eastern tent caterpillar (67.6%)
- Asian longhorned beetle (49.3%)

## Condition

Of the 14,183 tree sites, there were:

- 24% in Good or Excellent condition.
- 15.2% in Fair condition.
- 1.4% in Critical condition.
- 1.2% Dead.

## Defect Observations

Of the 14,183 tree sites:

- 34.2% had root, trunk or branch injury.
- 31.8% had no significant defects. “NONE”
- 13.6% had cavities or decay.
- 9.6% had poor structure.
- 2.6% had ‘serious decline’.
- 2.2% had mechanical damage.
- 1.24% had poor locations.

# Recommended Maintenance



## Tree Removal

Trees designated for removal have defects that cannot be cost-effectively or practically corrected. Many of the trees in this category have a large percentage of dead crown.

1386 removals (total)

25 High-Risk removals

574 Low-Risk removals

787 Moderate Risk removals

198 stump grindings



## Priority Pruning (Tree Cleans)

Priority pruning removes defects such as dead and dying parts or broken and/or hanging branches. Pruning the defective part(s) can lower risk associated with the tree while promoting healthy growth. Also known as 'cleaning prunes'.

Total = 3004 trees for priority pruning, including:

22 High-Risk trees to prune

1647 Moderate Risk trees to prune



## Routine Pruning Cycle (Discretionary / Routine pruning)

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

Discretionary: 7283 trees / five-year pruning cycles

Low-Risk trees to prune: 1335 / five years



## New Tree Planting

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

Planting goal: 2:1 replacement to removal ratio



## Young Tree Training (YTT) Cycle

Young trees may have branch issues that lead to structural problems as they age. Training prunes ensure healthy growth. We train young trees from the ground with pole prunes or shears.

Total = 2565 YTTs prescribed / three-year YTT cycle

= 855 training prunes per year



## Routine Inspection & Inventory Updates

Routine inspections and inventory updates are essential for finding potential issues with trees. Use a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees.

Total = 12,851 trees not recommended for removal

= 2570 inspections annually over five years

# Introduction

Muskegon is home to over 38,000 residents benefiting from trees in their community. Muskegon's Department of Forestry/ Public Works manages all trees, stumps, and planting sites throughout the public rights-of-way (ROW) and certain properties (parks, cemeteries, and 'no-sell' properties)

Between June and August of 2025, TRG collected data on Muskegon's urban forest to develop this Tree Inventory Analysis & Maintenance Strategy. This plan considers the diversity, distribution, and condition of inventoried trees to systematically maintain and improve Muskegon's urban forest

The sections of this plan are as follows:

- *Section 1* Structure and Composition summarizes species, condition and size of inventoried trees
- *Section 2* Functions and Benefits estimated value of ecological benefits provided by the urban forest.
- *Section 3* Recommended Maintenance maintenance scheduling & an estimated five-year budget.

Our goal with this *Inventory Analysis & Maintenance Strategy* is to help Muskegon understand the current state of its public trees, set goals, anticipate future needs, and focus on proactive maintenance.

The Urban Forest Program Continuum (shown on the next page) outlines the steps to effectively and sustainably care for Muskegon's urban forest. The continuum includes additional plans to support Muskegon's urban forest, such as

- *Urban Forest Management Plan* which establishes a detailed 3- to 5-year work plan to address risk and maintenance needs using current tree inventory data to streamline Muskegon's urban forest management program.
- An *Urban Forest Master Plan* engages stakeholder and community members to provide a comprehensive vision for the future of the City's urban forest, with recommendations and a road map of action steps to reach Muskegon's urban forestry goals.

# URBAN FOREST PROGRAM CONTINUUM™

## STAY ON TRACK FOR SUSTAINABLE GROWTH

Below are the steps that urban forest programs take to create and maintain the healthiest and most resilient urban forest possible. Each component creates a strong foundation of strategic planning, program funding, and community support which results in thriving urban forests.





Section 1:

# Structure and Composition

# Section 1: Structure and Composition

DRG Arborists collected data on trees and stumps along street Right-of-Ways (ROWs) and throughout public properties in Muskegon. We inventoried 14,436 sites, with 75% collected along the street ROW and 25% collected on public property (Figure 1). See Appendix B for detailed information on the data collection methods used in this inventory.

Figure 1. Sites inventoried by DRG Arborists, separated by location and type. **Stumps & Unknown / dead trees are considered non-tree sites.** They are not included in iTree's estimated ecobenefits, nor in the summary above.

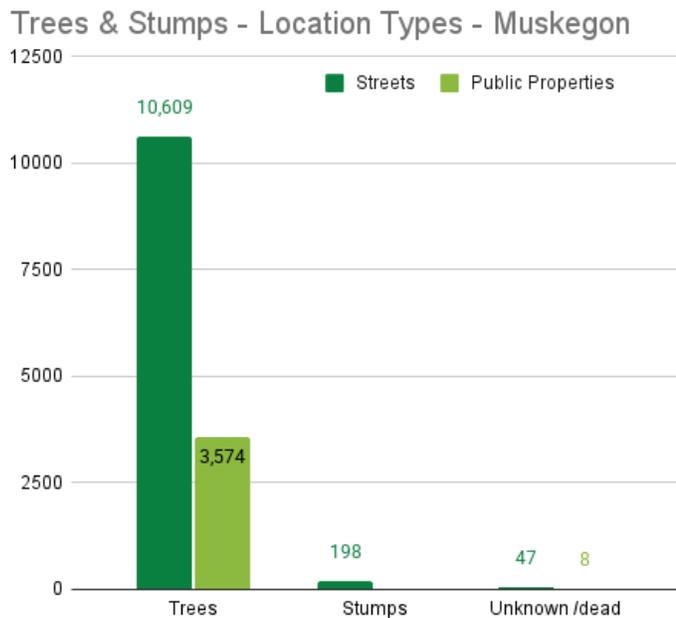


Figure 1. Sites inventoried by DRG Arborists, separated by location and type.

The following figures show Muskegon's inventoried tree population up against industry standards for species, genus, and family diversity. These are called the 10%, 20%, and 30% rules respectively.

Species, Genus, and Family are terms used to group and name organisms based on shared characteristics. We call this system taxonomy. Everything has a taxonomic designation which are names in Latin.

Genus + specific epithet (sometimes called 'species') Taxonomic name (in Latin)

For example, **Sugar maple (Acer saccharum)**:

**Sapindaceae** – Family

**Acer** – Genus

**saccharum** – specific epithet

Families are larger and more broadly defined groups of organisms than a genus (plural: genera).

Family Names:

- Fagaceae – Oak
- Sapindaceae – maple
- Pinaceae – spruce, pine
- Fabaceae – Honey locust, Black locust...
- Rosaceae – apple, pear, hawthorn

### 10% Rule - diversity by Species

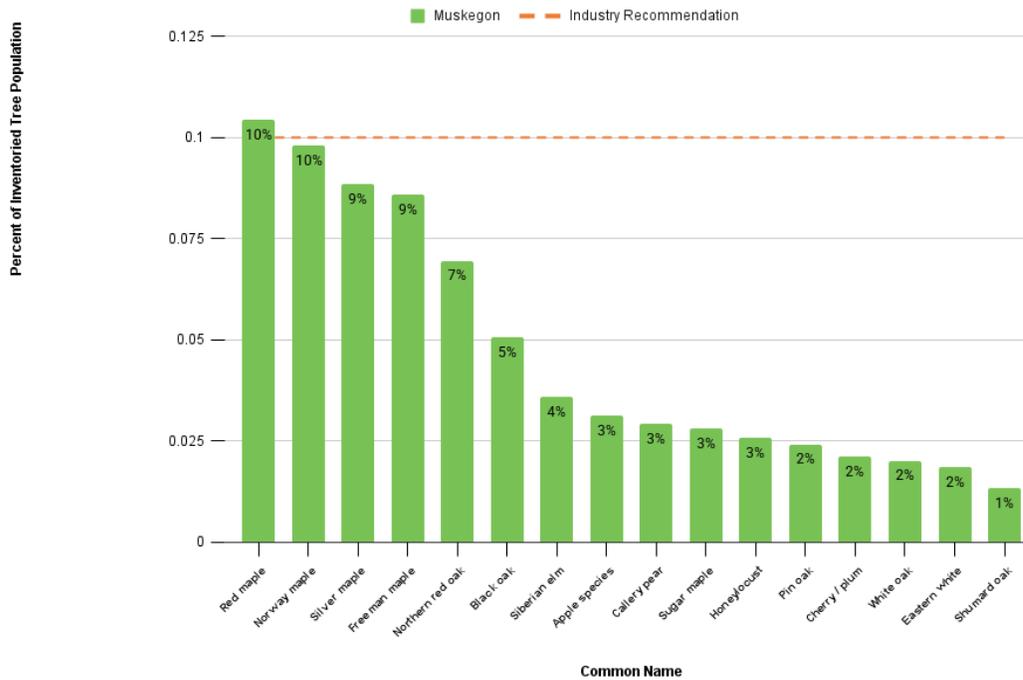


Figure 2—Most common tree species in Muskegon. For planting programs, choose species below the industry recommended threshold.

### 20% Rule - diversity by Genus

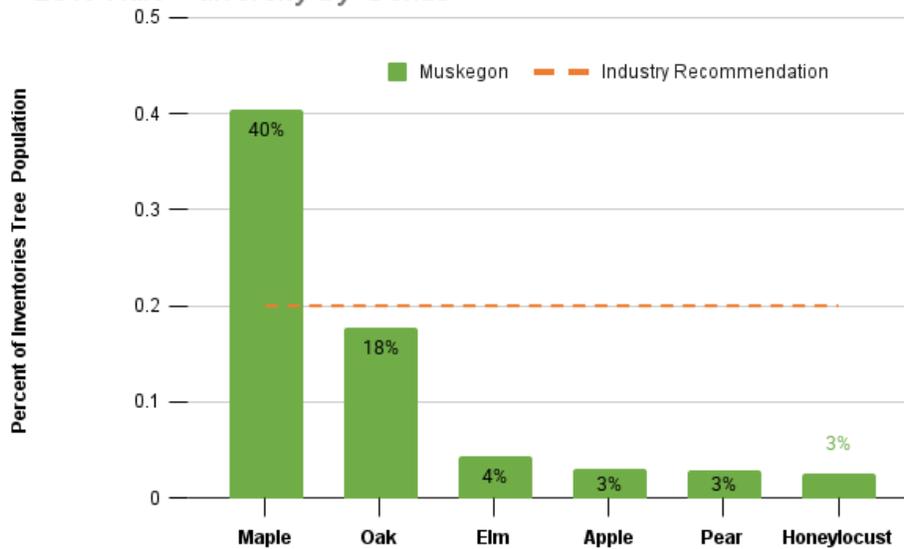


Figure 3—Most common tree genera in Muskegon. For planting programs, we would choose trees from less common genera (Elm, Apple, Pear, Honey locust, and others).

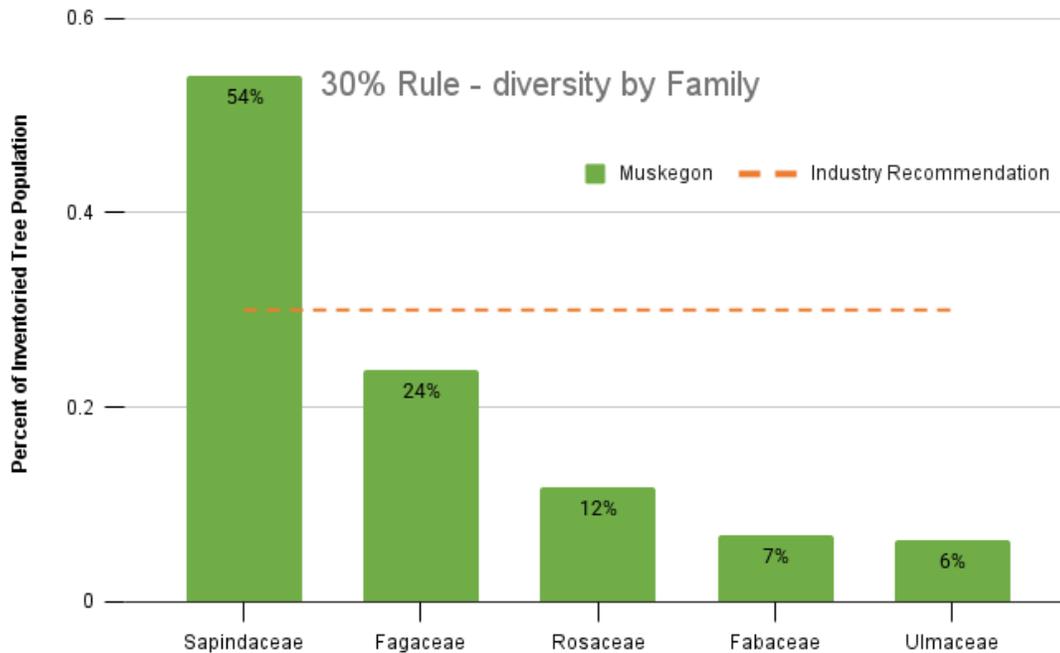


Figure 4– the most common tree families in Muskegon. For planting programs, choose trees in less common families (Fagaceae, Rosaceae, Fabaceae, Ulmaceae).

## SPECIES & GENUS DIVERSITY

Diversity within plant communities is important for increasing their resistance and resilience to disturbance (see side panel, “The Importance of Species Diversity”). The 20:10:30 rule is a common urban forestry industry metric for tree species diversity, which a single species should compose no more than 10% of the population, a single genus no more than 20%, and a single family no more than 30%. Some communities may be in the position to pursue more aggressive diversity goals, such as a 10:15 metric.

## SPECIES & GENUS DIVERSITY RECOMMENDATIONS

Avoid or limit planting of Maple and Oak. Increase planting of uncommon species and genera which are performing well in Muskegon. This list is not exhaustive.

- Shade trees to plant:
  - Hybrid elms (*Ulmus* x)
  - Honey locust (*Gleditsia tricanthos v inermis*)
  - Sycamore or planetree (*Platanus* species)
  - Linden (*Tilia cordata* or *Tilia americana*)
  - Ginkgo (*Ginkgo ginkgo*)
  - Catalpa (*Catalpa speciosa*)
  - Hackberry (*Celtis occidentalis*)
  - Coffee tree (*Gymnocladus dioica*)
- Ornamental, flowering, or fruit trees:
  - Apple (*Malus* species)
  - Cherry (*Prunus* species)
  - Redbud (*Cercis canadensis*)
  - Serviceberry (*Amelanchier* species)
- Large trees are not always good street trees.
- Remove volunteer trees that have invasive tendencies while they are small. These include:
  - White mulberry (*Morus alba*)
  - Tree of heaven (*Ailanthus altissima*)
  - Buckthorn (*Rhamnus*)

### THE IMPORTANCE OF DIVERSITY

The Dutch elm disease epidemic of the 1930s provides a key historical lesson on the importance of diversity. The disease killed millions of American elm trees, leaving behind enormous gaps in the urban canopy of many communities. In the aftermath, ash trees became popular replacements and were heavily planted along city streets. History repeated itself in 2002 with the introduction of the emerald ash borer into the US. This invasive beetle continues to devastate ash tree populations across the country.

Other Invasive pests and diseases, severe weather events, and climate change threaten our urban forests today, so it's vital that we learn from history and plant a wider variety of tree species and genera to develop a resistant and resilient public tree resource.

# PEST SUSCEPTIBILITY

The early identification of pests and/or disease infestations is crucial to protecting Muskegon's urban forest. When infestations are small and still limited to a small tree population they are easier to manage. For this reason, we highly recommend ongoing monitoring and regular inventory updates to catch and limit the spread of potential pests.

Pests and diseases usually have preferred tree species and general hosts, but infestations are impossible to predict. We use known hosts and pests of concern in this analysis. It may underestimate the true risks that tree pests pose to Muskegon.

We can reduce pest-related risks with well-planned planting and removal programs.

It is important to remember that Figure 5 only reflects data collected during the inventory. More trees throughout Muskegon, such as those on private property, may be able to host these pests. Some of these pests are not common or their status is unknown in Muskegon.

Pests of Concern - Muskegon, MI

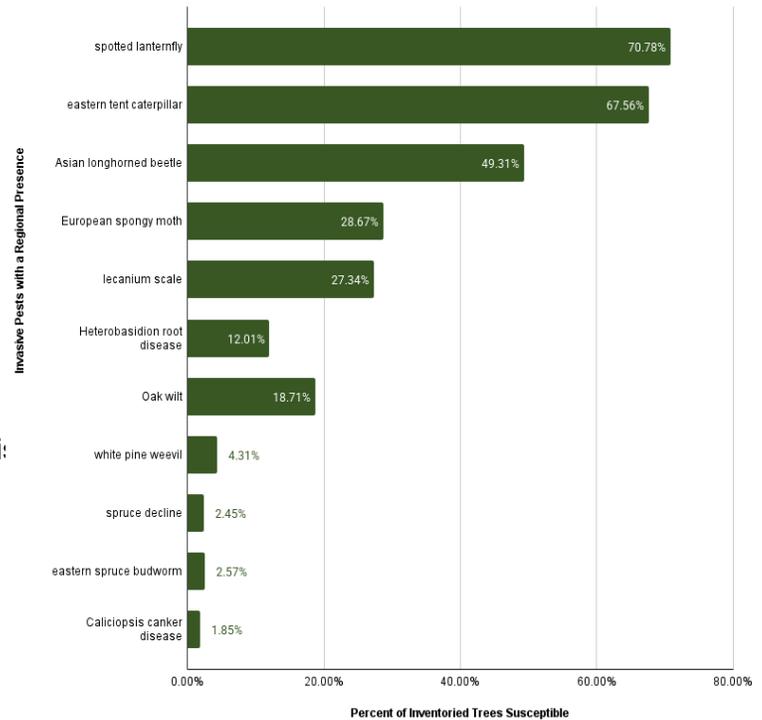


Figure 5 - Pest Susceptibility in Muskegon

## PEST/DISEASE SUSCEPTIBILITY RECOMMENDATIONS

- Monitor trees for signs and symptoms of pests and diseases on a regular basis. Include pest-monitoring activities as part of other routine maintenance, like pruning.
- Identify any pests present and begin management at the earliest possible signs of an infestation.
- Prepare an invasive species management plan to guide responses to future pest issues.
- Spotted lanternflies use many species as a host, but they prefer Tree of heaven. Consider eliminating Tree of heaven populations to reduce Muskegon's risk to Spotted lanternfly.
- When planting trees, select pest- or disease-resistant species or cultivars whenever possible.

Use preventative pesticide treatments on high-value or historic trees that are susceptible to problematic pests and/or diseases in Muskegon.

Search for additional resources about pests and diseases from the following agencies:

- Michigan Department of Natural Resources
- Michigan Department of Agriculture and Rural Development (MDARD)
- United States Department of Agriculture (USDA)
- Michigan State University Extension Office

## CONDITION

During the inventory, each tree was assigned a condition rating based on several factors, including root characteristics; branch structure, trunk, canopy, and foliage condition; and the presence of pests or diseases. Then we chose the most appropriate condition rating: Excellent, Good, Fair, Poor, Critical or Dead.

Figure 6 provides the condition rating breakdown for street and park trees in Muskegon. Most trees were in Good or Fair condition (83%). 17% of Muskegon's trees were in Poor, Critical or Dead condition.

### CONDITION RECOMMENDATIONS

- Dead and dying trees should be removed as soon as possible in order of priority (highest to lowest risk) to eliminate public hazards, create space for new planting, and improve the appearance of Muskegon's streets and parks.
- Monitor Poor condition trees that are not recommended for removal. After Pruning hazardous parts, check the tree's health periodically.
- Condition ratings can improve over time with proactive maintenance schedules:
  - Routine pruning cycles (RPC)
  - Young tree training cycles (YTT)

All tree pruning should follow ANSI A300 (Clause 5) guidelines.

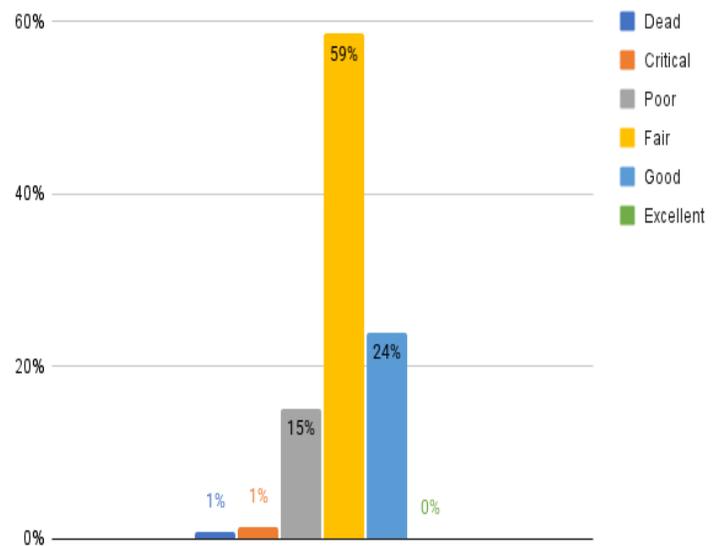


Figure 6. Tree health / condition ratings of trees in Muskegon.

# RELATIVE AGE DISTRIBUTION

We analyze the relative age distribution in an urban forest by assigning an age class to a range of diameters (DBHs). For example, 'young' trees are 8 inches (8") in DBH or smaller. We cannot determine a tree's actual age like this, but we can approximate its age relative to other trees. Since trees have different maintenance needs at the various stages of their development, we use relative age to inform our management strategy.

These size classes are based on the industry-recognized idea for relative age distribution

40% Young trees: 0-8" DBH

- Muskegon currently has 28% young trees.
- We can increase this to our goal of 40% by planting new, young trees.

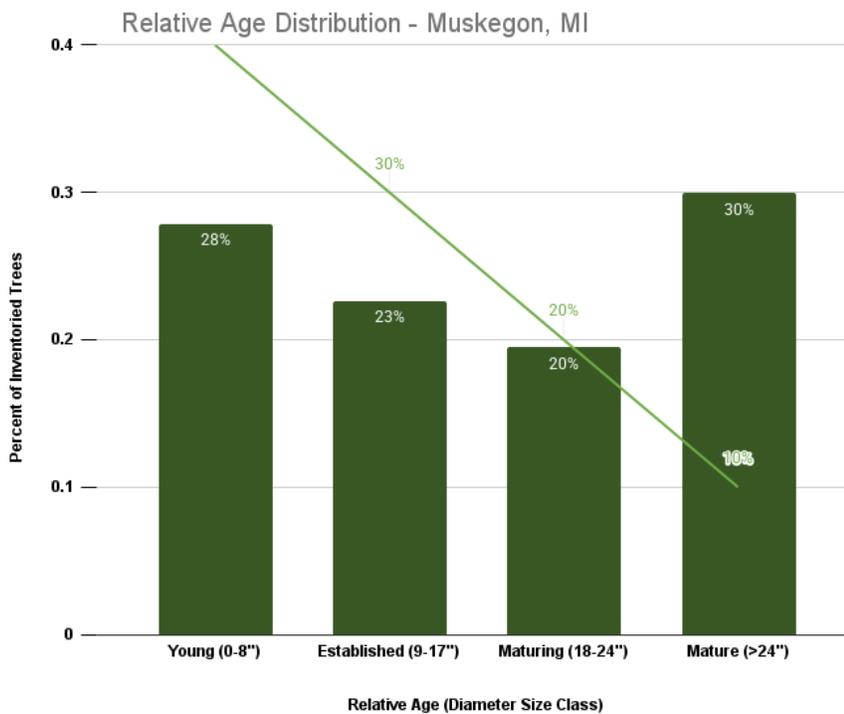


Figure 7 – Relative age distribution of trees in Muskegon, MI.

30% established: DBH range 9-17''

- Muskegon's current proportion of established trees is 23%.
- **Maintain and train young and established trees to increase the portion of established trees in Muskegon to the 30% goal.**

20% Maturing trees: DBH range 18-24'' (GOAL MET)

10% Mature trees: DBH range >=25''

- **Focus on removals of mature trees (high and moderate risk first)**

Figure 8 compares tree condition ratings across the relative age classes for inventoried trees. Trees across all age classes are generally in Fair condition, except for the young age class. In general, trees in the young age class are more likely to be in good condition, while maturing and mature age classes are more likely to have trees in Poor condition.

### RELATIVE AGE RECOMMENDATIONS

- Muskegon’s trees are aging. Focus on proactive care for large-stature trees, especially removals.
- Succession planning: as we remove mature trees, we plant young trees in their place (replacement).
- Young tree training programs - structurally prune small trees to ensure good form and improve health as they establish and mature.
- Street planting programs can begin before removals, if schedules and resources allow.
- Routine, proactive maintenance, such as young tree training and routine pruning, may help improve tree condition, particularly among maturing and mature trees.

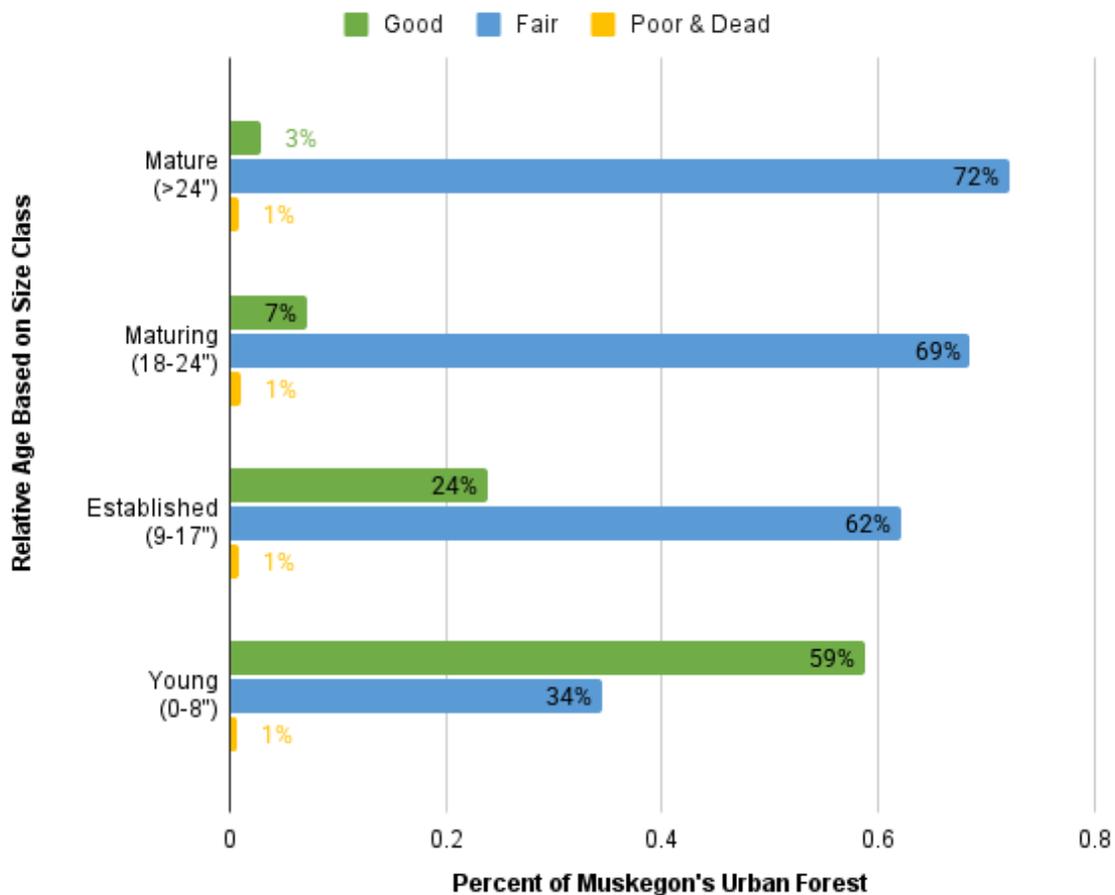


Figure 8. Inventoried tree condition ratings compared to age class.

# DEFECT OBSERVATIONS

During the inventory, arborists took note of damage, decay, structural flaws, pests/diseases, and dead parts of trees and recorded these observations for each site. **Where a tree had more than one defect, we record the most significant defect** (i.e., the defect causing the greatest detriment to the tree and/or most likely to cause whole or partial tree failure within a year). If we did not find any significant defects at the time of inspection, we recorded the defect as 'None.'

## DEFECT OBSERVATION RECOMMENDATIONS

- Root, trunk and branch injury are the most common defects we noticed in Muskegon. This includes dead, dying, broken, hanging, and/or diseased branches.
  - Routine / proactive pruning will improve the health of these trees and reduce the risk associated with dying branches. Removal of dead limbs also improves the visual aesthetics of trees and may help improve public perception of Muskegon’s tree care.

Structural pruning while trees are young can help improve defects like poor structure or improper pruning. See Young Tree Training for more information.

Table 1 - Defect observations for sites in Muskegon

Defect	Count (# of trees)	Percent occurrence
Percent Of Root Trunk Or Branch Injury	4867	34.32%
None (no significant defects)	4516	31.84%
Cavity/Decay	1928	13.59%
Poor Structure	1365	9.62%
Serious Decline	369	2.60%
Mechanical Damage	309	2.18%
Remove Hardware	288	2.03%
Poor Location	176	1.24%
Memorial Tree	95	0.67%
Pest Problem	68	0.48%
Improperly Pruned	42	0.30%
Grate/Guard	20	0.14%
Improperly Installed	11	0.08%
Cables/Rods	3	0.02%
'N/A' OR 'Other'	126	0.89%
<b>Total</b>	<b>14183</b>	<b>100.00%</b>

# INFRASTRUCTURE AND GROWING SPACE

In developed settings, like a street, growing space for trees can be limited both above and below ground. To maximize tree growth, health, and benefits, it is important to consider the amount of space available (above and below ground) for a tree to grow. Selecting “the right tree, for the right place” not only positively impacts tree health and vigor, but it can improve public safety, reduce utility outages, increase walkability, reduce sidewalk/hardscape damage, and ensure compliance with the American Disabilities Act (ADA). During Muskegon’s inventory, we recorded conflicts between trees and overhead utilities (Table 2) and nearby hardscape damage (Table 3).

Table 2- Infrastructure conflicts recorded for sites in Muskegon.

Conflict	Street Trees	(%) of urban forest
Not Present	12065	83.6
Present & Conflicting	1559	10.8
Present & not conflicting	812	5.6
<b>Total</b>	<b>14436</b>	<b>100%</b>

Table 3–Hardscape damage recorded for sites in Muskegon. This reflects displacement in the sidewalk around the base of a tree and is a potential trip hazard.

Hardscape Damage		
Severe (2.5"+)	315	2%
Moderate (12.5")	773	5%
Light (0-0.5")	1,877	13%
N/A	11,471	79%
<b>Total</b>	<b>14,436</b>	<b>100%</b>

## INFRASTRUCTURE RECOMMENDATIONS

- Plant only small stature trees beneath or near overhead electric utilities.
- Consider looking for dwarf cultivars of typically large-stature trees to diversify small stature planting lists.
- Tree roots can damage water and sewer pipes, gas lines, and electric conduit. Installing and maintaining these utilities often damages tree roots, and leads to tree failure, reduced tree vigor, and/or tree death.
- Plant trees at least 5 feet from underground utilities to allow room for large, structural roots to develop without impacting the utility. Consult municipal engineers and/or utility companies for help.
- Also consider conflicts with other infrastructure such as buildings, road signage, streetlights, and driveways. Municipalities should develop and document required clearance needs for different types of infrastructure.

## GROWING SPACE RECOMMENDATIONS

- Right tree, right place. Select tree species based on root system characteristics that match the planting site. Set required growing space dimensions and/or soil volumes for various sizes of trees. Planting only small trees where the growing space and soil volume is restricted will help reduce damage to trees and infrastructure.
- Develop design standards for sidewalks, roads, and other hardscapes that are tree friendly and allow a tree to grow without causing future conflicts.
- Collaborate with city planners, engineers, and public works. Considering trees early when repairing or redesigning streets and sidewalks ensures trees can be a productive part of the new streetscape.

## DRG RECOMMENDED MINIMUM SPACING FOR TREE PLANTING

### Overhead Utility Clearances:

Small trees (>30 feet tall at maturity) can be within 20 feet.

Medium trees (30-45 feet tall at maturity) should be planted 20 feet or further.

Large trees (>45 feet tall at maturity) should be planted 40 feet or further.

*Contact local utility companies for specific local distance requirements.*

### Other Infrastructure Clearances:

40 feet between large trees

30 feet from intersections (approaching traffic)

30 feet between medium trees

20 feet from fire hydrants

20 feet between small trees

15 feet from utility poles, streetlights, buildings

10 feet from driveways, intersections (retreating traffic), crosswalks, important street signage

5 feet from underground utilities

### Growing Space Dimensions:

Small trees - 4 feet x 4 feet

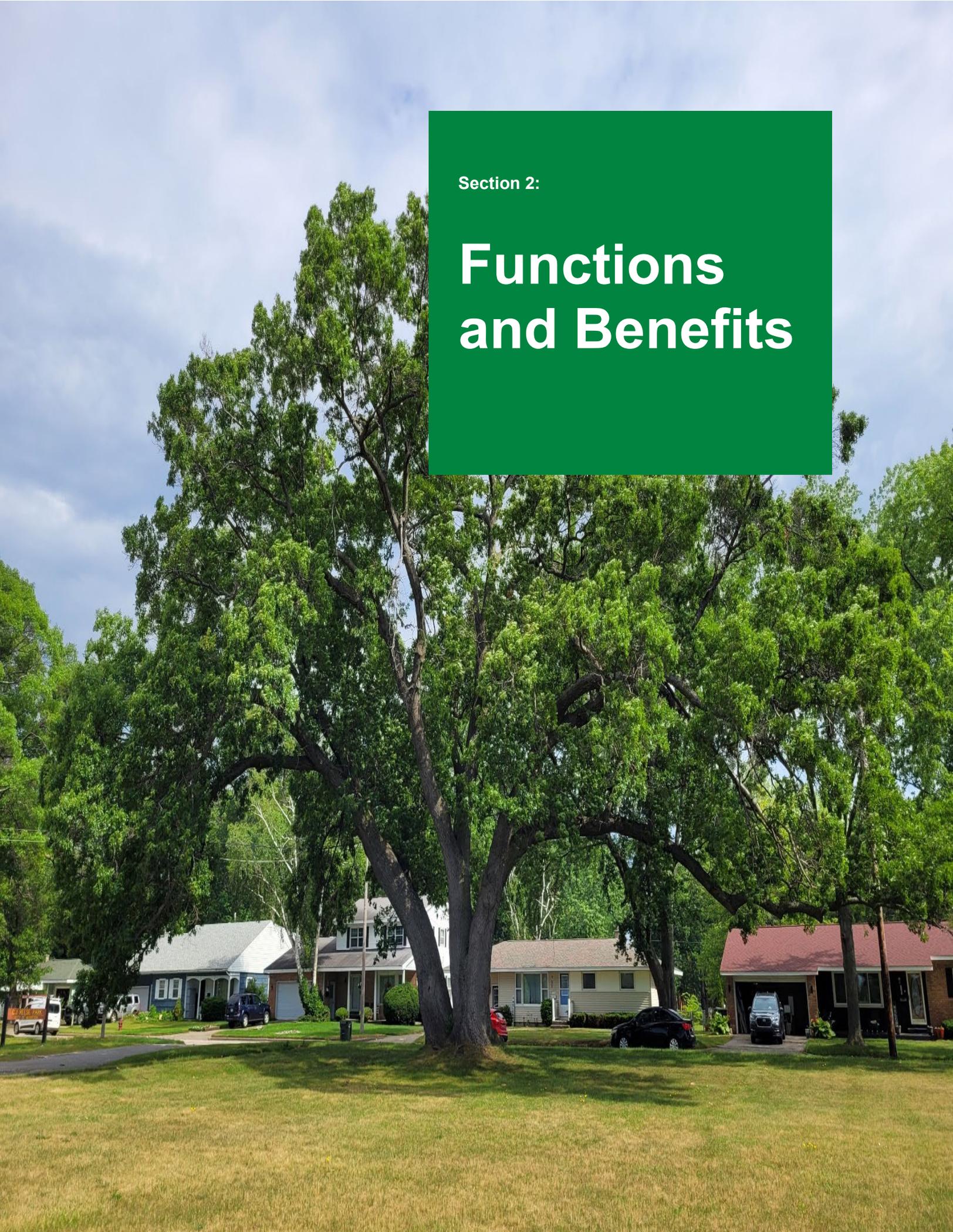
Medium trees - 6 feet x 6 feet

Large trees - 8 feet x 8 feet

- Alternatives to small growspaces:
  - Enlarge planting wells, or site them on the back edge of the sidewalk adjacent to lawns
  - Create new wells, lawns, and/or traffic bump-outs.
  - Silva Cell/ structural soil technology.
- If possible, reroute sidewalks or build temporary ramps over tree roots. Sidewalk repairs may require tree and stump removal.
- City streetscapes must balance needs for driving, parking, pedestrian access, overhead and underground utilities, street furniture, signage, lighting, winter snow removal, and many other considerations. Some areas will not be suitable for trees, and alternatives to street planting should be used in these areas instead of planting street trees.

Section 2:

# Functions and Benefits



# Section 2: Functions and Benefits

Trees play a vital role in the environment by providing a wide array of economic, environmental, and social benefits which far exceed the investments in planting, maintaining, and removing them. Trees reduce air pollution, improve public health outcomes, reduce stormwater runoff, sequester and store carbon, reduce energy use, and increase property value, among other benefits.

## Environmental Benefits

Trees decrease energy consumption and moderate local climates by providing shade, cooling through their transpiration processes, and acting as windbreaks.

Trees act as mini reservoirs, helping to slow and reduce the amount of stormwater runoff and pollutants that reaches storm drains, rivers, and lakes by 60% (Johnson et al. 2017).

Trees reduce greenhouse gasses that can trap and retain heat in the atmosphere and cause the city to get warmer.

Trees can reduce street level air pollution by up to 60% (Coder 1996).

Trees stabilize soil and provide a habitat for wildlife.

## Improved Public Health

Trees have been shown to prevent 1,200 heat-related deaths each year in the US (McDonald et al. 2020).

By intercepting particulate matter, trees save over 850 lives and prevent 670,000 incidents of acute respiratory symptoms in the US each year (Nowak et al. 2014).

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 1986).

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

## Increased Safety & Community

Treelined streets slow traffic and are safer for drivers, pedestrians, and cyclists (Swift et al. 1997, Ewing & Dumbaugh 2009).

A 10% increase in neighborhood tree canopy cover has been associated with a 15% reduction in violent and property crimes (Gilstead et al. 2015, O'Neil 2012).

## Economic Benefits

Properly placing three trees around a home can reduce energy costs for the average household by \$100 to \$250 per year, while shading air conditioning units can help them run up to 10% more efficiently (U.S. Department of Energy, n.d.).

Trees in a yard or neighborhood increase residential property values by an average of 10% (USDA Forest Service 2011), and commercial property rental rates are 7% higher when trees are on the property (Wolf 2007).

Shoppers spend more time and money in shopping districts with mature, healthy tree canopies, and are willing to spend 12% more at businesses with trees in front of them (Wolf 2005, Hughes 2013).

# I-TREE RESULTS

DRG used Tree Eco, a tool within the Tree suite, to model benefits provided by Muskegon's inventoried sites. iTree Eco combines tree inventory data with local air pollution and weather data to quantify the environmental benefits of a community's trees (Table 4). By framing trees and their benefits as dollars saved per year, iTree models can help communities understand trees as both a natural resource and an economic investment. Understanding the composition, function, and economic value of trees is essential for making informed planning and management decisions. This knowledge helps to better understand how trees affect human health and environmental quality and empower Muskegon to advocate for their urban forest.

Table 4. Summary of benefits provided by the most common inventoried trees.

Species	Count	Percent Of Total	Carbon Storage (Ton)	Carbon Sequestered (Ton/Yr)	Runoff Avoided (Gal)	Air Pollution Removed (Lb/Yr)	Replacement Value (\$)
Red maple	1,479	10.43%	1,480.78	34.52	266,201.69	0.74	4,965,630.95
Norway maple	1,393	9.82%	1,079.12	23.92	170,481.86	0.47	4,430,524.15
Silver maple	1,257	8.86%	2,267.62	28.12	364,668.61	1.01	5,267,110.56
Freeman maple	1,218	8.59%	1,578.62	25.31	322,176.29	0.89	4,822,340.24
Northern red oak	986	6.95%	3,039.60	30.01	228,640.35	0.63	10,618,320.19
Black oak	717	5.06%	3,616.24	28.08	176,454.41	0.49	9,751,590.11
Siberian elm	509	3.59%	697.92	11.77	70,521.02	0.20	1,194,781.41
Apple spp	442	3.12%	43.51	1.50	6,281.48	0.02	195,436.84
Sugar maple	425	3.00%	829.80	7.55	94,069.85	0.26	2,664,225.69
Callery pear	398	2.81%	76.21	2.76	17,396.92	0.05	341,975.31
Thornless honeylocust	367	2.59%	165.39	3.57	28,175.93	0.08	719,993.43

# ANNUAL BENEFITS

The iTree Eco model estimates the annual value of three environmental benefits: carbon sequestration, air pollution removed, and stormwater runoff reduced. The model also calculates the lifetime carbon storage of inventoried trees as well as their replacement value. The inventoried trees in Muskegon provide over \$212,600 of air quality, stormwater management, and carbon sequestration benefits each year.

Different tree species provide varying levels of benefits.

Table 5 summarizes the key tree species that contribute the most to Muskegon's annual benefits based on the results of the Tree Eco analysis of the public tree inventory. Spruce, pine and fir provide extra benefits because they are evergreen (they keep their leaves in the winter). Beech and oak are also contributors to the annual quantifiable benefits within the public tree resource.

Table 5. The inventoried species which provide the greatest annual benefit per tree.

Species	Annual Benefits Per Tree(\$)
Norway spruce	51.15
Scots pine	39.99
Beech spp	37.39
Red pine	34.08
Pin oak	31.89
Japanese black pine	30.99
Austrian pine	28.82
Eastern white pine	27.76
Black oak	25.72
Douglas fir	25.03

## IMPROVING AIR QUALITY

Trees and other vegetation improve air quality by intercepting and filtering particulate matter from the air, including dust, ash, pollen, and smoke. Their leaves also absorb harmful gaseous pollutants like ozone, nitrogen dioxide, and sulfur dioxide; and reduce ozone formation by shading surfaces and reducing air temperatures. Since airborne pollutants can have serious effects on human health, this benefit is extremely important, especially in heavily developed areas. 34.6% of Muskegon's annual public tree benefits are associated with air pollution removal derived from the air pollutant removal.

The inventoried trees in Muskegon remove 16,000 pounds of airborne pollutants each year; a service valued at \$73,580 (Table 4).

Total Estimated Ecological Benefits

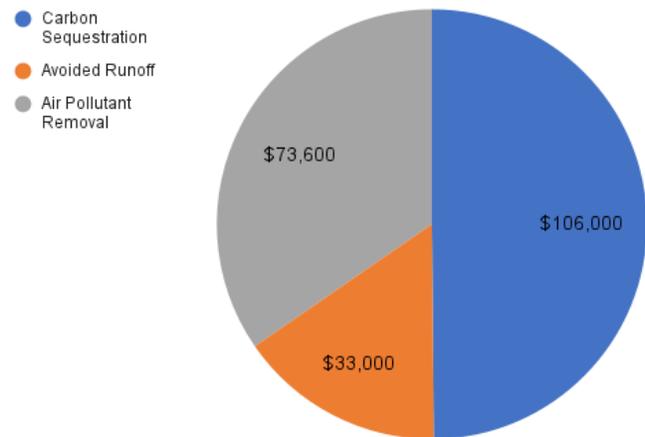


Figure 9 – Total estimated ecoBenefits provided by Muskegon's urban forest.

# SEQUESTERING AND STORING CARBON

Trees are carbon sinks, which means they absorb carbon from the atmosphere the opposite of carbon sources which produce and emit carbon into the atmosphere. While carbon is released from fossil fuel consuming vehicles and smokestacks, it is absorbed by trees during photosynthesis and stored in their tissue as they grow. Muskegon's Urban Forest has stored an estimated total of 18,999 tons of carbon to date, valued at \$8.22 million. Annually, Muskegon's public trees sequester (absorb) an estimated 244 tons of carbon each year, valued at \$5605.

# CONTROLLING STORMWATER

Trees play a significant role in local hydrology and water cycling, helping to reduce the amount of stormwater runoff during rain events (Figure 10). Since stormwater runoff can cause infrastructure damage and flooding, reducing the amount of precipitation that becomes surface runoff can save a community costs in infrastructure repair and flood mitigation. The inventoried trees in Muskegon divert 3,723,647 gallons of stormwater each year valued at \$3,275 (Table 4).

# REPLACEMENT VALUE

Replacement value is the approximate cost to replace an existing tree with a tree of a similar size and species. Doing this is not always reasonable. For example, we would not replace a 20-inch diameter tree with another tree of similar size, but replacement value can give us an idea of the overall value of trees in Muskegon.

In total, Muskegon's inventoried trees have a replacement value of \$60.7 million. Table 6 compares trees with the highest overall replacement values. Pin oak, black oak, red oak, and white oak are the most valuable trees in Muskegon.

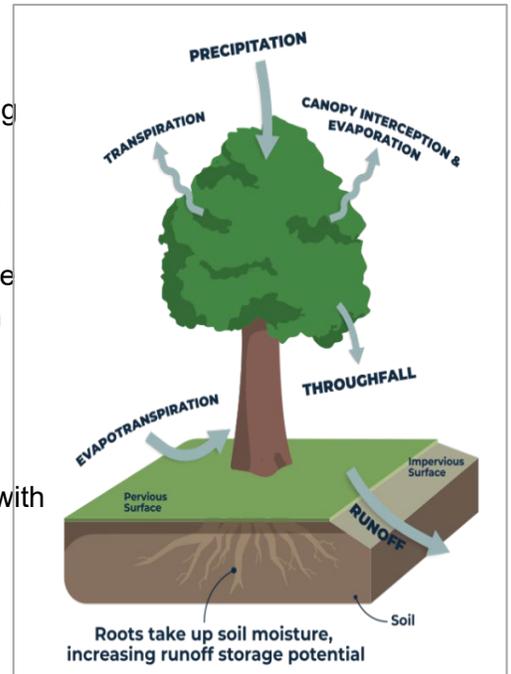


Figure 10 - Hydrological functions of trees. Source: 'Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management', EPA publication 841 B 13 001.

Table 6. Tree species in Muskegon with the highest replacement value.

Species	Count	Total Value (\$/Yr)	Value Per Tree (\$/Tree/Yr)
Northern pin oak	58	830505.25	14319.06
Black oak	717	9751590.11	13600.54
Shumard oak	190	2272527.09	11960.67
White oak	285	3151866.71	11059.18
Northern red oak	986	10618320.19	10769.09

## TREE BENEFIT RECOMMENDATIONS

- Large-stature, deciduous trees tend to provide the greatest benefits. Muskegon should plant these types of trees wherever possible to increase the biological benefits to the city.
- Enlarge existing planting spaces & create new planting spaces to accommodate large trees.
- Preserve and protect existing large-stature trees
- Structurally prune and maintain young trees to ensure they become established
- Oak was among the largest contributors to tree benefits, but they are overabundant in Muskegon. Planting oak is not recommended.
  - Protect against Oak wilt wherever possible.
- The public trees account for only a fraction of the total tree benefits in Muskegon.
  - Private trees also provide benefits. Preserve existing trees and promote new tree plantings on private property throughout the city to increase the associated eco-benefits.



Section 3:

# Recommended Maintenance

# Section 3: Recommended Maintenance

This five-year maintenance schedule takes a multifaceted and proactive approach to managing Muskegon's urban forest. We assigned risk ratings and maintenance activities to each inventoried tree. We recommend prioritizing and completing recommended maintenance activities based on risk rating. In this way, trees with elevated risks will receive attention first.



# RISK MANAGEMENT AND RECOMMENDED MAINTENANCE

Every tree, regardless of condition, poses a risk to people and property. DRG arborists considered species and their failure profiles during collection because some species are more prone to certain failure types. We assessed risk based on the most severe and/or most likely mode of failure. In other words, we considered the likelihood of failure, likelihood of target impact, and consequences of impact over the inspection period. Then we recorded the risk rating for the most severe failure and impact scenario.

Inspection period: 12 months (one year)

Modes of failure:

- Deciduous trees – Partial (branch) failure is more likely.
- Evergreen trees – Whole tree failure (WTF) and branch failure are equally likely.

This inventory included Level 2 risk assessments to assign risk ratings to each site based on:

- ANSI A300 (Clause 13)
- ISA Best Management Practices: Tree Risk Assessment.

We recommend scheduling tree maintenance based on risk ratings.

1. High-Risk pruning & removals (first)
2. Moderate-Risk pruning & removals
3. Low-Risk pruning & removals
4. Discretionary maintenance (Routine / Proactive Pruning Cycles, Young Tree Training programs)
5. Further inspections & inventory updates (last)

The following sections describe the recommended maintenance activities for each risk rating category.

## PRIORITY MAINTENANCE (PRUNING & REMOVAL)

### 1. PRIORITY MAINTENANCE NEEDS – HIGH-RISK PRUNING & REMOVALS

Addressing Extreme and High-Risk trees in a timely manner will mitigate risk, improve public safety, maximize tree benefits, and reduce long-term costs (Figures 11 & 12). We recommend removal when pruning will not correct the tree's defects, will not eliminate the risks caused by the defects, or when pruning is cost prohibitive. In general, Extreme and High-Risk maintenance activities should be completed first for larger diameter trees, as they can cause the most damage. Once we address the high-risk sites, we may move on to maintenance activities for smaller diameter trees.

The inventory identified:

- Zero (0) Extreme Risk trees.
- 22 High-risk trees are recommended for pruning (Figure 11).
- 25 High-Risk trees recommended for removal (Figure 12).

## PRIORITY MAINTENANCE RECOMMENDATIONS

- Prune High-Risk rated trees: we recommend pruning these trees immediately, largest trees first.

Remove High-Risk trees, largest first (they could cause the most damage).

Perform High-Risk pruning and removals together for maximum efficiency.

## 2. MODERATE-RISK PRUNING & REMOVALS

During the inventory, we identified and recommended:

- 1647 Moderate Risk trees for pruning.
- 787 Moderate Risk trees for removal.
- 574 Low Risk trees for removal.

Pruning and/or removing Moderate and Low Risk trees are the next priorities for maintenance activities.

Address moderate and low risk maintenance when removing adjacent higher risk trees. In this way, we would **schedule work based on location (a specific street or neighborhood)**.

Prune Low risk rated trees with routinely scheduled pruning cycles. After completing the list of elevated risk tree work, implement proactive tree maintenance programs incrementally over time to accommodate the needs of young and established trees, as well.

Low Risk removals pose little threat; these trees are generally small, dead, invasive, or poorly formed. Healthy trees growing in poor locations or undesirable species are also included in this category. Eliminating these trees will reduce breeding locations for insects and diseases and increase aesthetics in Muskegon.

Some large trees received Low risk ratings. This occurs if they are in poor condition and have uncorrectable defects, but we do not expect them to fail over the next year. Trees in parks pose low risk to people and property due to low occupancy rates in the target impact zone (Appendix C).

## MODERATE AND LOW RISK PRUNING & REMOVAL RECOMMENDATIONS

- Prune and remove Moderate-Risk trees after High-Risk maintenance needs.
- Prune and remove Low-Risk trees after all higher risk maintenance needs.
  - Start with mature trees (DBH greater than 25") with low-risk ratings.
  - Perform Low-Risk pruning and removals concurrently with routine pruning (see below).
  - Schedule work by location (specific streets or neighborhoods) for maximum efficiency.

## Muskegon's Recommended Priority Pruning

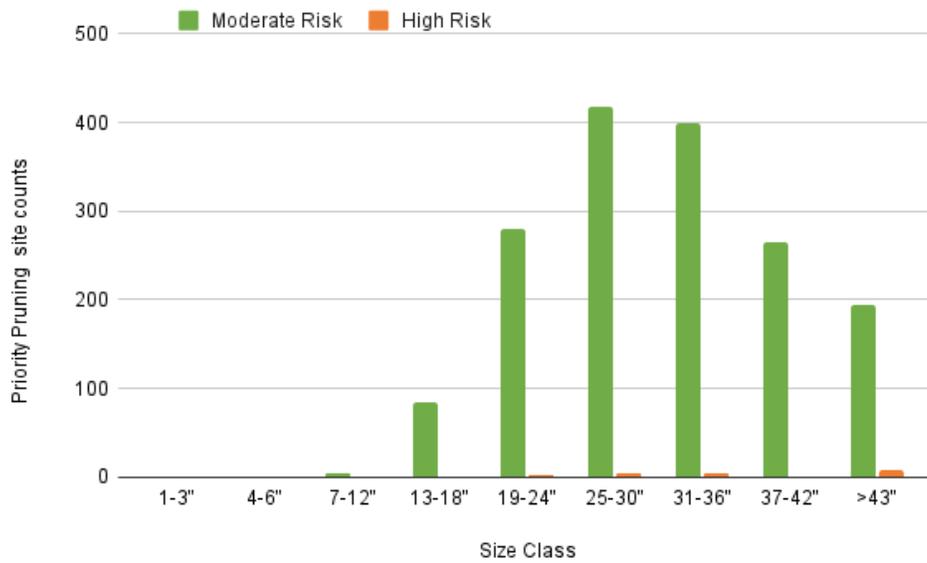


Figure 11. Priority pruning recommendations

## Muskegon's Recommended Tree Removals

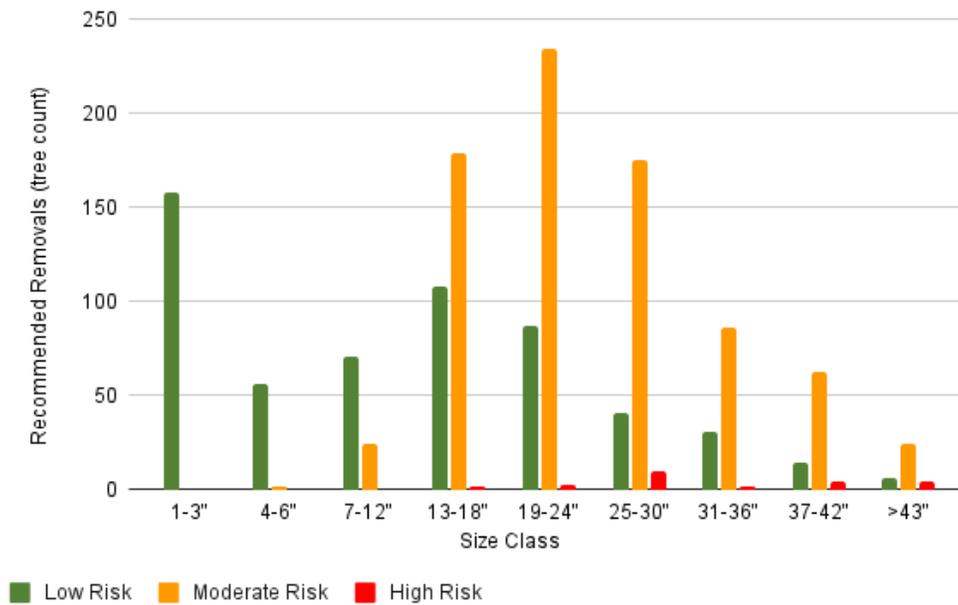


Figure 12. Removal recommendations.

# ROUTINE PRUNING CYCLE (RPC): PROACTIVE PRUNING + DISCRETIONARY MAINTENANCE

This section includes 8617 trees for a Routine Pruning Cycle (RPC)

- 1335 Low-Risk trees with a primary maintenance need of ‘prune,’ and,
- 7282 trees assigned ‘discretionary’ (routine) maintenance. OPTIONAL

These trees pose some risk but have a smaller defect size and/or a lower probability of impacting a target. So, they do not require priority maintenance. Over time, routine pruning can minimize reactive maintenance, limit instances of elevated risk, and provide the basis for a robust risk management program.

We recommend Muskegon follow a ten-year RPC (see side panel, “Proactive Pruning”) to maintain its urban forest. This is not always possible based on budgetary constraints, the size of the inventoried tree population, or both. In these cases, extending the length of the routine pruning cycle is an option; however, best practice is to not exceed a 10-year pruning cycle. Tree conditions have been shown to deteriorate significantly after 10 years without regular pruning because as defects worsen, they reduce tree health and increase risk.

## ROUTINE PRUNING CYCLE (RPC) RECOMMENDATIONS

- **The ten-year cycle outlined here includes 875 trees annually for pruning.**
- Perform regular inventory updates. This can help direct RPC planning by identifying trees, streets or neighborhoods with greater maintenance needs.
  - Inventory updates can find trees to include in the RPC.
  - Plantings and removals will also change RPC tree counts.
- After pruning High- and Moderate-Risk trees, add them to the RPC or Inventory Update schedules.

### PROACTIVE PRUNING

Relationship between tree condition and years since previous pruning.  
Adapted from Miller and Sylvester 1981

Miller and Sylvester studied the pruning frequency of 40,000 street trees in Milwaukee, Wisconsin.

Trees that had not been pruned for more than 10 years had an average condition rating 10% lower than trees that had been pruned in the previous several years. Their research suggests that a five-year pruning cycle is optimal for urban trees.

Routine pruning cycles help detect and correct most defects before they reach higher risk levels. DRG recommends that pruning cycles begin after all Extreme and High-risk tree maintenance has been completed.

DRG recommends two pruning cycles: a young tree training cycle and a routine pruning cycle.

Newly planted trees will enter the young tree training cycle once they become established and will move into the routine pruning cycle when they reach maturity. A tree should be removed and eliminated from the routine pruning cycle when it outlives its usefulness.

- When trees outgrow the YTT cycle, add them to the RPC.
- Not every tree will need pruning each cycle, so the actual cost to maintain a routine pruning cycle may be lower than projected (Table 7).
- Extend the RPC time frame to decrease annual costs. Keep RPCs on a 2-year cycle or less.

Low risk pruning & Routine pruning in Muskegon

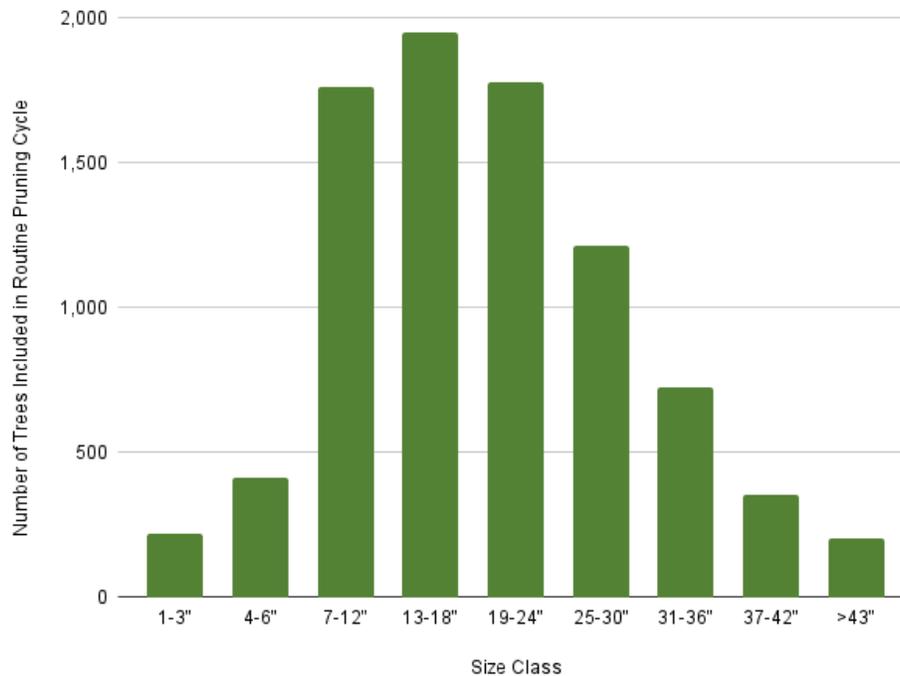


Figure 13. Trees to include in Muskegon’s routine pruning cycle

## YOUNG TREE TRAINING (YTT) CYCLE

We recommend young tree training (YTT) cycles to improve the form and structure of young trees that are less than 8 inches in diameter. Not all trees less than 8" in DBH need a structural prune. Neither do we train small variety trees (less than 20' tall when mature). Training prunes removed defects like codominant leaders, weak branch unions, and crossing or interfering limbs. If not corrected, these issues can lead to problems as the tree ages. We did not assign training prunes to evergreen trees (pine, spruce, fir).

Young trees grow at a rapid rate, so we must be proactive in the first few years of their lives to reduce future risks and avoid costly pruning when the tree is larger.

We identified 2565 trees in Muskegon to include in a young tree training cycle.

## YOUNG TREE TRAINING (YTT) CYCLE RECOMMENDATIONS

Begin a three-year YTT cycle after the completion of all recommended higher priority work.

With 2565 young trees recommended training prunes:

- **YTT 855 trees annually during a three-year cycle.**

Over time, the number of trees in the YTT cycle will depend on the number of new trees planted and their growth rates. One to two years after planting new trees, start YTT programs and return every three years until the tree can no longer be safely pruned from the ground with a pole pruner shears.

- At the time of planting, prune new trees minimally to remove broken or crossing branches.

Not every tree in the YTT cycle will need pruning each cycle so Muskegon will likely spend less than projected over the course of the YTT program shown in Table 7.

## ROUTINE INSPECTIONS, INVENTORY UPDATES & FURTHER INSPECTIONS

Regular inspections are essential practices to incorporate into proactive urban forest management programs. They should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees. Ideally, the arborist will be Certified by the International Society of Arboriculture (ISA Certified) and hold the ISA Tree Risk Assessment Qualification (TRAQ). Level 1 and 2 assessments can be completed during regular tree maintenance activities, such as routine pruning. Consider this to streamline the process and reduce workload and costs. When trees need additional maintenance, add them to the work schedule immediately. Use asset management software such as TreeKeeper® to update inventory data and schedule work records.

### ROUTINE INSPECTIONS & INVENTORY UPDATE RECOMMENDATIONS

Regularly monitor public trees to proactively maintain the urban forest. Reactive inspections are also important, especially after storms. The likelihood of tree failure increases with storm severity and frequency.

- Level 1 walk-by or drive-by assessments can be a cost-effective way to inspect trees after storm events and can help identify trees which need more detailed inspections (Level 2 or 3).

When trees require additional or new work, add them to the maintenance schedule. Update the budget to include the new work. We recommend using asset management software like TreeKeeper® to make updates, edits, and keep a log of work records.

Routinely complete **inventory updates every 5 to 10 years** These include **Level 2 risk assessments**.

- Inspect 1/10 of public trees each year to keep costs regular. With 12,852 sites not recommended for removal, **we included 1285 site inspections annually over a 10-year inventory update cycle. Prioritize sites identified for further inspections (see below).**

## FURTHER INSPECTIONS

This data field indicates when a tree needs additional assessment or monitoring. We identified these trees with defects that might escalate over the next year, becoming risky to people or property. **Further inspections included 783 trees** in the following categories:

- Annual inspections (periodic/yearly): 755 trees
  - At the time of inspection, we identified trees with defects or conditions that do not warrant removal this year, but we expect their health to decline. Inspect or maintain these trees yearly to maintain acceptable risk levels.
- Recent damage inspection: 8 trees (post-storm inspections, like annual inspections)
- Insect and disease monitoring. 20 trees (check for signs of emerald ash borer (EAB), oak wilt)

## FURTHER INSPECTION RECOMMENDATIONS

- 20 sites identified for Insect/disease monitoring - confirm the presence of damaging insects or diseases and determine the best course of action. Check trees in surrounding areas, as well.
- 8 sites identified for Recent damage inspection – annually monitor tree conditions and look for signs of worsening defects that may merit intervention.
- 755 trees identified for Annual inspections – monitor their defects and conditions yearly until they must be removed.

# TREE PLANTING & STUMP REMOVAL

Planting trees is an important part of maintaining and growing Muskegon's tree canopy and maximizing the ecological benefits provided to the community. Opportunity exists in suitable vacant street sites and sites with stumps, as well as in parks and private property.

We did not collect planting sites during the inventory.

198 stumps were identified throughout Muskegon.

## TREE PLANTING & STUMP REMOVAL RECOMMENDATIONS

- Include stump removal in maintenance contracts. Conduct Quality assurance and control checks of contractors' work to ensure stumps are completely removed.
- Remove stumps before planting new trees. Avoid planting trees in a location where a stump was recently removed, when possible. Decomposing roots can cause air pockets, nutrient depletion, and space constraints that can impact the establishment of newly planted trees.
- Strive to plant the largest possible tree in each vacant planting site. Large-stature, deciduous trees provide the greatest benefits to the community. See the strategies for providing sufficient growing space outlined in the Growing Space Recommendations section.

- To avoid loss of public trees, Muskegon should aim for, at minimum, a 1-for-1 replacement rate of planted trees to removed trees. Ideally, the community will surpass this and establish a 2-for-1 or even a 3-for-1 replacement rate, which will ultimately help to increase the community's public trees.
  - This is not always reasonable. Muskegon responded to the Urban Forestry Questionnaire with an annual planting budget of \$25k. The sample 5-year budget table reflects this in years 3 through 5 (table 7).
- Select species to plant based on their tolerance to heat, drought, salt, and climate change, among other factors, like the size and function of the growing space.
- Where planting space along streets is limited and traditional street tree planting is not possible, consider alternative options to create more space for trees:
  - Create pocket parks.
  - Improve / maintain existing public properties.
  - Set-back planting programs: plant behind, but within 20 feet of the public ROW.
  - Encourage tree planting on private property via education, giveaways, etc.
- Where possible, Muskegon should enlarge and improve planting areas along streets by:
  - Enlarging the dimensions and soil volume of planting strips and planting wells.
  - Considering use of structural soils or Silva Cells to improve root movement through soils and reduce infrastructure conflicts.
  - Work with other city departments, such as engineering, to ensure that plans for new development or street improvement consider trees during the design process.
- Seek out / apply for grant funding for tree planting projects. Significant funding is available at the state and federal level, particularly for planting projects within Environmental Justice areas. These are areas with low Tree-Equity scores.
- Build relationships with local organizations who can help promote and support tree planting goals.

## MAINTENANCE STRATEGY AND EXAMPLE BUDGET

Using Muskegon's tree inventory data, we provide an example 5-year maintenance schedule and budget. Below you will find recommended tasks to complete each year (Table 7). We base budget projections on Muskegon's current tree care contract rates, city staff costs, industry knowledge, and public bid tabulations. Following this or a similar schedule can help shift Muskegon toward a more proactive tree-care approach.

To implement this schedule, Muskegon's tree maintenance budget should be:

- No less than \$625,000 for the first year of implementation.
- No less than \$550,000 for the second year.
- No less than \$475,000 for the third year.
- No less than \$425,000 for the fourth year.
- No less than \$350,000 for the fifth year.

In the budget table and maintenance schedule (table 7), we address High-Risk rated trees in the first year and we highly recommend this approach. After high-risk trees we spread stump removals and Moderate-Risk pruning and removals across years one to four. These costs decrease annually.

Replacement tree plantings in years one and two exceed Muskegon's budget for tree planting. So, in years one and two, the total expected costs would surpass Muskegon's overall tree care budget because we followed a 1:1 tree replacement to removal ratio. During years 3-5, we limited tree planting to 50 trees per year, which would keep costs within Muskegon's annual tree planting budget (\$25k).

This schedule also outlines a 10-year routine pruning cycle (RPC) beginning in year two. The RPC includes

- 875 trees for pruning annually, with constant costs throughout the 10-year cycle.

The young tree training (YTT) program begins in the first year and keeps constant costs across all five years. YTT program costs will change based on tree plantings and removals in previous years.

Further inspection needs and inventory updates begin in year one, with 800 walk-by assessments scheduled annually. These inventory updates are optional but recommended. Choose drive-by inspections to reduce these costs but be aware that drive-by inspections are less thorough and may miss moderate-risk defects (Appendix C).

Modify this maintenance schedule accordingly if resources are available to complete more tree work each year. If maintenance needs change, then adjust budgets, staffing, and equipment to meet the new demand.

Table 7. Example maintenance schedule and budget for a five-year tree management program.

Diameter at Breast Height (DBH in Inches)	Cost / Tree	Year 1 Count	Year 1 Cost	Year 2 Count	Year 2 Cost	Year 3 Count	Year 3 Cost	Year 4 Count	Year 4 Cost	Year 5 Count	Year 5 Cost	Total accumulated costs (over five-years)	Total activity count (over five-years)
1-3"	\$28		\$-		\$-		\$-		\$-		\$-	\$-	<b>High Priority Removals</b>
4-6"	\$58		\$-		\$-		\$-		\$-		\$-	\$-	
7-12"	\$138		\$-		\$-		\$-		\$-		\$-	\$-	
13-18"	\$314	2	\$628		\$-		\$-		\$-		\$-	\$628	
19-24"	\$605	3	\$1,815		\$-		\$-		\$-		\$-	\$1,815	
25-30"	\$825	10	\$8,250		\$-		\$-		\$-		\$-	\$8,250	
31-36"	\$1,045	2	\$2,090		\$-		\$-		\$-		\$-	\$2,090	
37-42"	\$1,485	4	\$5,940		\$-		\$-		\$-		\$-	\$5,940	
>43"	\$2,035	4	\$8,140		\$-		\$-		\$-		\$-	\$8,140	
<b>High Priority Removals</b>		<b>25</b>	<b>\$26,863</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>\$26,863</b>	<b>25</b>
1-3"	\$28		\$-		\$-		\$-		\$-		\$-	\$-	<b>Moderate Priority Removals</b>
4-6"	\$58		\$-		\$-		\$-		\$-	2	\$116	\$116	
7-12"	\$138		\$-		\$-		\$-		\$-	24	\$3,312	\$3,312	
13-18"	\$314		\$-		\$-	104	\$32,656	25	\$7,850	50	\$15,700	\$56,206	
19-24"	\$605		\$-		\$-	134	\$81,070	100	\$60,500		\$-	\$141,570	
25-30"	\$825		\$-	125	\$103,125	50	\$41,250		\$-		\$-	\$144,375	
31-36"	\$1,045	36	\$37,620	50	\$52,250		\$-		\$-		\$-	\$89,870	
37-42"	\$1,485	63	\$93,555		\$-		\$-		\$-		\$-	\$93,555	
>43"	\$2,035	24	\$48,840		\$-		\$-		\$-		\$-	\$48,840	
<b>Moderate Priority Removals</b>		<b>123</b>	<b>\$180,015</b>	<b>175</b>	<b>\$155,375</b>	<b>288</b>	<b>\$154,976</b>	<b>125</b>	<b>\$68,350</b>	<b>76</b>	<b>\$19,128</b>	<b>\$577,844</b>	<b>787</b>
1-3"	\$28		\$-		\$-		\$-		\$-		\$-	\$-	<b>Low Priority Removals</b>
4-6"	\$58		\$-		\$-		\$-		\$-		\$-	\$-	
7-12"	\$138		\$-		\$-		\$-		\$-		\$-	\$-	
13-18"	\$314		\$-		\$-		\$-		\$-		\$-	\$-	
19-24"	\$605		\$-		\$-		\$-		\$-	10	\$6,050	\$6,050	
25-30"	\$825		\$-		\$-		\$-		\$-	10	\$8,250	\$8,250	
31-36"	\$1,045		\$-		\$-		\$-	30	\$31,350	10	\$10,450	\$41,800	
37-42"	\$1,485		\$-		\$-		\$-	14	\$20,790	10	\$14,850	\$35,640	
>43"	\$2,035		\$-		\$-		\$-	6	\$12,210	10	\$20,350	\$32,560	
<b>Low Priority Removals</b>		<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>50</b>	<b>\$64,350</b>	<b>50</b>	<b>\$59,950</b>	<b>\$124,300</b>	<b>100</b>

1-3"	\$18		\$-		\$-		¢		¢	0	¢	\$-	
4-6"	\$28		\$-		\$-		¢		¢	0	¢	\$-	
7-12"	\$44		\$-	24	\$1,056		¢		¢	0	¢	\$1,056	
13-18"	\$72		\$-	31	\$2,232		¢		¢	0	¢	\$2,232	
19-24"	\$94		\$-	47	\$4,418		¢		¢	0	¢	\$4,418	
25-30"	\$110	38	\$4,180		\$-		¢		¢	0	¢	\$4,180	
31-36"	\$138	13	\$1,794		\$-		¢		¢	0	¢	\$1,794	
37-42"	\$160	15	\$2,400		\$-		¢		¢	0	¢	\$2,400	
>43"	\$182	19	\$3,458		\$-		¢		¢	0	¢	\$3,458	<b>Stump Removals</b>
<b>Stump Removal (Totals)</b>		<b>85</b>	<b>\$11,832</b>	<b>102</b>	<b>\$7,706</b>	<b>0</b>	<b>¢</b>		<b>¢</b>	<b>0</b>	<b>¢</b>	<b>\$19,538</b>	<b>187</b>
1-3"	\$20		\$-		\$-		¢		¢		¢	\$-	
4-6"	\$30		\$-		\$-		¢		¢		¢	\$-	
7-12"	\$75		\$-		\$-		¢		¢		¢	\$-	
13-18"	\$120	1	\$120		\$-		¢		¢		¢	\$120	
19-24"	\$170	3	\$510		\$-		¢		¢		¢	\$510	
25-30"	\$225	5	\$1,125		\$-		¢		¢		¢	\$1,125	
31-36"	\$305	5	\$1,525		\$-		¢		¢		¢	\$1,525	
37-42"	\$380	1	\$380		\$-		¢		¢		¢	\$380	
>43"	\$590	7	\$4,130		\$-		¢		¢		¢	\$4,130	<b>High Priority Pruning</b>
<b>High Priority pruning (Totals)</b>		<b>22</b>	<b>\$7,790</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>¢</b>	<b>0</b>	<b>¢</b>	<b>0</b>	<b>¢</b>	<b>\$7,790</b>	<b>22</b>
1-3"	\$20		\$-		\$-		¢		¢		¢	\$-	
4-6"	\$30		\$-		\$-		¢		¢		¢	\$-	
7-12"	\$75		\$-		\$-		¢		¢	5	\$375	\$375	
13-18"	\$120		\$-		\$-		¢	85	\$10,200		¢	\$10,200	
19-24"	\$170		\$-	129	\$21,930	50	\$8,500	100	\$17,000		¢	\$47,430	
25-30"	\$225	18	\$4,050	200	\$45,000	200	\$45,000		\$-		¢	\$94,050	
31-36"	\$305	400	\$122,000	0	\$-		¢		¢		¢	\$122,000	
37-42"	\$380	265	\$100,700		\$-		¢		¢		¢	\$100,700	<b>Moderate Priority Pruning</b>
>43"	\$590	194	\$114,460		\$-		¢		¢		¢	\$114,460	
<b>Moderate priority pruning (totals)</b>		<b>877</b>	<b>\$341,210</b>	<b>329</b>	<b>\$66,930</b>	<b>250</b>	<b>\$53,500</b>	<b>185</b>	<b>\$27,200</b>	<b>5</b>	<b>\$375</b>	<b>\$489,215</b>	<b>1646</b>

Drive-by	\$1		\$-		\$-		\$-		\$-		\$-	\$-	Further Inspections & Inventory Updates
Walkby	\$5	1285	\$6,425	1285	\$6,425	1285	\$6,425	1285	\$6,425	1285	\$6,425	\$32,125	
<b>Further Inspections &amp; Inventory Updates (Totals)</b>		<b>1285</b>	<b>\$6,425</b>	<b>\$32,125</b>	<b>6425</b>								
1-3"	\$20		\$-	500	\$10,000	500	\$10,000	500	\$10,000	500	\$10,000	\$40,000	Young Tree Training (3-year Cycle)
4-6"	\$30		\$-	300	\$9,000	300	\$9,000	300	\$9,000	300	\$9,000	\$36,000	
>6"	\$40		\$-	50	\$2,000	50	\$2,000	50	\$2,000	50	\$2,000	\$8,000	
<b>YTT Cycle Totals</b>		<b>0</b>	<b>\$-</b>	<b>850</b>	<b>\$21,000</b>	<b>850</b>	<b>\$21,000</b>	<b>850</b>	<b>\$21,000</b>	<b>850</b>	<b>\$21,000</b>	<b>\$84,000</b>	
1-3"	\$20		\$-		\$-		\$-		\$-		\$-	\$-	Routine Pruning Cycle (RPC;10-years)
4-6"	\$30		\$-		\$-		\$-		\$-		\$-	\$-	
7-12"	\$75		\$-	125	\$9,375	125	\$9,375	125	\$9,375	125	\$9,375	\$37,500	
13-18"	\$120		\$-	125	\$15,000	125	\$15,000	125	\$15,000	125	\$15,000	\$60,000	
19-24"	\$170		\$-	125	\$21,250	125	\$21,250	125	\$21,250	125	\$21,250	\$85,000	
25-30"	\$225		\$-	125	\$28,125	125	\$28,125	125	\$28,125	125	\$28,125	\$112,500	
31-36"	\$305		\$-	125	\$38,125	125	\$38,125	125	\$38,125	125	\$38,125	\$152,500	
37-42"	\$380		\$-	125	\$47,500	125	\$47,500	125	\$47,500	125	\$47,500	\$190,000	
>43"	\$590		\$-	125	\$73,750	125	\$73,750	125	\$73,750	125	\$73,750	\$295,000	
<b>RPC totals</b>		<b>0</b>	<b>\$-</b>	<b>875</b>	<b>\$233,125</b>	<b>875</b>	<b>\$233,125</b>	<b>875</b>	<b>\$233,125</b>	<b>875</b>	<b>\$233,125</b>	<b>\$932,500</b>	
Purchasing	\$250	148	\$37,000	175	\$43,750		\$-		\$-			\$80,750	Tree Replacement & Maintenance
Planting & watering	\$200	148	\$29,600	175	\$35,000		\$-		-			\$64,600	
Mulching	\$25	148	\$3,700	175	\$4,375		\$-		\$-			\$8,075	
<b>Replacement tree (totals)</b>	<b>\$475</b>	<b>148</b>	<b>\$70,300</b>	<b>175</b>	<b>\$83,125</b>		<b>\$-</b>		<b>\$-</b>		<b>\$-</b>	<b>\$153,425</b>	
Purchasing	\$250		\$-		\$-	50	\$12,500	50	\$12,500	50	\$12,500	\$37,500	New Tree Planting & Maintenance
Planting & Watering	\$200		\$-		\$-	50	\$10,000	50	\$10,000	50	\$10,000	\$30,000	
Mulching	\$25		\$-		\$-	50	\$1,250	50	\$1,250	50	\$1,250	\$3,750	
<b>New tree plantings (totals)</b>	<b>\$475</b>	<b>0</b>	<b>\$-</b>	<b>0</b>	<b>\$-</b>	<b>50</b>	<b>\$23,750</b>	<b>50</b>	<b>\$23,750</b>	<b>50</b>	<b>\$23,750</b>	<b>\$71,250</b>	
Tree Removal	\$314		\$-		\$-	4	\$1,256	5	\$1,570	6	\$1,884	\$4,710	Tree Mortality Activities
Stump Removal	\$72		\$-		\$-	4	\$288	5	\$360	6	\$432	\$1,080	
Replacement Tree	\$475		\$-		\$-	4	\$1,900	5	\$2,375	6	\$2,850	\$7,125	
<b>Naturally expected tree mortality (1%)</b>	<b>\$861</b>		<b>\$-</b>		<b>\$-</b>	<b>4</b>	<b>\$3,444</b>	<b>5</b>	<b>\$4,305</b>	<b>6</b>	<b>\$5,166</b>	<b>\$12,915</b>	
<b>Sum of all Activities(s)</b>		<b>2565</b>	<b>\$644,435</b>	<b>3791</b>	<b>\$573,686</b>	<b>3602</b>	<b>\$496,220</b>	<b>3425</b>	<b>\$448,505</b>	<b>3197</b>	<b>\$368,919</b>	<b>\$2,531,765</b>	<b>16590</b>

# Conclusion

When properly cared for, public trees offer valuable, enduring benefits that surpass the investments of time and resources put into their planting, maintenance, and eventual removal. **Muskegon's 14183 trees generate at least \$212,000 annually in estimated benefits, including stormwater reduction, carbon sequestration, and air pollution removal. It is important to note that these are just the quantifiable benefits provided by trees in the community.** The complete array of benefits from Muskegon's public trees extends far beyond what we can calculate through inventory data and Tree modeling alone. The successful execution of this five-year maintenance program should increase the ecological benefits provided to the community and decrease the associated tree risks in Muskegon.

This five-year maintenance initiative focuses on proactive tree care and involves a large initial investment. Addressing High- and Moderate Risk trees through removal or pruning is costly, but it is vital for public safety and reducing long-term maintenance expenses. After finishing priority work, we can extend the time frame for the remaining tasks depending on funding and resource availability. We encourage Muskegon to use the Tree Inventory Analysis & Maintenance Strategy to advocate for the community and increase funding and public interest for the urban forest.

We commend Muskegon's effort toward cultivating a sustainable and resilient urban forest. Use this document as a guide to set goals, assess progress, regularly update inventory data, and revise objectives as needed. The Urban Forest Program Continuum shown on Page 2, can serve as a valuable roadmap for Muskegon as it continues its ongoing mission to improve tree care policies and procedures. This mission will enrich the lives of all residents, workers, and recreational enthusiasts within Muskegon. Thank you all for the opportunity to work with you.

## EVALUATING AND UPDATING THIS PLAN

This *Tree Inventory Analysis & Maintenance Strategy* provides management ideas for the next five years. To ensure the maintenance schedule and budget remain accurate, it is important to update the inventory using TreeKeeper® or other asset management software as work is completed, so the software can provide updated species distribution, maintenance needs, and benefit estimates.

Keeping the inventory up to date empowers the community. The adaptive management cycle (above) shows how Muskegon might update their goals over time.



Consider these activities for the above flow chart

- Schedule and assign high-priority tree work as soon as possible.
  - Slow reactions to low priority work requests.
- Prepare tree planting plans as soon as possible.
  - Schedule and complete stump removals.
  - Select species that are best suited to the available sites.
- Annually compare the number of trees planted to the number of trees removed.
  - Annually compare the species distribution with the previous year after planting.
  - Monitor changes in species and genera abundance.
  - Check for gaps in canopies and other potential planting sites.
  - Adjusting future planting plans accordingly.
- Regularly update inventory data during other maintenance activities.
  - Good practice is to update a tree's DBH, condition, and maintenance need every time we work on a public tree.

# References

- Coder, K. D. (1996). Identified Benefits of Community Trees and Forests. University of Georgia Cooperative Extension Service: Forest Resources Unit. Publication FC-96  
<https://nfs.unl.edu/documents/communityforestry/coderbenefitsofcommtrees.pdf>
- Ewing, R. and Dumbaugh, E. (2009). The built environment and traffic safety: a review of empirical evidence. *Journal of Planning Literature*, 23(4), 346-357.
- Gilstad-Hayden, K., Wallace, L.R., Carr-Saunders, A., et al. (2015). Greater Tree Canopy Cover Is Associated with Lower Rates of Both Violent and Property Crime in New Haven, CT. *Landscape and Urban Planning*, 143, 248-253. <https://doi.org/10.1016/j.landurbplan.2015.08.005>.
- Hughes, N. (2013). Trees Mean Business. Invest From the Ground Up, California Urban Forests Council. <https://investfromthegroundup.org/treesmean-business/>
- Johnson, Z. S., Koski, T., and O'Conner, A. (2017). The hidden value of landscapes. [http://webdoc.agsci.colostate.edu/hortla/Colorado\\_Water\\_2017.pdf](http://webdoc.agsci.colostate.edu/hortla/Colorado_Water_2017.pdf)
- McDonald, R.I., Kroeger, T., Zhang, P. et al. (2020). The Value of US Urban Tree Cover for Reducing Heat Related Health Impacts and Electricity Consumption. *Ecosystems*, 23, 1507-1537. <https://doi.org/10.1007/s10024-019-003955>
- McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., & Xiao, Q. (2005). Municipal forest benefits and costs in five U.S. cities. *Journal of Forestry*. 103(8): 411-416.
- Miller, R. W., & Sylvester, W.A. (1981). An Economic Evaluation of the Pruning cycle. *Journal of Arboriculture*, 7(4), 109-112.
- Nowak, D.J., Hirabayashi, S., Bodine, A., and Greenfield, E. (2014). Tree and Forest Effects on Air Quality and Human Health in the United States. *Environmental Pollution*, 193, 1129-1149. <https://doi.org/10.1016/j.envpol.2014.05.028>.
- Richards, N. A. (1983). Diversity and Stability in a Street Tree Population. *Urban Ecology*, 7(2), 115-119
- Santamour, F.S. (1990). Trees for Urban Planting: Diversity Uniformity, and Common Sense. U.S. National Arboretum: Agricultural Research Service. [https://pdfs.semanticscholar.org/26a2/4c5361ce6d6e618a9fa307c4a34a3169e309.pdf?\\_ga=2.266051527.959145428.1587418895.1587418895.1587418896](https://pdfs.semanticscholar.org/26a2/4c5361ce6d6e618a9fa307c4a34a3169e309.pdf?_ga=2.266051527.959145428.1587418895.1587418895.1587418896)
- Swift, P., Painter, D., and Goldstein, M. (1997). Residential street typology and injury accident frequency. Swift and Associates.
- Troy, A., Grove, M., and O'Neill, J. (2012). The relationship between tree canopy and crime rates across an urban-rural gradient in the greater Baltimore region. *Landscape and Urban Planning*, 106, 262-270.

- Ulrich, R.S. (1984). View through Window May Influence Recovery from Surgery. *Science*, ~~202~~202, 420  
<https://pdfs.semanticscholar.org/43df/b42bc2f7b212eb288d2e7be289d251f15bfd.pdf>
- Ulrich, R.S. (1986). Human Responses to Vegetation and Landscapes. *Landscape and Urban Planning*, 13, 29-44.
- Ulrich R.S., R.F. Simmons, B.D. Losito, E. Fiority, M.A. Miles, & M. Zeison. (1991). Stress Recovery During Exposure to Natural and Urban Environments. *Journal of Environmental Psychology*, 11(3), 301
- United States Census Bureau. 2020. Quick Facts: Fall River city, Massachusetts. Retrieved from <https://www.census.gov/quickfacts/fallrivercitymassachusetts>.
- USDA Forest Service. (2011). Trees pay us back in the Inland Empire Region.  
[https://www.fs.fed.us/psw/topics/urban\\_forestry/products/18/804uesd\\_uep\\_tpub\\_InlandEmpire.pdf](https://www.fs.fed.us/psw/topics/urban_forestry/products/18/804uesd_uep_tpub_InlandEmpire.pdf)
- USDA Animal and Plant Health Inspection Service. (2020). Pest Tracker.  
<https://www.aphis.usda.gov/aphis/resources/pestdiseases/hungrypests/PestTracker>
- US Department of Energy. (n.d.) Low Income Community Energy Solutions.  
<https://www.energy.gov/eere/slsc/lowincome-community-energy-solutions>
- Wolf, K. L. (1998). Trees in Business Districts: Positive Effects on Consumer Behavior! University of Washington: College of Forest Resources Human Dimensions of the Urban Forest Fact Sheet #5.  
<https://www.naturewithin.info/CityBiz/Biz3PsFS5.pdf>
- Wolf, K. L. (1999). Grow for the Gold: Trees in Business Districts. Washington State DNR: Community Forestry Program Number 14. <https://www.naturewithin.info/CityBiz/TreeLink.PDF>
- Wolf, K.L. (2005). Business district streetscapes, trees, and consumer response. *Journal of Forestry*, 103(8), 396-400. [https://nacto.org/docs/usdg/city\\_trees\\_retail\\_wolf.pdf](https://nacto.org/docs/usdg/city_trees_retail_wolf.pdf)
- Wolf, K. L. (2007). City trees and property values. *Arborist news*, 16(4), 34

# Appendix A

## Summary of Recommendations

Section	Recommendation
<p><b>Species &amp; Genus Diversity</b></p>	<p>Avoid or limit planting of Maple and Oak. Increase planting of uncommon species and genera which are performing well in Muskegon. This list is not exhaustive.</p> <ul style="list-style-type: none"> <li>• Shade trees to plant:               <ul style="list-style-type: none"> <li>○ Hybrid elms (<i>Ulmus</i> x)</li> <li>○ Honey locust (<i>Gleditsia tricanthos v inermis</i>)</li> <li>○ Sycamore or planetree (<i>Platanus</i> species)</li> <li>○ Linden (<i>Tilia cordata</i> or <i>Tilia americana</i>)</li> <li>○ Ginkgo (<i>Ginkgo ginkgo</i>)</li> <li>○ Catalpa (<i>Catalpa speciosa</i>)</li> <li>○ Hackberry (<i>Celtis occidentalis</i>)</li> <li>○ Coffee tree (<i>Gymnocladus dioica</i>)</li> </ul> </li> <li>• Ornamental, flowering, or fruit trees:               <ul style="list-style-type: none"> <li>○ Apple (<i>Malus</i> species)</li> <li>○ Cherry (<i>Prunus</i> species)</li> <li>○ Redbud (<i>Cercis canadensis</i>)</li> <li>○ Serviceberry (<i>Amelanchier</i> species)</li> </ul> </li> <li>• Large trees are not always good street trees.</li> <li>• Remove volunteer trees that have invasive tendencies while they are small. These include:               <ul style="list-style-type: none"> <li>○ White mulberry (<i>Morus alba</i>)</li> <li>○ Tree of heaven (<i>Ailanthus altissima</i>)</li> <li>○ Buckthorn (<i>Rhamnus</i>)</li> </ul> </li> </ul>
<p><b>Pest Susceptibility</b></p>	<ul style="list-style-type: none"> <li>• Monitor trees for signs and symptoms of pests and diseases on a regular basis. Include pest-monitoring activities as part of other routine maintenance, like pruning.</li> <li>• Identify any pests present and begin management at the earliest possible signs of an infestation.</li> <li>• Prepare an invasive species management plan to guide responses to future pest issues.</li> <li>• Spotted lanternflies use many species as a host, but they prefer Tree of heaven. Consider eliminating Tree of heaven populations to reduce Muskegon’s risk to Spotted lanternfly.</li> <li>• When planting trees, select pest- or disease-resistant species or cultivars whenever possible.</li> </ul> <p>Use preventative pesticide treatments on high-value or historic trees that are susceptible to problematic pests and/or diseases in Muskegon’</p> <p>Search for additional resources about pests and diseases from the following agencies:</p> <ul style="list-style-type: none"> <li>• Michigan Department of Natural Resources</li> <li>• Michigan Department of Agriculture and Rural Development (MDARD)</li> <li>• United States Department of Agriculture (USDA)</li> <li>• Michigan State University Extension Office</li> </ul>

Section	Recommendation
<b>Condition</b>	<ul style="list-style-type: none"> <li>• Dead and dying trees should be removed as soon as possible in order of priority (high to lowest risk) to eliminate public hazards, create space for new planting, and improve the aesthetics in Muskegon.</li> <li>• Monitor Poor condition trees that are not recommended for removal. After Pruning hazardous parts, check the tree's health periodically.</li> <li>• Condition ratings can improve over time with proactive maintenance schedules: <ul style="list-style-type: none"> <li>○ Routine pruning cycles (RPC)</li> <li>○ Young tree training cycles (YTT)</li> </ul> </li> </ul> <p>All tree pruning should follow ANSI A300 (Clause 5) guidelines.</p>
<b>Relative Age Distribution</b>	<ul style="list-style-type: none"> <li>• Muskegon's trees are aging. Focus on proactive care for large-stature trees, especially removals.</li> <li>• Succession planning: as we remove mature trees, we plant young trees in their place (replacement).</li> <li>• Young tree training programs - structurally prune small trees to ensure good form and improve health as they establish and mature.</li> <li>• Street planting programs can begin before removals, if schedules and resources allow.</li> <li>• Routine, proactive maintenance, such as young tree training and routine pruning, may help improve tree condition, particularly among maturing and mature trees.</li> </ul>
<b>Defect Observations</b>	<ul style="list-style-type: none"> <li>• Root, trunk and branch injury are the most common defects we noticed in Muskegon. This includes dead, dying, broken, hanging, and/or diseased branches. <ul style="list-style-type: none"> <li>○ Routine / proactive pruning will improve the health of these trees and reduce the risk associated with dying branches. Removal of dead limbs also improves the visual aesthetics of trees and may help improve public perception of Muskegon's tree care.</li> </ul> </li> </ul> <p>Structural pruning while trees are young can help improve defects like poor structure or improper pruning. See Young Tree Training for more information.</p>
<b>Infrastructure Conflicts</b>	<ul style="list-style-type: none"> <li>• Plant only small stature trees beneath or near overhead electric utilities.</li> <li>• Consider looking for dwarf cultivars of typically large-stature trees to diversify small-stature planting lists.</li> <li>• Tree roots can damage water and sewer pipes, gas lines, and electric conduit. Installing and maintaining these utilities often damages tree roots, and leads to tree failure, reduced tree vigor, and/or tree death.</li> <li>• Plant trees at least 5 feet from underground utilities to allow room for large, structural roots to develop without impacting the utility. Consult municipal engineers and/or utility companies for help.</li> <li>• Also consider conflicts with other infrastructure such as buildings, road signage, streetlights, and driveways. Muskegon should develop and document required clearance needs for different types of infrastructure.</li> </ul>

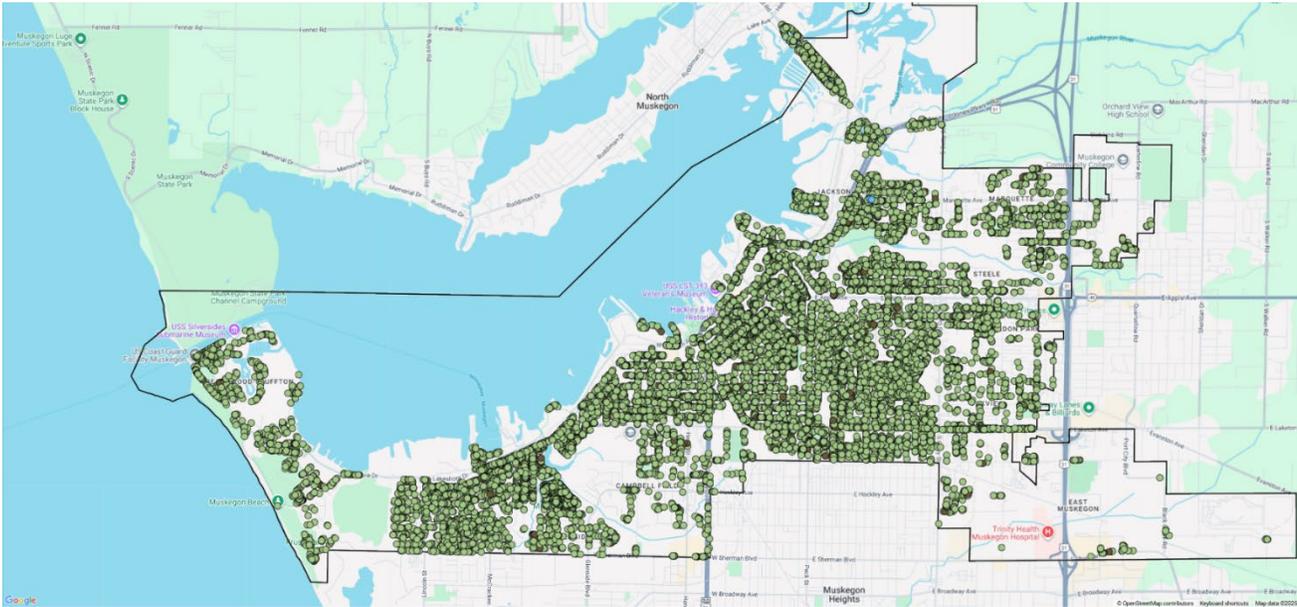
Section	Recommendation
<p><b>Growing Space</b></p>	<ul style="list-style-type: none"> <li>• Right tree, right place. Select tree species based on root system characteristics that match the planting site. Set required growing space dimensions and/or soil volumes for various sizes of trees. Planting only small trees where the growing space and/or time is restricted will help reduce damage to trees and infrastructure.</li> <li>• Develop design standards for sidewalks, roads, and other hardscapes that are tree friendly and allow a tree to grow without causing future conflicts.</li> <li>• Collaborate with city planners, engineers, and public works considering trees early when repairing or redesigning streets and sidewalks ensures trees can be a productive part of the new streetscape.</li> <li>• Alternatives to small growspaces: <ul style="list-style-type: none"> <li>○ Enlarge planting wells, or site them on the back edge of the sidewalk adjacent to lawns</li> <li>○ Create new wells, lawns, and/or traffic bump-outs.</li> <li>○ Silva Cell/ structural soil technology.</li> </ul> </li> <li>• If possible, reroute sidewalks or build temporary ramps over tree roots. Sidewalk repairs may require tree and stump removal.</li> <li>• City streetscapes must balance needs for driving, parking, pedestrian access, overhead and underground utilities, street furniture, signage, lighting, winter snow removal, and many other considerations. Some areas will not be suitable for trees, and alternatives to street planting should be used in these areas instead of planting street trees.</li> </ul>
<p><b>Tree Benefits</b></p>	<ul style="list-style-type: none"> <li>• Large-stature, deciduous trees tend to provide the greatest benefits. Muskegon should plan to plant these types of trees wherever possible to increase the ecological benefits to the city.</li> <li>• Enlarge existing planting spaces / create new planting spaces to accommodate large trees.</li> <li>• Preserve and protect existing large-stature trees.</li> <li>• Structurally prune and maintain young trees to ensure they become established.</li> <li>• Oak was among the largest contributors to tree benefits, but they are overabundant in Muskegon. Planting oak is not recommended. <ul style="list-style-type: none"> <li>○ Protect against Oak wilt wherever possible.</li> </ul> </li> <li>• The public trees account for only a fraction of the total tree benefits in Muskegon. <ul style="list-style-type: none"> <li>○ Private trees also provide benefits. Preserve existing trees and promote new tree plantings on private property throughout the city to increase the associated eco-benefits.</li> </ul> </li> </ul>
<p><b>Priority Maintenance</b></p>	<ul style="list-style-type: none"> <li>• Prune High-Risk rated trees: we recommend pruning these trees immediately, largest trees first.</li> </ul> <p>Remove High-Risk trees, largest first (they could cause the most damage).  Perform High-Risk pruning and removals together for maximum efficiency.  Prune and remove Moderate-Risk trees after High-Risk maintenance needs.  Prune and remove Low-Risk trees after all other maintenance needs.</p> <ul style="list-style-type: none"> <li>○ Start with mature trees (DBH greater than 25”).</li> <li>○ Perform Low-Risk pruning and removals concurrently with routine pruning (see below).</li> </ul> <p>Schedule work by location (specific streets or neighborhoods) for maximum efficiency.</p>

Section	Recommendation
<p><b>Routine Pruning Cycle (RPC)</b></p>	<ul style="list-style-type: none"> <li>• <b>The nine-year cycle outlined here includes 875 trees annually for pruning.</b></li> <li>• Perform regular inventory updates. This can help direct RPC planning by identifying trees, streets or neighborhoods with greater maintenance needs. <ul style="list-style-type: none"> <li>○ Inventory updates can find trees to include in the RPC.</li> <li>○ Plantings and removals will also change RPC tree counts.</li> </ul> </li> <li>• After pruning High- and Moderate-Risk trees, add them to the RPC or Inventory Update schedules.</li> <li>• When trees outgrow the YTT cycle, add them to the RPC.</li> <li>• Not every tree will need pruning each cycle, so the actual cost to maintain a routine pruning cycle may be lower than projected (Table 7).</li> <li>• Extend the RPC time frame to decrease annual costs. Keep RPCs on a ten-year cycle or less.</li> </ul>
<p><b>Young Tree Training (YTT) Cycle</b></p>	<p>Begin a three-year YTT cycle after the completion of all recommended higher priority work. With 2565 young trees recommended training prunes:</p> <ul style="list-style-type: none"> <li>• <b>YTT 855 trees annually during a three-year cycle.</b></li> </ul> <p>Over time, the number of trees in the YTT cycle will depend on the number of new trees planted and their growth rates. One to two years after planting new trees, start YTT programs and return every three years until the tree can no longer be safely pruned from the ground with a pole pruner or shears.</p> <ul style="list-style-type: none"> <li>• At the time of planting, prune new trees minimally to remove broken or crossing branches.</li> </ul> <p>Not every tree in the YTT cycle will need pruning each cycle, so Muskegon will likely spend less than projected over the course of the YTT program shown in Table 7.</p>
<p><b>Routine Inspections, Inventory Updates &amp; Further Inspections</b></p>	<p><b>Routing Inspections / Inventory Updates</b></p> <p>Regularly monitor public trees to proactively maintain the urban forest. Reactive inspections are also important, especially after storms. The likelihood of tree failure increases with storm severity and frequency.</p> <p>Level 1 walk-by or drive-by assessments can be a cost-effective way to inspect trees after storm events and can help identify trees which need more detailed inspections (Level 2 or 3).</p> <p>When trees require additional or new work, add them to the maintenance schedule. Update the budget to include the new work. We recommend using asset management software like TreeKeeper® to make updates, edits, and keep a log of work records.</p> <p>Routinely complete inventory updates every 5 to 10 years. These include Level 2 risk assessments.</p> <ul style="list-style-type: none"> <li>• Inspect 1/10 of public trees each year to keep costs regular. With 12,852 sites not recommended for removal, we included 1285 site inspections annually over a 10-year inventory update cycle. Prioritize the sites we identified for further inspections (below).</li> </ul> <p><b>Further Inspections</b></p> <ul style="list-style-type: none"> <li>• 20 sites identified for Insect/disease monitoring - confirm the presence of damaging insects or diseases and determine the best course of action. Check trees in surrounding areas, as well.</li> <li>• 8 sites identified for Recent damage inspection – annually monitor tree condition and look for signs of worsening defects that may merit intervention.</li> <li>• 755 trees identified for Annual inspections – Monitor their defects and conditions yearly until they must be removed.</li> </ul>

Section	Recommendation
<p><b>STUMPREMOVAL&amp; TREEPLANTING</b></p>	<ul style="list-style-type: none"> <li>• Include stump removal in maintenance contracts. Conduct Quality assurance and con checks of contractors' work to ensure stumps are completely removed.</li> <li>• Remove stumps before planting new trees. Avoid planting trees in a location where a stump was recently removed, when possible. Decomposing roots can cause air pocke nutrient depletion, and space constraints that can impact the establishment of newly planted trees.</li> <li>• Strive to plant the largest possible tree in each vacant planting site. <del>Large</del> <sup>Large</sup> deciduous trees provide the greatest benefits to the community. See the strategies for providing sufficient growing space outlined in the Growing Space Recommendations section.</li> <li>• To avoid loss of public trees, Muskegon's should aim for, at minimum, <del>for a 1</del> replacement rate of planted trees to removed trees. Ideally, the community will surpass this and establish a <del>2</del> <sup>2</sup>-1 or even a <del>3</del> <sup>3</sup>-1 replacement rate, which will ultimately <del>up</del> <sup>help</sup> to increase the community's public trees. <ul style="list-style-type: none"> <li>○ This is not always reasonable. Muskegon responded to the Urban Forestry Questionnaire with an annual planting budget of \$25k. The sample 5-year budget table reflects this in years 3 through 5 (table 7).</li> </ul> </li> <li>• Select species to plant based on their tolerance to heat, drought, salt, and climate change, among other factors, and the size and function of the growing space.</li> <li>• Where planting space along streets is limited and traditional street tree planting is not possible, consider alternative options to create more space for trees: <ul style="list-style-type: none"> <li>○ Create pocket parks.</li> <li>○ Improve / maintain existing public properties.</li> <li>○ Set-back planting programs: plant behind, but within 20 feet of the public ROW.</li> <li>○ Encourage tree planting on private property via education, giveaways, etc.</li> </ul> </li> <li>• Where possible, Muskegon should enlarge and improve planting areas along streets by: <ul style="list-style-type: none"> <li>○ Enlarging the dimensions and soil volume of planting strips and planting wells.</li> <li>○ Considering use of structural soils or Silva Cells to improve root movement through soils and reduce infrastructure conflicts.</li> <li>○ Work with other city departments, such as engineering, to ensure that plans for new development or street improvement consider trees during the design process.</li> </ul> </li> <li>• Seek out / apply for grant funding for tree planting projects. Significant funding is available at the state and federal level, particularly for planting projects within Environmental Justice areas. These are areas with low Tree-Equity scores.</li> </ul> <p>Build relationships with local organizations who can help promote and support tree planting goals.</p>

# Appendix B Study Area and Data Collection

## STUDY AREA



Screenshot from TreeKeeper. Green dots are trees. Brown are stumps. Blue are vacant / potential planting sites.

WMSRDC & the City of Muskegon shared boundaries and street centerlines with our GIS department. The above picture shows our proprietary GIS software, TreeKeeper. The green dots show all collected tree sites within city boundaries as specified in our initial Inventory Proposal.

Between June and August of 2025, DRG Arborists collected trees and stumps in the following areas

- Street trees – public rights of way
- Public properties
  - Parks
  - Cemeteries
  - Municipal 'No-Sell' properties
    - City hall, farmers market, fire stations

# Data Collection

DRGArborists run a customized ArcGIS program called Rover. Rover is an offline data collection software we use to record and store tree inventory data. At each site we collect the following attributes:

The screenshot shows the 'Attribute Form' interface with the following fields and values:

- Address : 1101
- Assigned Addressed :
- Street : W FOREST AVE
- OnStreet : W FOREST AVE
- Side :
- Hardscape Damage : N/A
- Overhead Utilities : Clear
- Utilities : None
- Location Name :

On the right side, the 'UniqueID' is TF20251015114308, Geometry is 0, Date and Time is 2025-10-15 11:43:08, Inspector is TF, Work Region is N/A, and Work Area is MUSKEGON.

The screenshot shows the 'Attribute Form' interface with the following fields and values:

- Species :
- Common :
- Multi Stem : No
- DBH :
- Height :
- Defects/Observations :
- Condition :
- Primary Tree Maintenance :
- Secondary Maintenance Need :
- Further Inspection : None

On the right side, the 'UniqueID' is TF20251015114308, Geometry is 0, Date and Time is 2025-10-15 11:43:08, Inspector is TF, Work Region is N/A, and Work Area is MUSKEGON.

Maintenance needs are based on Best Management Practices: Tree Risk Assessment (International Society of Arboriculture 2011). The knowledge, experience, and professional judgment of DRG's arborists ensure the high quality of inventory data.

## EQUIPMENT AND BASE MAPS

Inventory arborists use FZ-G1 Panasonic Toughbook® units with internal GPS receivers. Geographic information system (GIS) map layers are loaded onto these units to help locate sites during the inventory. Arborists use GPS location data and aerial background imagery to locate and place each site.

## ADDRESSING & SITE DATA

In addition to XY geographic coordinates for each site, we also record address information. While geographic coordinates allow spatial representation of the data within a geographic information system, parcel data with local addresses can place and/or locate sites without a GPS. Other data attributes we collect are:

- **Address:** House number Rover automatically fills in parcel addresses when available. If parcel addresses were not available we used our best judgement to assign the site a house number.
- **Suffix:** Indicates whether we manually assigned an address number to the site. We added the house number manually, this field reads "X". If the Rover assigned an address number, this field is left blank.
- **Street:** The street to which the assigned parcel is addressed. Together, the Address and Street fields form the street address of the site (e.g., 111 Example Rd). Rover assigns streets based on parcel and street centerlines included in the program.
- **On Street:** The street on which the site is physically located. Assigned by Rover.
- **Side:** Indicates on what side of the parcel a site is physically located. Assigned by the arborist, this field can read front, side, rear, median, or N/A.
  - **Front** – The site is in the front of the parcel. The Street and On Street names match.
  - **Side** – The site is on the side of the parcel. The Street and On Street names do not match.
  - **Rear** – The site is in the rear of the parcel. This occurs when a parcel occupies the full space between two roads. Street and On Street names do not match.
  - **Median** – All median sites will have Suffix = X. These are islands with traffic on either side of the growing space. Public properties may also list a site "in the median."
- **Hardscape Damage** broken or displaced sidewalks or roads that could be trip hazards.
  - Light (0.5 – 1")
  - Moderate (1-2.5")
  - Severe (>2.5")
- **Overhead utilities** : are communication or electrical lines near the site? Is the site / tree in contact with communication lines or within the Minimum Approach Distance (MAD) to electrical lines?
- **Location name:** for parks and other city-maintained properties.

# Appendix C

## Risk Assessment

Every tree, regardless of defects, condition, location, and other factors, has an inherent risk of whole or partial tree failure. Arborists perform qualitative risk assessments to determine the level of risk associated with any given tree. This allows tree managers to assign maintenance and mitigate the tree's associated risks. The current editions of the ANSI A300 (Clause 13) standards and the ISA's Best Management Practices: Tree Risk Assessment systematically outline reproducible methods for assessing tree risk.

It is possible for trees to have multiple modes of failure with varying levels of associated risk.

When this was the case, we recorded the risk rating for the mode of failure with the greatest associated risk. We performed all tree risk assessments with inspection period / time frame of one-year.

Risk ratings can help tree managers set priorities and organize tree work. Generally, we perform mitigation work on trees with higher risk ratings first. The goal is always to lower the risk and liability associated with these trees. It is up to the tree manager to decide what level of risk is acceptable, but it may change.

## Levels of Risk Assessment

Arborists assess tree risk using different tools and at different levels of detail. These are the three levels of risk assessment, from least to most intensive.

### LEVEL 1: LIMITED VISUAL ASSESSMENT

Arborists walk- or drive-by a large population of trees to identify trees of concern. Level 1 assessments do not typically result in risk ratings but provide a list of sites with recommended work. Arborists performing Level 1 assessments may request more advanced assessments (Level 2 or 3). This method may be a good option when funding for a full inventory and risk assessment is not available. Many municipalities employ level 1 assessments after major storms to rapidly assess damage and assign corrective action.

### LEVEL 2: BASIC ASSESSMENT

A detailed, 360-degree visual inspection of individual trees. Arborists assess roots, trunks, branches and site conditions of individual trees to determine tree health and assign a risk rating. We use condition and risk results to determine primary maintenance needs. DRG applies level two guidelines during most inventories like in Muskegon.



DRG arborists conducting a Level 2 risk assessment.

## LEVEL 3: ADVANCED RISK ASSESSMENT (ARA)

Arborists performing ARA's use specialized equipment to provide more detailed information about a specific tree. We use the results to inform our management decisions. Examples of ARA equipment and techniques include, but are not limited to:

- Drones or bucket trucks to inspect a canopy
- Sonic tomography to map internal decay
- Probes & microscopes for tissue extraction and analysis

## Process of Risk Assessment

Risk assessment protocols follow the current editions of *ANSI A300 (Clause 13)* and the ISA's *Best Management Practices: Tree Risk Assessment*. They are summarized below.

### TIME FRAME

All trees will experience whole or partial tree failure during their lives. Since environmental conditions and tree health can change rapidly, we must set a specific time frame for risk assessment. This is necessary to convey risk accurately and determine appropriate management practices.

Predictive power decreases over large time spans. Inspection periods vary but are generally less than five years. Inspection periods of one to three years are common.

### LIKELIHOOD OF FAILURE

The first step in assessing tree risk involves determining the likelihood that the tree or tree part will fail within the specified time frame. Site factors, such as slope, soil texture and saturation, and recent grading or tree removals are considered in tandem with tree factors such as health, species-specific failure profile, damage, and structural defects. The likelihood of failure is then characterized as either:

- **Improbable**—The tree or tree part is not likely to fail during normal weather conditions and may not fail in extreme weather conditions within the specified time frame
- **Possible**—Failure is expected in extreme weather conditions, but it is unlikely during normal weather conditions within the specified time frame, or,
- **Probable**—Failure is expected under normal weather conditions within the specified time frame

### LIKELIHOOD OF TARGET IMPACT

The next step is to determine how likely it is that the tree or tree part in question will impact a target if it fails. This involves consideration of the potential targets located around a tree, which may include fixed structures such as houses or playground equipment with a constant occupancy rate and mobile targets such as people or vehicles with lower occupancy rates, as well as an assessment of the location where the tree part may land if it fails. The likelihood of target impact is then characterized as either:

- **Very Low**—The chance of the failed tree or tree part impacting the specified target is remote.
- **Low**—There is a slight chance that the failed tree or tree part will impact the target.
- **Medium**—The failed tree or tree part could impact the target, but it is not expected to do so.
- **High**—The failed tree or tree part is likely to impact the target.

## COMBINED LIKELIHOOD OF FAILURE & TARGET IMPACT

The likelihood of failure and the likelihood of impacting a target are combined using the matrix below to determine the likelihood of failure impacting a target.

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

## CONSEQUENCE OF FAILURE & TARGET IMPACT

The consequences of a tree failing and striking a target are a function of the value of the target and the severity of damage that the failure and impact could cause. Things to consider for consequences include size of the part which may fail, the fall distance, characteristics of the target, and whether there are structures protecting the target. Consequences of failure and target impact fall into one of these categories:

- *Negligible*—Does not result in personal injury, involves low-value property damage, or disruptions that can be replaced or repaired.
- *Minor*—Involves minor personal injury, low to moderate-value property damage, or small disruption of activities.
- *Significant*—Involves substantial personal injury, property damage of moderate to high-value, or considerable disruption of activities.
- *Severe*—Involves serious personal injury, high-value property damage, or major disruption of important activities.

## RISK RATING

We combine the likelihood of failure & target impact with the consequence of failure & target impact in the matrix below to produce a risk rating. There may be multiple modes of potential tree failure and multiple targets to consider. Since each combination of failure and target will result in a different risk rating, we would use our best professional judgement to assign the most severe or most likely risk rating to the tree.

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

## RISK MITIGATION, PRIORITIZATION, AND RESIDUAL RISK

Once we assign a risk rating, we choose tree maintenance activities to reduce any associated risk. We always prioritize Extreme and High-Risk trees first, followed by Moderate Risk trees. We schedule Low Risk tree work during routine maintenance cycles when time and budgets allow.

Risk mitigation can take many forms. Common methods of mitigation include tree removal or pruning to remove hazardous parts. Other forms of mitigation may include

- cabling and bracing for weak branch unions,
- moving targets such as sheds or play equipment outside the impact zone,
- excluding targets from the impact zone using fencing or other barriers, and/or
- monitoring the tree.

Ultimately, it is up to the tree manager to decide what mitigation techniques are appropriate for each tree and what level of risk is acceptable.

Residual risk is the risk remaining after completing work on a tree. For example, a tree with a large dead limb over a busy intersection might have a High-Risk rating, but removal of that limb would mitigate the risk such that the residual risk is low. In this case, we removed the dead limb but retained the tree. In other cases, the residual risk after pruning may exceed our risk tolerance, so then we would remove the tree.