# Model Emerald Ash Borer Management Plan

***Save the best, replace the rest***

Jeffrey M. Hafner and J. Michael Orange

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Also, approximately 50 people who attended a two-hour work session during the Emerald Ash Borer Symposium held March 5 and 6, 2014 in Roseville, Minnesota vetted a draft of the original plan.


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# About the Authors

Jeffrey M. Hafner is the Director of Municipal Consulting for Rainbow Treecare where he helps municipalities manage their public trees. After a thirty-year career as a city planner and environmental manager for the City of Minneapolis, J. Michael Orange formed his own consulting company, ORANGE Environmental, LLC. He is also a member of the Minnesota Pollution Control Agency's RETAP Program (Retired Environmental Technical Assistance Program).

Both authors have been actively involved since 2013 in helping the state, region, and local governments manage the EAB infestation via science-based management strategies that are both cost-effective and environmentally sound. For example, they prepared the "Proposal to Create the Minnesota Ash Tree Preservation Program" [1] in 2014, and in 2017, the "Emerald Ash Borer Information Packet: A Novel Solution for a Disastrous Situation."[2] Section 8 Related Resources lists other analyses they have authored.

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[1] The analysis predicted the annual need for an average of $12.3 million in state support for cities over a 20-year period. It compared the costs and benefits of a no-action base case versus a science-based strategy called the Ash Tree Preservation (ATP) Program. The following figures compare the average annual benefits for every dollar of state investment in the ATP Program:

Increased property value: ........................................................ $4
Stormwater interception: ....................................... 140 gal., $5
Energy conservation: ............................................................ $4
Air quality improvement: ................................................ $0.70
$CO_2$ reduction: .................................................. 33 lbs., $0.50
Overall economic value: ..................................................... $14

[2] Available at: http://www.mnstac.org/uploads/2/0/9/3/20933948/mnstac_eab_info_packet_022417.pdf

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# Executive Summary

**The Emerald Ash Borer infestation:** A beautifully iridescent green bug that hitched a ride here from China has become the most destructive and economically costly forest pest ever to invade North America. The Emerald Ash Borer (EAB) infestation threatens every one of the billion ash trees in Minnesota, including the 3 million ash trees in our urban forests. EAB will kill every unprotected tree within 3-4 years of being infested and the infestation will kill virtually all unprotected ash trees in an area within 10-12 years in most cases.

***Save the best, replace the rest***: This slogan summarizes the best strategy for the environment and for a city's budget. The recommended pesticide to inoculate high-quality ash trees against the infestation is emamectin benzoate (not a neonicotinoid). Scientists have concluded that the potential risks of saving the best ash trees using this systemic pesticide are minor and are far outweighed by the environmental effects of instead losing these trees. According to the US Forest Service's National Tree Benefit Calculator, a healthy ash tree (12-inch diameter) provides $116 worth of benefits each year. On average, a mature, healthy ash tree can be protected for more than 20 years for the cost of removing and replacing it, plus protection preserves 3-4 times the tree benefits.

**Failed strategies from the cities first hit by the infestation:** In the years soon after EAB was discovered in North America, most communities attempted to eliminate EAB through a single strategy—eliminating the food supply by removing ash trees. It did not work, and research indicates the strategy was counterproductive.

**Herd immunity and a regional strategy:** To fight a human epidemic, a critical percentage of the population needs to be inoculated—not everyone. Similarly, with the EAB infestation, scientists have concluded there is a "herd immunity" effect with a critical percentage of treatments. Cities can help preserve their urban forest, both public and private trees, by inoculating as many high-quality city trees as possible. Studies also predicted that a regional or landscape-based management and funding strategy will more effectively control an infestation than an inconsistent, city-by-city response.

**Integrated pest management:** The good news is that scientific advances have resulted in an integrated pest management approach that includes detection techniques, pest control measures, and the protection of high value, healthy trees. The so-called SLAM (SL.ow A.sh M.ortality) study predicted that random treatment of 20% the population of ash trees annually should protect 99% of the trees after 10 years. This coordinated strategy preserves 3-4 times as much of the tree canopy and tree value over 20 years as the outdated approach, yet it costs much less and it helps protect untreated private ash trees that are nearby.

**Model EAB Management Plan:** The purpose of the Model EAB Management Plan is to describe best practices for managing the infestation The Plan is organized around seven goals, each with the accompanying best practices designed to implement them:

1. Maintain accurate assessments and records, and an updated city code.
2. Detect the infestation as early as possible and suppress the pest pressure.
3. Postpone and decrease peak ash mortality.
4. Preserve the most valuable ash trees.

5. Expand the tree canopy and improve tree diversity.
6. Minimize public costs.

**Parts of the Plan:** The first part of this plan, Sections 1 through 4, provides a summary of the characteristics of the EAB infestation and two critical peer-reviewed, scientific studies upon which this Model EAB Management Plan heavily relies. Attachment C includes more detailed summaries of these crucial analyses. Section 4 describes the goals and the specific best practices for the Model EAB Management Plan including the science that forms the bases for them. Since there is concern for any plan that calls for the introduction of additional pesticides into the environment, Section 5 addresses pesticide safety. Section 6 summarizes the findings of a regional analysis that estimates the costs, savings, and effectiveness of the integrated pest management strategy called for herein compared to a Base Case of not treating ash trees. Attachment D provides charts that illustrate these findings over the 20-year study period. Section 8 includes links to free resources to help cities manage the infestation. Attachment A lists the primary references for this report and Attachment B lists the terms used throughout. Finally, Attachment E includes additional information regarding the experience of cities first hit by the infestation

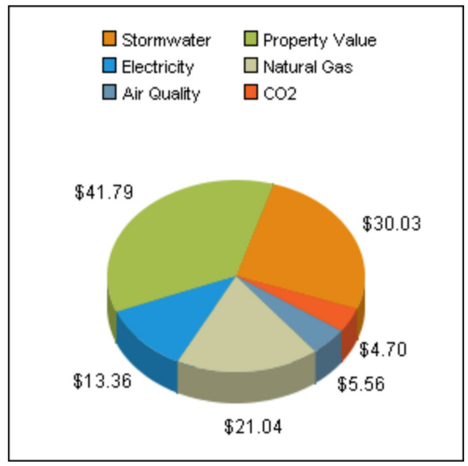
**The time to act is now:** The local government that delays action or relies on a removals-only approach will be overwhelmed with public hazard trees and probably the lawsuits that will follow. The time to act is now—before the infestation exponentially increases in population, and tree deaths escalate as seen in other cities. As the pest population increases and a greater number of trees die, the number of management options goes down

# Model Emerald Ash Borer Management Plan

A beautifully iridescent green bug that hitched a ride here from China has become the most destructive and economically costly forest pest ever to invade North America. The Emerald Ash Borer (EAB) infestation threatens every one of the billion ash trees in Minnesota, including the 3 million ash trees in our urban forests. EAB will kill every unprotected tree within 3-4 years of being infested and the infestation will kill virtually all unprotected ash trees in an area within 10-12 years in most cases.

## 1. Trees—Environmental Heroes

The Minnesota Department of Natural Resources estimates that one in five (1.7 million) urban trees in the Twin Cities metro area is ash.[3] While the aesthetic value of trees is easily grasped, scientific studies have also quantified their benefits to the environment, the economy, and to human health. When the quantifiable benefits of trees are weighed against the costs (e.g. purchase, planting, pruning, protection, and removal), the benefits outweigh the costs by a margin of about 3 to 1. According to the US Forest Service's National Tree Benefit Calculator, an average-sized, healthy, ash tree (12-inch diameter) provides $116 worth of benefits each year (see figure at right).[4]




The net cooling effect of a young, healthy tree is equivalent to 10 room-size air conditioners operating 20 hours a day.[5] One acre of urban forest absorbs 6 tons of carbon dioxide and emits 4 tons of oxygen annually.[6] Street trees even help extend the life of expensive asphalt by 40-60% by reducing daily heating and cooling of roads.[7]

Stormwater interception by trees reduces the peak-flow and flooding during intense storms, thereby reducing the amounts of pollutants that are washed into our rivers and lakes. Tree roots have a profound effect on the soil environment. They will direct 40-73% of assimilated carbon below ground,[8] and an average tree will intercept over 1,800 gallons of stormwater annually.

As regards human health, a recent analysis by the World Health Organization confirmed that air pollution is now the world's single largest environmental health risk.[9] In one study, stands of

[3] Source: "Rapid Assessment of Ash and Elm Resources in Minnesota Communities," Resource Assessment Unit, Forestry Division, Minnesota Dept. of Natural Resources, 1/12/07.
[4] National Tree Benefits Calculator for a 21-inch tree, http://www.treebenefits.com/calculator/
[5] http://www.arborday.org/trees/benefits.cfm
[6] Ibid.
[7] Source: "City to Consider Special Funding for Trees," City of Madison Wisconsin, 7/31/14, http://www.cityofmadison.com/news/city-to-consider-special-funding-for-trees
[8] Source: http://www.dailycamera.com/guest-opinions/ci_26131781/silent-environmental-devastation
[9] "7 million premature deaths annually linked to air pollution," World Health Organization press release, 3/25/14, www.who.int/mediacentre/news/releases/2014/air-pollution/en

trees reduced particulates by 9-13%, and the amount of dust reaching the ground was 27-42% less under a stand of trees than in an open area. Another recent analysis, this one prepared by U.S. Forest Service scientists and collaborators, provides the first broad-scale estimate of how trees reduce air pollution, protect our health, and reduce health care costs. The article describing the analysis quoted Michael T. Rains, Director of the Forest Service's Northern Research Station and the Forest Products Laboratory: "With more than 80 percent of Americans living in urban areas, this research underscores how truly essential urban forests are to people across the nation."[10] The study estimated that in 2010, trees in the urban areas of Minnesota removed 4,600 tons of pollutants from the air and that this resulted in $26.7 million in reduced health care costs.[11]

The above paragraph covers studies that quantify how trees benefit human health. Another study demonstrates how tree deaths from the infestation are associated with human deaths. The analysis by U.S. Forest Service scientists concluded that, "Poor air quality and stress are risk factors for [lower respiratory disease and cardiovascular disease], and trees can improve air quality and reduce stress. Results showed that the spread of EAB across 15 states was associated with an additional 15,000 deaths from cardiovascular disease and an additional 6,000 deaths from lower respiratory disease."[12]

EAB will not only kill trees, it will severely affect the budgets of local governments. The negative impacts of EAB will extend beyond budget stress to include local governmental staff currently overwhelmed by constantly having to "do more with less." The future holds even more peril considering that, over the course of this infestation, climate change effects and the costs to adapt to them will dwarf any previous challenges cities have faced. The future ability of Minnesota cities to effectively address the needs of their citizens while managing damage to infrastructure from invasive pests, an explosive increase in the number of hazard trees, and increased severe weather events is uncertain. The urban forest is one of the most valuable parts of the infrastructure of many Minnesota cities. For example, Minneapolis' urban forest has an estimated value of $756 million.[13]

## 2. The Emerald Ash Borer Infestation and the Experience of Other Cities

**2.1. Extent of the Infestation:** The Emerald Ash Borer, *Agrilus Planipennis*, is an invasive beetle from Asia that was discovered in the United States during the summer of 2002 near Detroit, Michigan. It is the most destructive and economically costly forest insect ever to invade the U.S. By 2011, it was approximately 4 times as destructive nationally as

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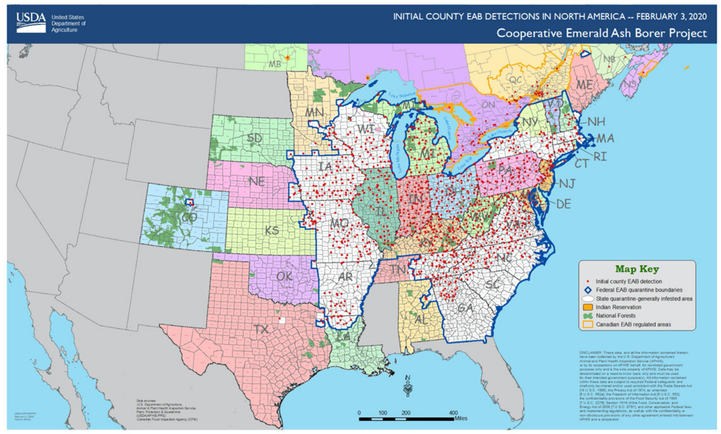
[10] "Tree and forest effects on air quality and human health in the United States," Nowak, David, et al., *Environmental Pollution*, 7/25/14, http://www.nrs.fs.fed.us/pubs/46102

[11] The health impacts and their monetary values are based on the changes in $NO_2$, $O_3$, $PM_{2.5}$ and $SO_2$ concentrations using information from the U.S. EPA Environmental Benefits Mapping and Analysis Program model (http://www.epa.gov/air/benmap/).

[12] "Exploring Connections Between Trees and Human Health," *Science Findings*, Pacific Northwest Research Station, U.S. Forest Service, Jan./Feb. 2014, http://www.fs.fed.us/pnw/sciencef/scifi158.pdf

[13] Source: http://www.americanforests.org/our-*Program*s/urbanforests/10-best-cities-for-urban-forests/10-best-cities-for-urban-forests-minneapolis/

the next two most costly pests, the Gypsy moth and the Hemlock adelgid.[14] The adult beetles ingest ash foliage but cause minimal damage. However, the larvae (during the beetle's immature stage) feed on the inner bark of ash trees and disrupt the tree's ability to transport water and nutrients. EAB may take years to build populations large enough to infest an entire tree, and low densities of EAB have little effect on the health of a tree (McCullough and Siegert 2007). However, once an ash tree is infested, it has almost zero chance of survival unless it is treated in time.




Evidence from Michigan and Ohio shows that, depending on pest pressure, EAB takes five to ten years to infest and kill the majority of the ash trees in a city. Cities infested with this devastating pest have lost tens of millions of ash trees and endured billions of dollars of losses. As of January 2019, 5 Canadian provinces and 35 states, including Minnesota,[15] have discovered the EAB and enforced quarantines.

Many Minnesota cities have an abundance of ash trees on both private and public property, including boulevards. The complete loss of these trees due to EAB would have a devastating effect on home values, quality of life, and the environment. The time to act is now.

**2.2. Life Cycle of the Beetle and the EAB Death Curve:** Recent research shows that the EAB beetle can have a one- or two-year life cycle. Adults begin emerging in mid-to-late May with peak emergence in late June. Females usually begin laying eggs about 2 weeks after emergence. Eggs hatch in 1-2 weeks, and the tiny larvae bore through the bark and into the cambium—the area between the bark and wood where nutrient levels are high. The larvae feed under the bark for several weeks, usually from late July or early August through October. Most EAB larvae overwinter in a small chamber in the outer bark or in the outer inch of wood. Pupation occurs in spring, and the new generation of adults will emerge in May or early June, to begin the cycle again.[16]

Cities that have been decimated by EAB have observed the EAB "death curve" where the rates at which infested trees die occur in two phases. EAB populations grow by a factor of 40 (or more) each year because the beetle has few natural predators and its host tree

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[14] Aukema JE, Leung B, Kovacs K, Chivers C, Britton KO, et al. (2011), "Economic Impacts of Non-Native Forest Insects in the Continental United States," *PLoS ONE*, 6(9): e24587. doi:10.1371/journal.pone.0024587, http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0024587

[15] Source: US Dept. of Agriculture, http://www.emeraldashborer.info/about-eab.php

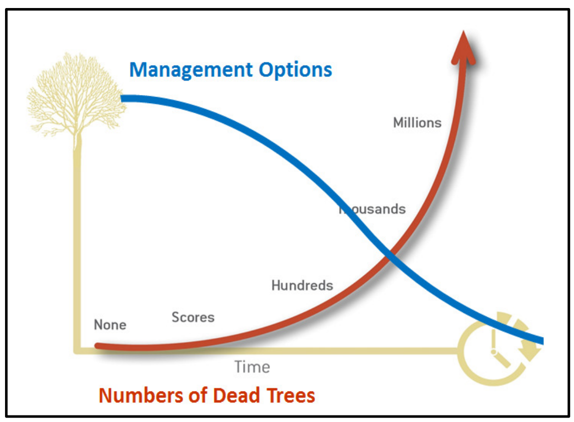
[16] Source: http://www.emeraldashborer.info/faq.cfm#sthash.Bw4elMK7.dpbs. See more at: http://www.emeraldashborer.info/faq.cfm#sthash.Bw4elMK7.dpuf

has limited natural defenses. However, healthy trees can tolerate an infestation for probably 3 to 4 years before they reach a tipping point that leads quickly to death. This results in a linear phase of the death curve where tree deaths are limited to about 1-5% a year. During the second phase of the death curve (the exponential phase), pest pressure builds, and tree deaths begin to parallel the exponential growth rate of beetle populations. Annual tree deaths can exceed 20%, and thousands of dead trees quickly overwhelm city crews, equipment needs, debris yards, and budgets. Most local governments that manage urban forests are woefully unprepared.

### 2.3. Failed Strategies From the Past:

In the years soon after EAB was discovered in North American, most communities attempted to eliminate EAB through a single strategy—eliminating the food supply. It did not work, and subsequent research determined that the strategy was counterproductive.[17] The beetles can fly up to 12 miles per year and the infestation can expand close to a mile in a year. Another strategy was to replace ash trees with different species as fast as possible. However, a 2005 study of the urban forest in Minneapolis by the US Forest Service stated, “There is a delay of 30 years until the annual benefit of a replacement tree equals that of the ash tree removed because of EAB.”[18]

The experiences of other cities and states that have already been devastated by EAB offer valuable lessons. One such lesson is from the Wisconsin Department of Natural Resources, “It will hit you like a freight train.”




Cities that have been decimated by EAB have observed the EAB “death curve” where the rates at which infested trees die occur in two phases. EAB populations grow by a factor of 40 (or more) each year because the beetle has few natural predators and its host tree has limited natural defenses. However, healthy trees can tolerate an infestation for probably 3-4 years before they reach a tipping point that leads quickly to death. This results in a linear phase of the death curve where tree deaths are limited to about 1-5% a year. During the second phase of the death curve (the exponential phase), pest pressure builds, and tree deaths begin to parallel the exponential

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[17] At the Emerald Ash Borer Symposium held March 5 and 6, 2014 in Roseville, Minnesota, Dr. Daniel Herms, Professor and Chairperson of Entomology, Ohio State University, stated that it is a myth that preemptive removal of ash trees will slow the spread of the infestation. He argued that the removal of infested trees is effective but not the removal of healthy trees because the beetles will simply fly further to find host trees. He said that this would only spread the infestation faster. “We can’t cut our way out of this.” Another presenter at the conference, Dr. John Bell, agreed and commented, “Don’t burn down the village to save it.”

[18] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S., Gardner, S., Cozad, S., et al., 2005. City of Minneapolis, Minnesota Municipal Tree Resource Analysis. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. http://www.treesearch.fs.fed.us/pubs/45984

growth rate of beetle populations (refer to above chart). Annual tree deaths can exceed 20%, and dead trees quickly overwhelm city crews, equipment needs, debris yards, and budgets. As the pest population increases and a greater number of trees die, the number of management options goes down. (Attachment E includes additional information regarding the experience of other cities first hit by the infestation).

**2.4. The Need for a Landscape-Based Management Strategy:** Trees are an integral part of the region's urban infrastructure and they should be viewed similarly to other components of our regional systems (land use, transportation, aviation, parks, and water resources). The best approach to an EAB infestation is to fight it like a human health epidemic. Just as epidemiologists cannot fight a flu epidemic city by city, EAB cannot be efficiently fought city by city. While it is not necessary for 100% of the host population to be inoculated to control an epidemic, better results are achieved by inoculating a critical percentage of all hosts susceptible to the epidemic. That critical percentage is likely to be in the range of 20% of all ash trees in an area.[19] Since the beetle will kill virtually all untreated ash trees by the tenth year of an infestation, the percentage of treated trees relative to the total surviving ash population will eventually climb to 100%.

A scientific study, called the Kovacs Study, predicted that a regional or landscape-based management and funding strategy will more effectively control an infestation than an inconsistent, city-by-city response, or no response.[20] The report states that, "enabling municipalities to aggregate their budgets greatly improves total net benefits.... In addition, aggregate budget increases the percentage of healthy trees remaining in the final period by 18%, and the total net benefits more than double." The Kovacs report states that there is little active coordination among jurisdictions. We recommend that regional or state level public authorities formulate such a strategy as soon as possible (Attachment C includes a more detailed summary of the findings of the Kovacs report).

## 3. SLAM (SL.ow A.sh M.ortality) and Herd Immunity

The good news is that university scientists have developed and refined treatment protocols that can manage the infestation more effectively and at much lower cost when compared to past strategies that relied on preemptive removals or annual treatments for high-value trees.[21] The so-called SLAM (SL.ow A.sh M.ortality) study included over 200 computer simulations based on field-derived data and a best-case scenario that was most effective at preserving ash trees at the lowest cost.[22] This recommended scenario predicted that random treatment of 20% the population of ash trees annually should protect 99% of the trees after 10 years.

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[19] Based on personal communication with Deborah G. McCullough, Ph.D., 1/17/14.

[20] Kovacs, Kent. F.; Haight, Robert G.; Mercader, Rodrigo J.; McCullough, Deborah G.; "A bioeconomic analysis of an emerald ash borer invasion of an urban forest with multiple jurisdictions." *Resource Energy Econ*. (2013), http://dx.doi.org/10.1016/j.reseneeco.2013.04.008

[21] For more information, refer to "Coalition for Urban Ash Tree Conservation," http://www.emeraldashborer.info/files/conserve_ash.pdf

[22] McCullough, Deborah G.; Mercader, Rodrigo J.; "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plani*pennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23.

This coordinated strategy preserves 3-4 times as much of the tree canopy and tree value over 20 years as the outdated approach, yet it costs much less and it helps protect untreated private ash trees that are nearby. This Model EAB Management Plan is based on this research. The SLAM analysis concluded that, "The rate at which ash tree mortality advances is related to EAB density. Therefore, an over-riding theme within the SLAM approach is to reduce … the growth of EAB populations." The SLAM study argues for an integrated pest management strategy that includes efforts to reduce pest populations by means of pesticide treatments and other strategies to preserve valuable ash tree resources. (Attachment C includes a more detailed summary of the findings of the SLAM study).

Herd immunity, also known as community immunity, is the public health phenomenon where protection from a disease for a critical percentage of the population allows protection for untreated individuals in the population. This principle occurs with a range of microscopic 'bugs,' but the same concept applies to a larger bug—the emerald ash borer. By treating a certain amount of the population of ash trees, there is a net benefit within the communities.

The Minnesota Environmental Quality Board has recently produced the *2019 Minnesota Emerald Ash Borer Report*. It includes an extensive amount of information about the infestation.[23]

## 4. The Model Emerald Ash Borer Management Plan

The purpose of the Model EAB Management Plan is to describe best practices for managing the infestation based on the most recent scientific findings. The Plan also illustrates the cost advantages of using the full complement of integrated pest management strategies at the regional as well as local jurisdictional levels. The slogan, *Save the best, replace the rest*, summarizes its core strategy for the environment and for a city's budget.

The Plan is organized around seven goals, each with the accompanying best practices designed to implement them:

1. Maintain accurate assessments and records, and an updated city code.
2. Detect the infestation as early as possible and suppress the pest pressure.
3. Postpone and decrease peak ash mortality.
4. Preserve the most valuable ash trees.
5. Expand the tree canopy and improve tree diversity.
6. Minimize public costs.
7. Enlist private ash tree owners to manage their trees consistent with the Plan.

**4.1. Goal 1—Accurate Tree Assessment and Record Keeping, and Updating the City Code:** As with all infrastructure, maintenance is essential to maximize benefits, yet many cities lack the ability to track the maintenance and replacement needs of their urban forest. The Plan links specific management strategies to categories of ash trees based on

[23] https://www.eqb.state.mn.us/EAB

their condition, value, location, and ownership. Categories include woodlands, public trees and private trees, high- and low-quality trees, and high- and low-priority areas (refer to the Definitions section for explanations of each category).[24]

**Model EAB Management Plan Best Practices:**

- **Public tree inventory:** Forest managers need a complete inventory of public trees that includes the size, species, condition, and location. This is essential for preserving this green resource and for identifying appropriate ash trees for use as detection and sink trees, for insecticide treatments, for preemptive removals, or for utilization for their wood value.

- **Private tree survey:** Management strategies of public trees can only affect a portion of total trees. Managers should obtain estimates of private trees based on surveys with a high degree of accuracy to know the extent of their influence.

- **Ash tree assessment:** If budget or time constraints prevent a comprehensive tree inventory/survey, the first priority is to assess the ash trees located in high-priority areas, which are areas either within or within clear view from public lands and rights-of-way (boulevards, front yards of public and private property, and the maintained areas of public parks and open spaces).

- **Record keeping:** The implementation of an EAB management plan should include policies of regularly updating tree inventory database to reflect tree growth, removals, and replanting.

- **Updating the city code:** The infestation will likely require updates to the city code in the following ways:

    - **Nuisance language:** Few city codes will have up-to-date language regarding nuisances. Fortunately, the Minnesota Department of Agriculture and the League of Minnesota Cities have developed a model ordinance with specific language for controlling tree nuisances.[25] The site includes specific definitions for the terms infestation and infection and are available for cities to copy and paste into their code.

    - **Upgrading landscape requirements in the zoning code:** At a time when it is important to maximize tree canopy as a major strategy to mitigate the effects of climate change, EAB will destroy thousands of trees. In order to take advantage of every opportunity to plant trees, the city can harness the power of the private sector through the development review process. The zoning code needs to incorporate all the best practices that maximize tree benefits. Numerous websites

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[24] The i-Tree website is an excellent resource: http://www.itreetools.org/index.php.

[25] "Control of Tree Infections and Infestations" and "Declared Tree Nuisances, Control Measures, and Control Areas." http://files.dnr.state.mn.us/forestry/community/shadetreepestordinance.pdf.

and other resources exist that offer state-of-the-art specifics to maximize tree canopy in development projects and parking lots.[26] The Minnesota GreenStep Cities website includes the report, "Model Landscape Ordinance for a Municipal Zoning Code," which provides code-specific language and explanations that address this and the other issues described in the following bullet points. [27]

- **On and off-site tree root protection zones:** Construction activities can damage trees in many ways even though the effects are not obvious in the short-term. For example, soil compaction from vehicles and the storage of materials can have long-term effects on a nearby tree's roots such that it loses structural stability, becomes more susceptible to disease, and its life is shortened. The same is true when a tree's roots are severed, exposed, or buried.

  Most city codes will address the primary effects of construction activities (with a focus on erosion control) including regulations to protect important trees. Best practices require landscape plans identify trees both on-site and adjacent to the site that are classified as "Significant," or "Desirable" based on generally acceptable arboriculture standards. Landscape plans should demonstrate how land-disturbing activities or permanent changes to the site would have no deleterious effect upon the tree root protection zones of important on-site and off-site trees.

- **Tree fund:** In the event site constraints prohibit the reasonable protection of on-site Significant and Desirable trees, the city could establish a tree fund and require developers to pay the equivalent costs for the city to buy, plant, and maintain trees on public or private property in the same watershed as the site.

  These changes to the city code create roles for certified arborists in the development of landscape plans. This will slightly increase the costs of development but will significantly increase the quality of the landscape plans. This will make the job of city staff and decision makers easier because complete landscape plans will take the guesswork out of this aspect of the development approval process.

- **Alternative compliance:** It is very important to provide flexibility to accommodate unique site conditions and creative landscape designs. Cases will certainly arise where site constraints make it impossible or impractical to comply with all applicable requirements and still meet reasonable tree spacing needs (such as is needed for the health of the trees or to avoid underground or overhead utilities). Without the flexibility of an alternative compliance procedure, the increased rigor that would result from the other suggested text changes might

[26] The Site Plan Review chapter of the Minneapolis Zoning Code (Chapter 530) offers an excellent example of how to maximize canopy cover through the development review process. http://library.municode.com/index.aspx?clientId=11490&stateId=23&stateName=minnesota&ds=site+plan+review

[27] The Minnesota GreenStep Cities website includes the report, "Model Landscape Ordinance for a Municipal Zoning Code" (https://greenstep.pca.state.mn.us/modelOrdinances.cfm).

discourage development or desirable landscape designs that meet the intent of the ordinances but not the letter of the law.

**4.2. Goal 2—Early Infestation Detection and Suppression:** The SLAM study emphasizes the importance of early detection and actions to confine the infestation within the lessened pest pressure stage, which is the flat part of the death curve (refer to Section 2.2). This will reduce the vulnerability of the area to an overwhelming ash mortality event. Since appropriate control strategies vary according to the intensity of the infestation, it is important to detect the presence of the infestation as soon as possible and, once detected, periodically estimate the extent and the density of the EAB population.

Rather than remove low-value trees, they can serve a vital role as "trap trees." Recent studies have shown that EAB beetles are attracted to stressed ash trees and tend to lay more eggs on stressed trees than on healthy trees.

**Model EAB Management Plan Best Practices:**

- **EAB survey:** As soon as possible after initial detection, managers should conduct delimiting surveys organized in a grid pattern. Surveys should include visual inspections as well as some amount of destructive sampling (cutting and peeling of ash trees) to confirm the presence or absence of EAB.

- **Tree girdling:** Research has shown that girdled[28] trees, especially those in sunny locations, are highly attractive to adult beetles in locations where EAB populations are relatively low. Girdled trees organized in a grid pattern are very effective for detection and assessment. The strategy of girdling trees can serve two purposes: 1) to assess beetle distribution, as well as larval density and development rates; and 2) to function as beetle population "sinks" to concentrate and eliminate adult beetles before they can disperse and reproduce.

- **Trap trees and population sinks:** Girdled trees are often referred to as "trap-trees," a technique with a long history of use in forest pest management. The following are important considerations listed in the SLAM study:

  - If trees are girdled and remain standing for more than 1 year, they will serve as beetle magnets. Since girdled trees must be removed before the next generation of adults can emerge, a large component of future adults can be eliminated.

  - If tree cutting and removal is not a viable option, then creating *lethal* trap trees should be considered (refer to discussion below).

  - Girdled trees deployed in a systematic survey grid can concurrently serve as "sinks" for the subsequent generation of EAB.

[28] Refer to the Definitions for a description of tree girdling.

- Clustering three or four girdled trees creates a more powerful attraction for EAB adults than isolated single girdled trees in areas with low-density populations.

- There is evidence to suggest that at very low EAB population levels, the location of sink trees can influence how beetles disperse. Sink trees will pull some beetles towards them as EAB adults respond to the presence of artificially damaged trees. Placing clusters of sink trees inside the core of an outbreak versus outside the outer edges could pull dispersing beetles away from the edges and potentially reduce spread rates.

- Although all native ash trees will attract EAB adults, some species are more attractive than others. If different ash species are present, select by priority, from most to least preferred: (1) green ash, (2) black ash, (3) white ash, and (4) blue ash.

- **Timing for girdled trees:** Dates for girdling trap trees or setting traps and debarking trees or retrieving traps should be based on accumulated degree days for the local area since adults predictably fly at the same time each year. Girdled trees should be felled and debarked or destroyed in the fall, winter or early spring following their establishment to ensure that larvae die before completing development.

- **Removal of infested trees:** Infested trees must be removed or treated to ensure that developing EAB progeny are not allowed to emerge. Trees with canopy loss that exceeds 50% should be removed as soon as possible because dead ash trees generally deteriorate rapidly and many will become hazardous especially along streets, in yards, and along overhead power lines. This can entail chipping, grinding, debarking, burning or other methods.[29] Removing a few key infested trees, especially if they are large and heavily infested, could remove a locally significant number of EAB adults.[30] Since trees that have been dead for more than 1 year are unlikely to harbor EAB, their removal will not result in any reduction in the number of EAB.

- **Distant infestation:** The following guidelines apply if the closest known infestation is more than 15 miles away:

  - **Woodland detection trees:** Detection trees should be girdled in the early spring in accessible areas of woodlands, ideally in a grid pattern. Focus on areas closest to the expected wave front. Let trees die in place.

  - **High-priority area detection trees:** Same as above, but only girdle low-quality trees and remove them when they risk becoming hazard trees.

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[29] For information regarding firewood, refer to the following: http://www.nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/survival_in_firewood/

[30] "EAB infested trees can produce ca. 90-100 adult EAB per square meter (8-10 EAB per square ft.) of bark surface area. A single 20-inch diameter ash tree has the potential to produce approximately 3,600-4,000 beetles before it succumbs." ("SLAM: SLow Ash Borer Mortality Pilot Project").

- **Proximate infestation:** The following guidelines apply if the infestation is within 15 miles or already within the jurisdiction:

  - **Woodland trap trees:** Girdle trap trees in the spring in accessible areas of woodlands, ideally in a grid pattern. Focus on areas closest to the wave front. Remove or process dead trees before adults can emerge in the spring.

  - **High-priority area trap trees:** Girdle low-quality trees in the spring and remove before adults can emerge in the spring.

**4.3. Goal 3—Postpone and Decrease Peak Ash Mortality:** Not all ash trees should be preserved. The Model EAB Management Plan incorporates an important strategy intended to reduce the overall intensity of the infestation, the pest pressure. Past strategies have included the removal of low-value ash trees to reduce the food supply. For ash trees in woodland areas and in low-priority areas such as backyards, a policy of "benign neglect" allows the EAB to kill the trees so the natural forest canopy can grow into the gaps. This can also reduce the current overabundance of ash in the urban forest. The problem with the "benign neglect" approach is that it allows EAB populations to increase exponentially wherever ash trees are left untreated. This increases overall pest pressure and hastens its spread.

The Model EAB Management Plan includes the following best practices intended to reduce overall pest pressure, and to postpone and decrease peak ash mortality so forest managers can proactively manage the infestation rather than simply react to overwhelming numbers of dead, often hazardous trees.

**Model EAB Management Plan Best Practices:**

- **Preemptive removals and ash utilization:** The first priority for low-quality trees in high-priority areas is for them to serve as detection/trap trees. Trees in low-priority areas can be preemptively removed for ash utilization and to reduce available phloem.[31] The removal of other trees can be staged as convenient over time.[32]

  "Data from several sites have shown that in most areas, only a small proportion of ash trees are large (e.g. > 10 inches DBH),[33] while most ash trees are relatively small (< 4 inches DBH). Large ash trees can potentially produce hundreds to thousands of EAB adults but small ash trees produce relatively few, even when the small trees are

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[31] From the SLAM study: "Sanitation to remove low vigor or hazardous ash trees can also be useful, especially in urban areas. Simply felling or removing ash trees to reduce the amount of ash phloem available for larvae, however, has the least effect on A. planipennis population growth and, if used exclusively, could increase spread rates."

[32] Ash materials generated from tree removal should be disposed according to guidelines established by USDA Animal and Plant Health Inspection Service (APHIS) (http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/quarantine.shtml) and Minnesota Department of Agriculture. A properly managed community marshaling yard can enhance the disposal process.

[33] DBH refers to diameter at breast height i.e. 4.5 feet above the ground.

abundant. Removing a few large trees can sometimes eliminate much of the available food for EAB larvae. Landowners may recognize some economic benefits by targeted harvests of large ash trees for lumber or firewood. ... Reducing ash phloem by itself is unlikely to slow spread. In some cases local EAB spread rates may increase because beetles are forced to fly further to locate a suitable host tree. An integrated approach that combines phloem reduction (e.g. removing selected trees) with insecticide treatments or girdling and sinks will be more effective than simply reducing ash phloem." ("SLAM: SLow Ash Borer Mortality Pilot Project")

According to the SLAM study, ash trees are often common along road, railroad, utility, or trail right-of-ways, and that these types of corridors "enhance EAB dispersal and spread." Therefore, they are excellent, accessible trees for preemptive removals and, if girdled, to serve as valuable sink trees.

- **Reducing pest pressure during moderate and peak periods:** As the infestation builds, it may be economically preferable to invest in reducing pest pressure near high-quality trees. Strategies include additional preemptive removals of low-quality trees (to reduce the food supply) and the use of trap trees. Lethal trap trees can be used by treating trap trees with emamectin benzoate a few weeks before girdling. However, the effectiveness of girdled trees to function as traps or sinks appears to diminish as EAB densities build in an area.[34]

  SLAM study results indicate that achieving minimum overall treatment rates in an area (10-20% of all ash trees) can significantly reduce pest pressure. However, accomplishing even these seemingly low overall rates may require some degree of public investment in the management of private trees in the early years of the infestation before the beetles kill most of the untreated ash trees.

- **When budgets restrict ideal strategies:** When cities first decide to address the infestation, city foresters are often unsure how to prioritize their efforts—remove heavily infested trees (sanitation), protect the most valuable trees even if they are already infested, or save as many valuable, healthy trees as possible. Typically, forestry budgets are inadequate for the tasks ahead, especially during the early years of the infestation when comprehensive action is most cost effective.

  A new analysis using data from the City of Burnsville provides important guidance.[35] The report classifies 3 degrees of infestation for ash trees. The *first level* is for trees with the lowest intensity of the infestation, the *second level* is a moderate degree, and a *third level* classifies trees that are infested beyond hope, doomed to die, and, thus, not eligible for treatments. The authors conclude the following (emphasis added):

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[34] For more detail, refer to McCullough, Deborah G.; Siegert, Nathan W.; *Using Girdled Trap Trees Effectively for Emerald Ash Borer Detection, Delimitation and Survey*, Dept. of Entomology and Dept. of Forestry, Michigan State University, July 2007. http://www.emeraldashborer.info/files/handoutforpdf.pdf

[35] "A Multi-Stage Stochastic Programming Approach to the Optimal Surveillance and Control of Emerald Ash Borer in Cities," Eyyüb Y. Kıbış, İ. Esra Büyüktahtakın, Robert G. Haight, Najmaddin Akhundov, Kathleen Knight, Charlie Flower (not yet published, downloaded 2/8/20, https://icerm.brown.edu/video_archive/?play=1965)

> Note that it is crucial to initially treat trees in the second infestation level followed by trees in the first infestation level because this prevents trees from transitioning into [the third infestation level] where they may have more impact on susceptible trees. Furthermore, although the third infestation level poses the highest threat to susceptible trees in the first [level], they will transition to dead trees and will no longer spread the infestation. Therefore, treating lightly infested clusters are given priority to removing highly-infested trees.
>
> Another core result is that once the actual number of trees in each infestation level is detected, the optimal decision is to treat second-level-infested trees, followed by first- and third-level infested trees. This prevents mid-level-infested trees from becoming highly infested in the following period. Results indicate that if budget is not sufficient, then decision makers may need to let some highly infested trees die in favor of treating low- and mid-level-infested trees.

- **Strategies during periods of low pest pressure:** Strategies to reduce pest pressure, such as girdling and removing trap trees, can be expensive. Since ash trees can tolerate low levels of pest pressure, the best strategy is likely to invest only in treatments of high-quality trees closest to the likely wave front and inspections.

- **Encouraging natural enemies of EAB:** The SLAM study pointed out that treatments may increase the likelihood that beetle parasites and other natural enemies (e.g. beetle eating wasps and woodpeckers) can decrease beetle densities. Woodpeckers remain the most important natural enemy of EAB larvae, but woodpecker predation is not consistent. "Attracting woodpeckers into a local area and enhancing predation of EAB larvae could help to reduce EAB densities, it can also help in locating very lightly infested trees. Potential options for increasing woodpecker predation could include providing suet to retain woodpeckers in selected sites throughout the year. Classical biological control, which involves introducing a non-native natural enemy, may eventually be a part of SLAM efforts in some sites." ("SLAM: SLow Ash Borer Mortality Pilot Project")

**4.4. Goal 4—Preserve the Most Valuable Ash Trees:** The Model EAB Management Plan recommends reliance on trunk injection of emamectin benzoate (5 ml active ingredient per DBH) every 3 years to preserve important ash trees. Section 6 includes information regarding pesticide safety.

**Model EAB Management Plan Best Practices:**

- **Insecticide treatments:** Insecticide treatments should be used for the following public trees:

- **Aggressive treatment protocol—Years 1 to 12:** Treat 100% of high-quality trees beginning with those closest to the infestation wave front, if known. (If the budget does not permit 100% protection, refer to the section above "When budgets restrict ideal strategies" to prioritize treatments.) Since trees can tolerate three or more years of low-to-moderate infestation, treat 1/3 of the trees each year to even out demands on crews, equipment, and budgets. Emamectin benzoate treatments are effective for three years or more (Herms, McCullough 2014). [36]

- **Maintenance treatment protocol—Year 13 and beyond:** Inspect 100% of high-quality trees in Year 13. Treat (and track) those trees that show 30% or greater canopy decline thereafter. Implement SLAM Study practices by randomly selecting 20% of high quality trees for treatment in Year 13. Thereafter, treat 20% of randomly selected trees that had not been treated during the prior three years. Field research and the SLAM study confirm that treatments using emamectin benzoate will keep trees completely free of pests for the first two years after the injection, and that it takes three to four years after the start of an infestation for trees to decline to the degree they show at least 30% canopy loss and require removal.

- **Staging for removal and to serve as trap trees:** For urban forests where large numbers of ash trees are likely to need removal during the peak of the EAB death curve, forest managers may wish to treat trees so that they can survive long enough to be removed after the main wave of the infestation has passed. Continued inspection can determine when canopy loss exceeds 30%, after which they can be treated again to postpone removal, or girdled to serve as trap trees and then removed the following spring.

**4.5. Goal 5—Expand Tree Canopy and Improve Tree Diversity:** The tree diversity guideline known as the "10-20-30 rule" is an arboriculture guideline to reduce the risk of catastrophic loss due to pests like EAB. Since green ash, a single species, currently accounts for 15-20% of the urban forest (while the guideline suggests no more than 10%), the inevitable loss of virtually all untreated ash trees will eliminate this overabundance, and allow replacement trees to diversify forest and urban tree resources.

**Best Practice—Tree replacement:** Establish a policy that replaces trees in high-priority areas with at least a one-to-one ratio from a diversified list of eligible trees.

**4.6. Goal 6—Minimize Public Costs:** The Model EAB Management Plan is significantly less expensive and more effective than a remove-and-replace approach; and it preserves tree canopy and tree benefits. For the cost of removing and replacing 2 average 17-inch diameter trees, 5 mature trees can be preserved with treatments for over a decade.

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[36] A recent study examined the percentage of canopy decline in treated ash trees located in the midst of an EAB infestation ("Systemic Insecticide Technology for Tree Care," by Dan Herms, Department of Entomology, Ohio State University, Ohio Agricultural Research and Development Center, Wooster, Ohio). The study found that trees treated with emamectin benzoate in 2006 (0.8 g ai / DBH) had only 5% canopy decline 3 years later in 2009.

**Model EAB Management Plan Best Practices:**

- **Budget balancing:** The following shows an approximate budgetary breakout by groups of best practices. It is intended to aid in the development of an EAB management plan for a local jurisdiction. During the implementation of the local jurisdiction's plan, allocations should be expected to vary according to conditions on the ground. The percentage breakouts do not account for the costs of inventorying and estimating tree populations.

  - Cost of detection activities and the management of pest pressure: Approximately 15% of EAB management plan budget.

  - Cost of treatments, removals, and replacements: Approximately 80% of EAB management plan budget.

  - Cost of public outreach efforts: Approximately 5% of EAB management plan budget.

- **Record keeping:** A local government's EAB management plan should include a tree inventory/survey. Proper record keeping over the course of the infestation will produce a trove of data that will be invaluable to the forest managers as well as other government officials and the scientific community as the knowledge base expands of how best to manage this infestation. It is an essential tool to battle the EAB infestation as well as future infestations and diseases. A wide variety of software programs exist for urban forest management, complete with standardized reports and the ability to customize them for EAB data recordation and evaluation. The data needed to evaluate the EAB management program include the following:

  - **For each individual high-quality ash tree on public property:** Data should include geographic location, setting (e.g. boulevard, public yard or park, etc.), condition, size, management protocol (treatment in this case), treatment data (pesticide, treatment method, date of treatment, and dosage), inspection history, date of removal.

  - **Ash trees in low-priority public areas and low-quality ash trees:** Same as above.

  - **Detection and trap trees:** Data should include geographic location, setting (e.g. boulevard, public yard or park, etc.), management protocol (e.g. girdling and removal).

  - **Costs:** All program costs must be logged and tracked.

  - **Public outreach history:** Records should include the program description, activity descriptions, and costs.

- **Program evaluation:** Careful record keeping will provide the data with which forest managers can compare the results on the ground with the predictions in the EAB management plan. For example, if the 3-year treatment protocol results in high-than-predicted canopy cover loss, the protocol should be changed to either every two years or the dosage per DBH increased. Similarly, some trees could serve as experiments in saving money by lengthening treatment periods or lowering dosages. A practice of early investments in detection and lowering pest pressure (e.g. through detection and trap trees) should be weighed against investing in treatments.

**4.7. Goal 7—Enlist Private Tree Owners:** A coordinated approach in urban areas will require a strong commitment to public outreach and education, especially in the years preceding the advent of the infestation and through its peak years.

**Model EAB Management Plan Best Practices:**

- **Education and communication:** Governments should use all communication tools available to promulgate the goals and best practices in their EAB management plans, and to ensure that the owners of private ash trees manage their trees consistent with those plans. Educational and communication tools include the governmental website, newsletters, utility billings (for cities), and press releases. Community meetings are an excellent way to collaborate with those property owners most interested in preserving their ash trees.

- **Public subsidy for private trees:** Public forest managers may decide to subsidize treatments for certain ash trees on private property in order to help suppress pest pressure and to preserve certain trees. Only high-quality trees located in high-priority areas on streets where the loss of private ash trees would have a significant effect should be eligible for public subsidy. The tree inventory specific to the jurisdiction will provide the information needed to craft definitions for eligibility that will be most effective and enforceable. Budgetary constraints will determine the percent of the treatment costs to be subsidized. The subsidy should be contingent upon the property owner complying with the best practices described herein and should end after the third treatment when the peak of the infestation should have already occurred and the wave front will have moved on by the time the trees may need another treatment.

## 5. Pesticide Safety

We recognize the increasing and well-warranted concerns regarding the overreliance on pesticides. Neonicotinoids and their effects on pollinators, such as bees, and soil-applied products that have the potential to reach stormwater or ground water have all been highly publicized.

The pesticide recommended herein, emamectin benzoate (EB), is not a neonicotinoid and is injected into the trunks of the trees. Ash trees are wind pollinated, they are not a substantial nectar source for bees, and they flower early in the growing season and only for a limited number of days. "It is highly unlikely that bees would be exposed to systemic insecticides applied to ash."[37] EB has a low toxicity rating for mammals, a low bioaccumulation potential within ecosystems, and is immobile in soil. This means that the insecticide will not build up levels within an ecosystem and will be minimally harmful to people and animals that might encounter tree debris.[38]

While there are valid concerns regarding the overuse of pesticides in our environment, those concerns should be aimed at reducing pesticide use where fewer benefits result. The environmental consequences of losing millions of ash trees are vastly greater than the minimal risk associated with inoculating high-quality ash trees to protect them from certain death. Marla Spivak, the Distinguished McKnight Professor in Entomology at the University of Minnesota, and an internationally recognized expert on bees, has said that the benefits of trunk-injected EB for ash trees outweigh the minimal potential harm to bees.[39] Dr. Deborah McCullough, a professor of entomology and forestry at Michigan State University, has stated, "There is no reason for a landscape ash tree to die from emerald ash borer anymore."[40]

## 6. Results of the Minnesota Ash Tree Preservation Analysis

We analyzed the theoretical costs and benefits assuming the entire seven-county Twin Cities region participated in a landscape-based EAB management approach. Our "Minnesota Ash Tree Preservation Analysis" includes 100% of the approximately 450,500 public ash trees that are in the region's urbanized areas.[41] The analysis compared two scenarios—a Base Case that assumed the removal of 100% of the ash trees and replacement of the 255,000 high-quality trees, and an integrated pest management approach called the Ash Tree Preservation Plan (ATP Plan). The ATP Plan scenario included pesticide treatments for the high-quality trees using trunk-injected emamectin benzoate. High-quality trees are public trees in good condition that are visible from active public areas (streets, front yards, and active areas of parks).[42]

Over the 20-year period of the infestation, the ATP Plan approach can preserve the high-quality trees at a total cumulative cost ($145 million) that is over 40% lower than the Base Case cost ($254 million) while preserving more than twice the tree canopy.[43] For every dollar of cost, the

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[37] "Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer," http://extension.entm.purdue.edu/eab/PDF/potentialSideEffectsofEABInsecticidesFAQ.pdf

[38] "Emamectin benzoate is derived from a naturally occurring soil bacterium and has been registered for more than 10 years as a foliar spray to control pests in vegetable and cotton fields and parasitic sea lice in salmon aquaculture. Similar products are used in veterinary medicine as wormers for dogs, horses, and other animals." "Insecticide concentrations that have been measured in treated trees are far below the levels known to be toxic to birds.... In Michigan and Ohio, where EAB has been established for several years, many ash trees have been treated with systemic insecticides. There have been no reported cases of woodpecker poisoning caused by insecticides applied for control of EAB." (Hahn, Herms, McCullough, 2011)

[39] At the Minnesota Shade Tree Short Course held in Arden Hills, Minnesota, March 18 and 19, 2014, Dr. Marla Spivak said that the benefits of trunk-injected emamectin benzoate outweigh potential harm to bees.

[40] "Emerald ash borer treatments costing less, working better," *Minneapolis StarTribune*, 8/8/13: http://www.startribune.com/local/south/218936301.html

[41] Excluded were trees in non-urban areas and in woodlands, and private trees.

[42] Both scenarios assumed removal without replacement of approximately 195,500 low-priority trees. Low-priority trees are those in poor condition and those in areas that are not visible from publically accessible areas.

[43] The analysis uses trunk size as a surrogate for tree canopy measurements. Trunk size is measured as *diameter at breast height* (DBH).

ATP Plan preserves approximately twice as much of the economic and environmental benefits from trees as the Base Case.

Using data from this analysis and from 17 Twin Cities suburbs, a typical city in the region is facing approximately $1.5 million in EAB management costs over the next 10 years if it relies solely on a strategy of removal and replacement of city trees (the Base Case), or an $800,000 savings if it employs the integrated pest management strategies described herein. Attachment D includes the key charts from the analysis.

## 7. Closing Comment

Acting individually, local governments can choose to manage the infestation or wait and let the beetles attack their already strained budgets. As the Minnesota Ash Tree Preservation Analysis shows, the third and best choice is a holistic, landscape-based response that is centrally managed and that will minimize costs and maximize the value of the remaining urban forest. This strategy will not only save money, it will reduce liabilities. The local government that delays action or relies on a removals-only approach will be overwhelmed with public hazard trees and probably the lawsuits that will follow. The time to act is now—before the infestation exponentially increases in population, and tree deaths escalate as seen in other cities. As the pest population increases and a greater number of trees die, the number of management options goes down (refer to the chart in Section 2.3).

## 8. Related Resources

The GreenStep Cities website includes a list of resources to help local governments manage the EAB infestation. [44] Rainbow Treecare developed the following resources that are available via the GreenStep Cities website:

- **Emerald Ash Borer Cost-Benefit & Emission Calculator:** This is a free, Excel spreadsheet model for cities. The calculator compares the approximate costs and benefits of two management strategies for the infestation over a 20-year study period. The Base Case assumes no preemptive actions are taken but city-owned trees are replaced as they succumb to the infestation. The Protection Plan assumes the removal and replacement of low-quality ash trees and the long-term protection of mature, healthy, properly located trees in order to minimize costs, minimize peak-period costs and debris management, preserve tree benefits, and enable the orderly transition to a more diversified urban forest.

- **Model Request For Proposal Components for Emerald Ash Borer Management:** This report includes components that a city can incorporate into its standard request for proposal (RFP) form to obtain private company bids for preparing an EAB management plan, and components that a city can incorporate into its standard RFP to obtain private company bids for ash tree injection services.

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[44] Refer to: https://greenstep.pca.state.mn.us/best_practice_action/build-community-capacity-protect-existing-trees-one-or-more

**Attachment A**

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**Attachment B**

# Definitions

**Agrilus *Plan*ipennis:** An exotic beetle from Asia that was discovered in the United States during the summer of 2002 near Detroit, Michigan. Emerald ash borer (EAB) (Buprestidae: *Agrilus Planipennis* Fairmaire) is an exotic pest of ash (*Fraxinus* spp.). Feeding by the larval stage of this beetle occurs in tunnels called galleries that are excavated in the inner bark and phloem. The galleries created by feeding larvae affect the ability of trees to transport food and water. Low densities of EAB have little effect on the health of a tree. However, when EAB populations increase, the canopy declines, branches die and eventually the entire tree dies. Trees ranging from 1 inch to more than 60 inches in diameter have been killed by EAB.

**Cambium:** The cambium cell layer is the growing part of the trunk. It annually produces new bark and new wood in response to hormones that pass down through the phloem with food from the leaves. Refer to the following site for a description of tree structure: http://www.arborday.org/treeGuide/anatomy.cfm

Condition rating: Condition rating refers to a system to rate the condition of trees from zero to four. A tree with a condition rating of four is the highest quality, zero is dead.

**EAB death curve:** The rates at which trees die occur in two phases: a linear phase (Years 1-4) and an exponential phase (Years 5-10).

**Emamectin benzoate:** A relatively new insecticide (sold as TREE-äge®) that can be used to protect valuable landscape ash trees from EAB. The product can be purchased and applied only by trained, certified arborists and landscapers. The product is applied as a trunk injection at the base of an ash tree. "A similar product has been used in salmon farming and in California for some fruit and vegetable crops. A related product is used in veterinary medicine." Source: http://www.emeraldashborer.info/treeage.cfm#sthash.MLsgMLtm.dpbs.

**Girdling:** "Girdling, or removing a band of bark and phloem around the trunk of a tree, interrupts the ability of the tree to transport carbohydrates—the food needed by the tree. Girdled trees become increasingly stressed over the summer. As stress increases, the chemicals emitted from the foliage, bark or wood of the tree change. The wavelengths of light reflected by the leaves (hyperspectral reflectance) also differ between healthy and girdled trees. Beetles can apparently detect these changes and are often more attracted to the stressed trees than to surrounding or nearby ash trees. ... Recent studies by MTU and MSU scientists have shown that many ash trees can survive for at least two years after girdling. Trees can be girdled in the fall, winter or spring." Source: McCullough, Deborah G.; Siegert, Nathan W.; *Using Girdled Trap Trees Effectively for Emerald Ash Borer Detection, Delimitation and Survey*, Dept. of Entomology and Dept. of Forestry, Michigan State University, July 2007. http://www.emeraldashborer.info/files/handoutforpdf.pdf

**Herd immunity:** Herd immunity (also known as community immunity) is the public health phenomenon where protection from a disease for a critical percentage of the population allows protection for untreated individuals in the population.

**High- and low-priority areas:** High-priority areas are areas either within or within clear view from public lands and rights-of-way. This includes boulevards, front yards of public and private property, and the mowed areas of public parks and open spaces. The term also applies to areas where it is especially important to preserve the environmental, economic, and aesthetic contributions from high-quality ash trees. Low-priority areas are areas that are not considered high-priority areas as regards the management of the EAB infestation.

**High-quality and low-quality trees:** High-quality trees refer to ash trees having a condition rating of 3 or greater located in high-priority areas. Low-quality trees are ash trees having a condition rating less than 3.

**Kovacs study and the landscape-based approach:** The response to the EAB infestation should be founded more on scientific conditions on the ground rather than constrained by governmental boundaries. A landscape-based focus can operate at all jurisdictional scales (state, region, city, neighborhood), and it incorporates both public and private trees (based on the Kovacs study[45]).

**Pest pressure:** The number of insects causing damage in one place at one point in time.[46]

- **Low pest pressure:** A condition in an area where beetle and larvae populations are relatively low such that the ash trees in an area can easily tolerate feeding levels and the associated phloem loss. A few trees may exhibit symptoms of infestation such as a few thinning branches but most trees appear healthy. Woodpecker holes may be present on the upper portion of the trunk or perhaps large branches on a few trees. EAB densities are low enough that most ash trees in the area will tolerate the associated phloem loss.
- **Moderate pest pressure:** A condition in an area where beetle and larvae populations are increasing. Symptoms of infestation will be apparent on several trees and a few trees may be seriously declining. Most ash trees in the area remain relatively healthy with less than 30% canopy dieback and/or thinning (transparency). If not treated with an effective pesticide, the pest pressure will continue to increase, leading to high mortality rates. If trees that remain relatively healthy (< 50% canopy dieback/thinning; little injury to the trunk) are treated with an effective product, trees should be able to recover (although dead branches will remain dead).
- **High pest pressure:** A condition in an area where beetle and larvae populations are at high densities. A few trees will be dead, a few others will be severely declining (and too injured to treat) and most others will exhibit canopy thinning and/or dieback. If not treated with an effective pesticide, most trees will die within 1-3 years. Trees that remain relatively healthy (<50% canopy decline) may recover, with the exception of the parts of the trees that suffered canopy loss.

**Phloem:** The food-conducting tissue of vascular plants, consisting of sieve tubes, fibers, parenchyma, and sclereids; also called bast.

**SLAM study:** The goal of the SLAM study was to "slow the onset and progression of ash mortality by slowing the growth of [beetle] populations."[47] The study addresses the life cycle of the EAB beetle, pest pressure, the natural ability of healthy trees to tolerate an infestation, the effectiveness of preemptive removals and chemical treatments, the importance of early detection, and the relative costs of a variety of scenarios.

**Staging for removal:** During period of high pest pressure, there will be the greatest number of ash tree deaths. Urban forest managers may wish to treat trees so that they can survive long enough to be removed after the main wave of the infestation has passed.

**Tipping point:** the point where a tipping point when beetle larvae have consumed more than 60% of the phloem and the infested tree cannot recover. This leads inevitably to the death of the tree within a year or two.

**Trap trees as population sinks:** A strategy to moderate pest pressure is to girdle low-quality trees, already infested trees, and trees in low-priority areas such as woodlands to serve as trap trees. This is

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[45] Kovacs, K.F., et al., "A bioeconomic analysis of an emerald ash borer invasion of an urban forest with multiple jurisdictions." *Resource Energy Econ*. (2013), http://dx.doi.org/10.1016/j.reseneeco.2013.04.008

[46] Definitions are based on personal communication with Deborah G. McCullough, Ph.D., 1/17/14.

[47] "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus planipennis): SLAM in an urban forest," p. 11, op. cit.

done in the fall in order to attract the adult beetles, which are especially drawn to stressed trees. The trees are felled the next spring and either processed or removed, thus killing concentrations of beetle larvae and the adults that are not yet mature enough to emerge.

**Tree diversity:** The tree diversity guideline known as the "10-20-30 rule" is an arboriculture best practice designed to reduce the risk of catastrophic loss due to pests like EAB. The guideline recommends an urban forest be made up of no more than 10 percent of any one species, 20 percent of any one genus, and 30 percent of any one family. Since ash, a single species, currently accounts for about 20% of the urban forest, a significant reduction in numbers is appropriate per this guideline.

**Woodland areas:** Areas where trees dominate and where development, mowed areas, and trails are absent or minimal. Topography and forest density makes protecting ash trees in woodlands difficult and uneconomical. However, to reduce overall citywide pest pressure, a minimum percentage of woodland trees should be girdled to act as traps and later removed and immediately processed to prevent adult beetles from dispersing. Beetles can emerge from ash logs or firewood for up to a year, and occasionally longer, after infested trees are felled. Woodland trees grow in close proximity to one another and compete for light. This competition reduces the canopy size of each tree, which makes the losses less significant to total canopy cover. Neighboring trees are positioned to quickly grow into the opened spaces created as ash trees die.

**Attachment C**

# Summaries of the Kovacs Study and the SLAM Study

## The Kovacs Study

A recent scientific study, called the Kovacs Study, predicts that a regional or landscape-based management and funding strategy will more effectively control an infestation than an inconsistent, city-by-city response, or no response (Kovacs, Haight, Mercader, McCullough, 2013). The Kovacs study was based on the then-current EAB management plans and budgets for the ash trees located within a 10-kilometer radius of where EAB was first detected in the Twin Cities, which included St. Paul, Minneapolis, and 15 nearby cities. This analysis included multiple scenarios, three of which are critical here: The base case strategy assumed no infestation management plans or budgets and an unmitigated EAB population spread over a five-year period. The second strategy assumed individual cities managed the infestation independently with the known budgets at the time of the study and included treatments for 7% of the trees. The third strategy assumed the 17 cities pooled their resources to manage the infestation on a regional scale and included treatments for 24% of the trees.

As Figure 1 shows, the removal costs ($5 million) in the base case far exceed the economic value of the remaining trees (not all of the ash trees will be dead after five years). The model returned a similar result if the cities acted independently and only treated 7% of the trees. However, when it was assumed in the third strategy that the cities pooled their resources and treated 24% of the trees in a manner that made sense for the region, the net present value of the surviving trees far exceeded the costs of removal. It is the comparison of the second and third strategies that makes this study unique. Even though both strategies assume the same amount is spent on management, the results are quite different. The report states that, "enabling municipalities to aggregate their budgets greatly improves total net benefits.... In addition, aggregate budget increases the percentage of healthy trees remaining in the final period by 18%, and the total net benefits more than double."

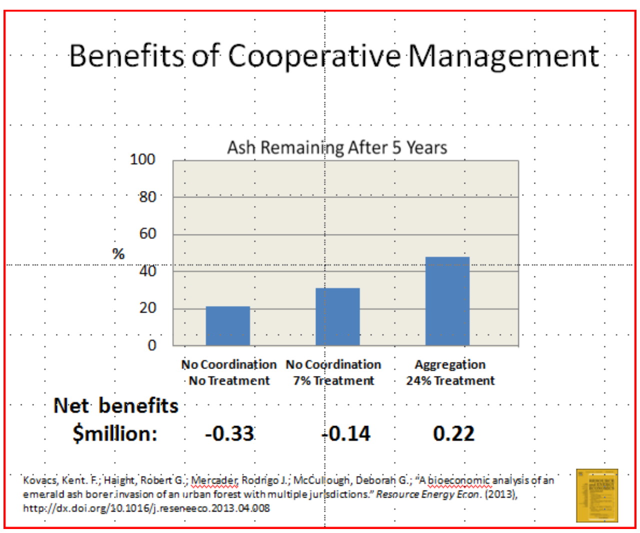



**Figure 1:** Net present value of surviving ash trees after five years for three different strategies

The Kovacs study states that there is little active coordination among jurisdictions. We recommend that regional or state level public authorities formulate such a strategy so that it will be in place when the infestation begins to kill trees at an exponential rate.

## The SLAM (SL.ow A.sh M.ortality) Study and Herd Immunity

The Model EAB Management Plan relies heavily on the scientific results from what is called the SLAM study (McCullough and Mercader 2012) and the study's website of the same name ("SLAM Steps in Implementing a Strategy to SL.ow A.sh M.ortality"). As such, it is important to summarize the study before describing the components of the Model EAB Management Plan.

The SLAM study addressed the life cycle of the EAB beetle, pest pressure, the natural ability of healthy trees to tolerate an infestation, the limited effectiveness of sanitation to reduce the food source, the effectiveness pre-emptive removals and chemical treatments, the importance of early detection, and the relative costs of a variety of scenarios.

The SLAM website provides a succinct summary of the effort: "The rate at which ash tree mortality advances is related to EAB density. [48] Therefore, an over-riding theme within the SLAM approach is to reduce EAB numbers and the growth of EAB populations. ... A do-nothing or a regulation-only approach means that EAB populations will build and advance unchecked. Under that scenario, extensive local tree mortality is likely to occur much sooner than under a SLAM management scenario. ... The goal of this management strategy is to slow the local invasion process and allow land managers time to be proactive rather than simply reacting to overwhelming numbers of dead, often hazardous trees. ... Continued research and methods development will yield more options for EAB management and increase the effectiveness of existing technologies. Slowing the movement of EAB and the advance of ash mortality buys time for research and technology development" ("SLAM: SLow Ash Borer Mortality Pilot Project")

The SLAM study included over 200 computer simulations based on field-derived data and a best-case scenario that was most effective at preserving ash trees at the lowest cost. This best-case scenario predicted that random treatment of 20% the population of ash trees annually should protect 99% of the trees after ten years. For comparison purposes, the study included a base case scenario that assumed no treatments. The costs of ash removal and replacement were "approximately fourfold higher than in any of the scenarios that included insecticide treatment. The dramatic difference in cumulative costs incurred, however, means that 20% of the ash trees could be treated for many years before treatment costs would approach removal and replacement costs" (McCullough and Mercader 2012).

[48] From the SLAM study: "A low-density of A. planipennis [the EAB beetle] larvae generally has little effect on the overall health of the tree, in part because ash trees are highly sectorial (Tanis et al. forthcoming 2012) and relatively efficient at vertical translocation of nutrients and water. As larval densities build, however, more tissue is damaged, translocation is disrupted, canopies thin, branches die and eventually the tree succumbs."

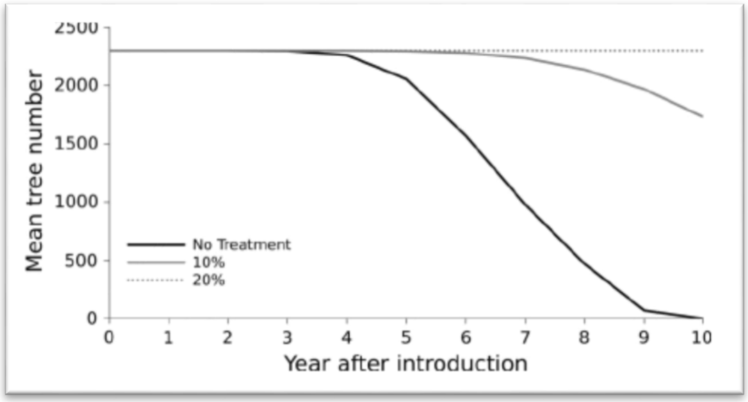
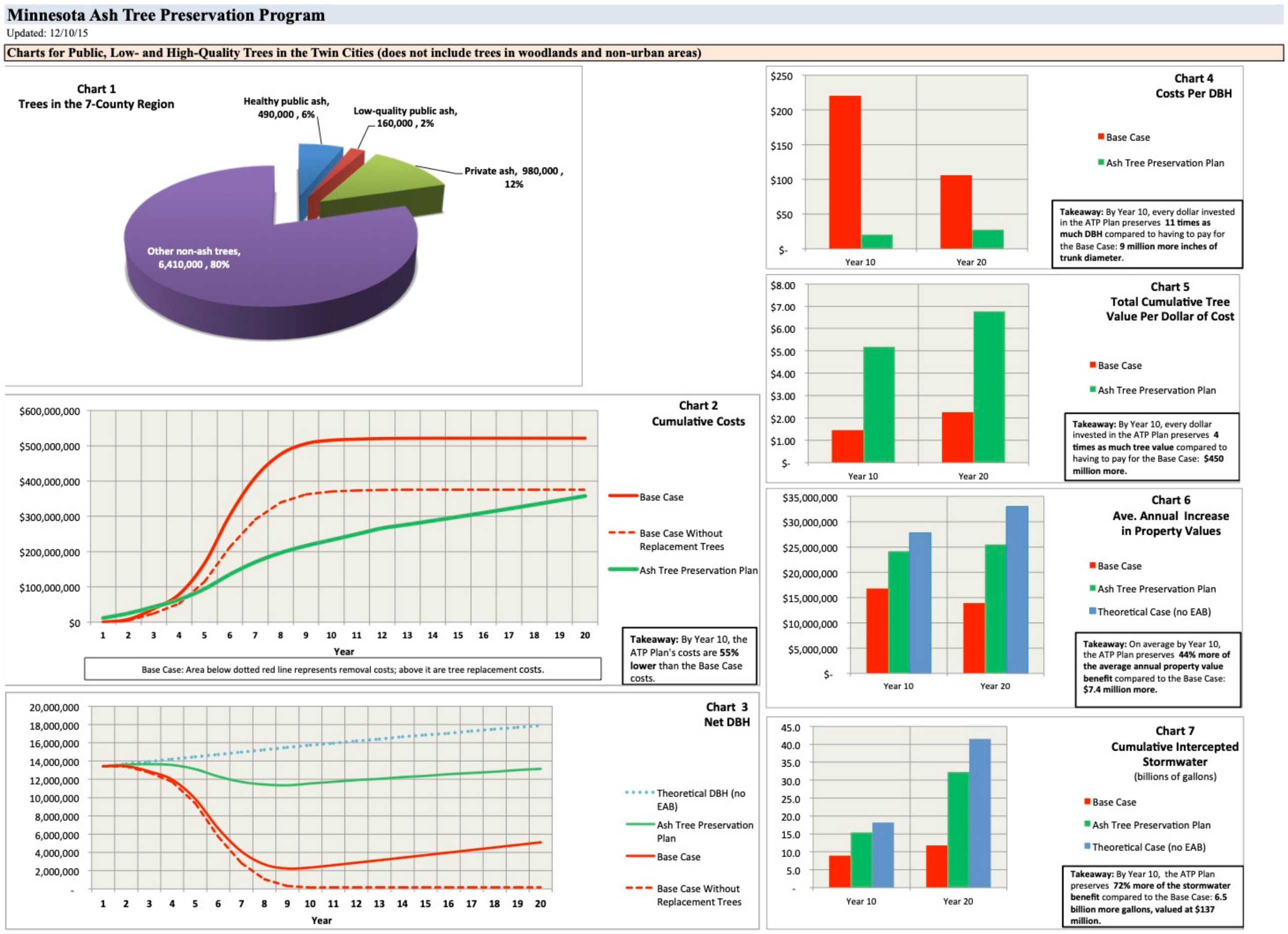



**Figure 2**: Simulations represent scenarios in which systemic insecticides were applied annually to zero (No Treatment), 10%, or 20% of randomly selected trees. Source: "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus planipennis): SLAM in an urban forest," Deborah G. McCullough and Rodrigo J. Mercader, *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23.

While the SLAM study predicts success with limited treatments, its model is based on a known size and timing of the EAB infestation. Practitioners and policy makers in infested areas will not have access to such information and, thus, will be forced to make a series of assumptions. The success of implemented plans will depend on the accuracy of these assumptions. The Model Emerald Ash Borer Management Plan was developed to provide tools to EAB managers that account for the unknown timeline and the uncertain growth rates of pest populations.

**Attachment D**

# Results from the Minnesota Ash Tree Preservation Program

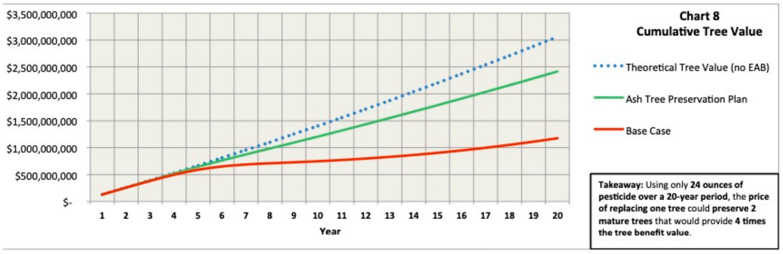


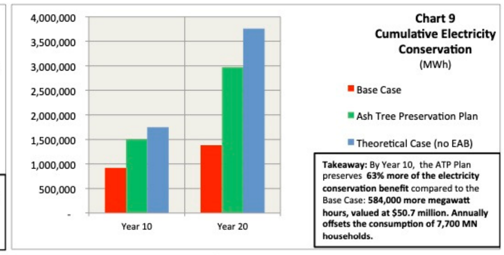

Minnesota ATP Program 121015.xlsx, Charts for report

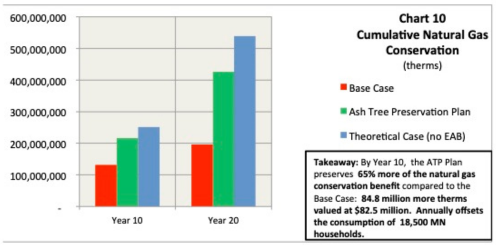
**Minnesota Ash Tree Preservation Program**

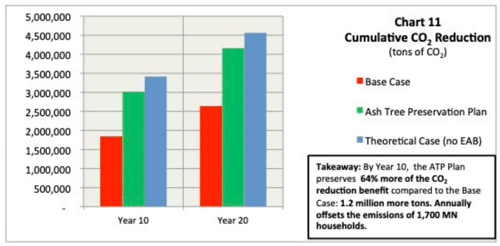
Updated: 12/10/15

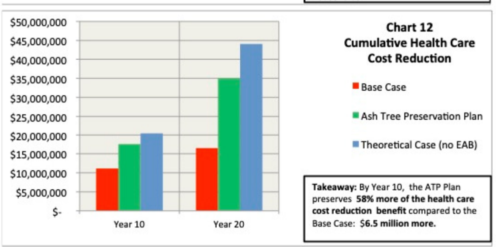
**Charts for Public, Low- and High-Quality Trees in the Twin Cities (does not include trees in woodlands and non-urban areas)**

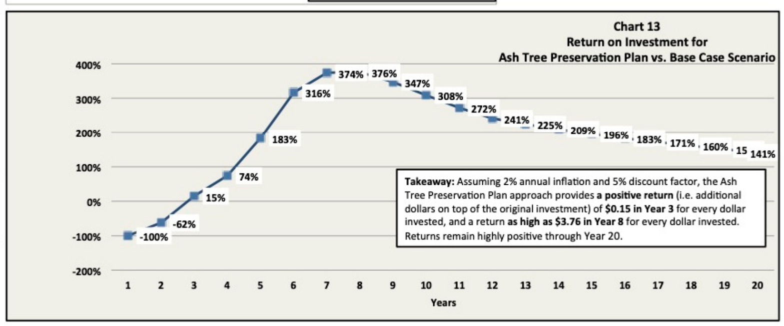



Minnesota ATP Program 121015.xlsx, Charts for report