[EMERALD ASH BORER COURSE OF ACTION PLAN]

A plan to prepare Bozeman for the emerald ash borer and efficiently manage the city's ash tree population during the infestation while creating a sustainable, healthy urban forest.

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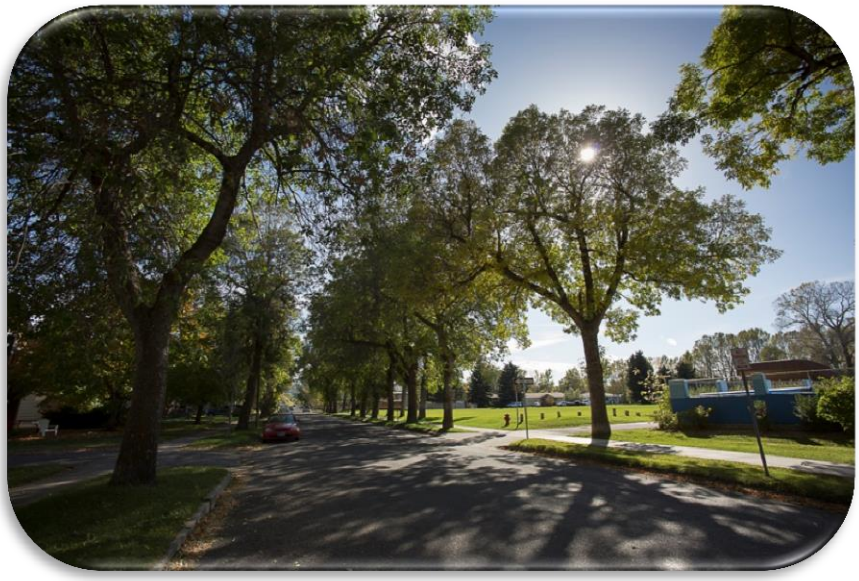
Introduction

A major weakness of Bozeman's urban forest is its lack of species diversity. In the downtown area, the urban forest is composed of approximately 80% ash trees. City wide, ash trees make up around 50% of the tree population. The tree population on any of Bozeman's downtown streets, especially the through streets, is dominated by ash. Church Avenue across from Bogert Park is entirely ash. Main Street, Willson, and Cleveland are marginally better.



Church Street ash trees

Species diversity is important to any plant population for the ecology to thrive. Monocultures in any plant community harm the greater environment by inviting disease and depleting soil resources and diversification of symbiotic animal life. The same principles hold true when looking at the population of trees in an urban forest. When low species diversity is present, the tree population is especially vulnerable to insects and disease. If an insect or disease were to be introduced to the area that affects the dominant species, it will devastate the tree population. This situation would reduce the quality of life for the people who live around these trees, and it would ruin benefits and cost savings the trees provide to the community.

Unfortunately, this is the problem Bozeman faces, and it is particularly disturbing in light of the looming emerald ash borer (EAB). Emerald ash borer is an invasive species that infests *Fraxinus* species. This pest was first introduced in the U.S. outside Detroit, Michigan, in 2002 and has spread throughout the Midwest, East and now the West.

The EAB can fly; however this mode of dispersion is limited. Generally, EAB can only fly one half-mile from where it was hatched. The spread of this bug is largely due to human means. It can be spread by transporting ash firewood and ash wood products. Rake handles, baseball bats, and pallets are all made from ash wood. As these products are distributed around the country, the risk of distributing the pest is elevated. Bozeman has a freight train route through town, also increasing our vulnerability. Infestations and pest outbreaks are almost always worse and spread faster than what was expected. Meaning, by the time a community realizes the extent of the infestation, it is often too late. For this reason, focusing on creating a healthy, sustainable urban forest ahead of EAB in Bozeman should be a priority.

The City of Bozeman faces many challenges when planning for EAB given the importance of our urban forest and sheer number of ash tree we have. Given that it is almost inevitable EAB will be introduced to Bozeman, we must approach this threat on many fronts. The impacts the city must consider are:

a. **Public safety**
   - When an ash tree or a limb dies, it becomes extremely hazardous. The grain of the wood in ash trees can cause the tree to fail with little or no cause or warning.
   - The city will become vulnerable to lawsuits from destruction caused by neglected ash trees.
b. **Public health**
   - Increased rates of cardiovascular disease from decreased air quality
   - Increased rates of lower cardiovascular disease from decreased air quality
c. **Economic**
   - Loss of benefits provided by urban trees
   - Substantial costs of removing many ash trees and stumps
   - Substantial biannual costs associated with treating trees
   - Decrease in value of properties without mature trees
   - Increased stormwater volume
   - Increased water usage
   - Higher utility bills for residents
d. **Environmental**
   - Decreased air quality from the loss of 75% canopy cover in Bozeman
     - Particulates not being filtered from air
     - Carbon dioxide not being absorbed
     - Oxygen not being emitted
e. **Political**
   - Losing many mature trees will create a negative political perception of the city and the Urban Forestry Department.

When EAB arrives in Bozeman, it is in the best interest to keep the ash trees that provide most of the urban forest benefits. Moreover, from a management cost perspective, treating trees for the duration of the pest outbreak or the lifespan of the tree is more cost effective than removing them in certain size classes of trees. Also consider the cost of replacing the tree and the time it would take for the tree to reach parity of the lost tree. Timely treatment of these assets preserves the benefits they offer the community, and this management philosophy will ultimately make money for the City of Bozeman.

This report details planning for EAB and managing it once it arrives. This is an issue that will initially cost the City of Bozeman money and must be dealt with. If this is done, the urban forest in Bozeman will continue to be a source of pride, offer benefits that far outweigh the cost, and remain a healthy urban forest. If proper planning and management is not executed, the city will:

- Experience exponential death of its ash trees
- Threaten public safety

- Devastate the budget of the urban forestry department for years
- Lose many of the benefits the urban forest provides

This EAB Course of Action Plan operates on the foundation of Bozeman's newly created Urban Forestry Management Plan (UFMP). The recommendations made in this report assume the appropriate personnel are in place, as recommended in the UFMP. By doing this, Bozeman will create the most efficient Urban Forestry Department possible and ultimately create millions of dollars in benefits for the city. This investment in city infrastructure addresses Bozeman's most current needs in our modern-day society.

The city will be the driving force for educating the public on the dangers of this pest. Once EAB arrives, it will be the city's responsibility to educate the public on management options. If this is executed well and efficiently, we will be implementing the most cost-effective approach, preserving the most canopy cover, and making our community forest healthier for it.

Organization of Plan

The Bozeman Emerald Ash Borer (EAB) Course of Action Plan operates in conjunction with the Bozeman Urban Forestry Management Plan. Together they create a holistic, sustainable urban forest in the most efficient way possible.

This EAB plan is broken in to two main parts: "Management of the Tree Infrastructure" and "Community Engagement." The two components cannot operate without the other and should be executed simultaneously. However, there is a natural division.

About the Emerald Ash Borer

The emerald ash borer (EAB) is considered to be the most destructive forest pest ever seen in North America. The emerald ash borer (*Agrilus planipennis)* is a beetle originally from Asia. It most likely was transported in hardwood packaging, such as a crate. Emerald ash borer was first detected outside Detroit, Michigan, in 2002 and since then has spread throughout the East, Midwest, South, and now the West. The areas shaded in green in Figure 1 have EAB, and the states in the sage green are in immediate danger of EAB's arrival. The earliest year that EAB was found to be responsible for an ash tree death was as early as 1997 (Seigert et al, 2014). It attacks any *Fraxinus* species, and any size tree is vulnerable to attack.

Figure 1

Emerald ash borer larvae bore holes into the cambium of ash trees, disrupting the flow of water and nutrients. This causes initial dieback and eventually kills the tree.

An ash tree infested by EAB exhibits dieback in the canopy above the infested portion of the tree. One-third to one-half of the canopy may die in one year. A tree may be treated if it shows less than 30% canopy dieback, and this can prevent further damage. Smaller trees may be killed by EAB in one or two years while larger trees will die in three to four years if left untreated.

The EAB emerges from a tree in late May though mid-June and begins to lay eggs two weeks after emergence. The eggs hatch in one to two weeks and begin feeding on the cambium, thus disrupting the flow in the phloem and girdling the tree. (emeraldashborer.info.)

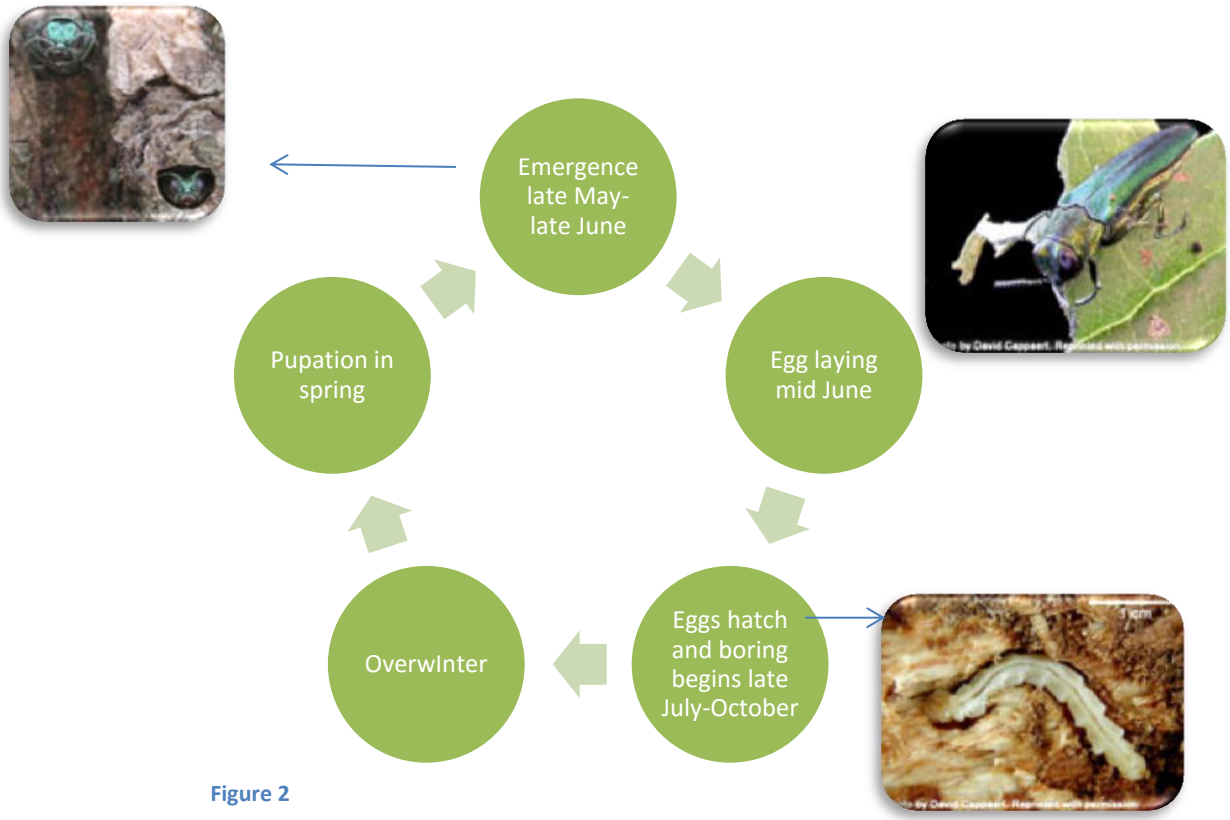


Figure 2

The population of EAB will stop growing if it runs out of a food source, experiences extreme low temperatures, or experiences human intervention. Ash trees are not native to the Bozeman area, in turn limiting the natural dispersion of EAB. Ash trees have largely been planted in landscaped areas; therefore, an island of ash trees is present, limiting the insect's ability to travel from ash tree population to ash tree population. The U.S. Forest Service, Northern Research Station concluded that sustained temperatures of -30F are required to kill EAB. These temperatures are rare in the Bozeman area. Emerald ash borer larvae (immatures) have high concentrations of glycerol and other antifreeze compounds, allowing them to survive extremely low temperatures within the tree. Human intervention is therefore the effective method to limit the expansion of EAB populations. This is done by treating ash trees to be retained and removing ash trees marked as such. In addition, introduced natural enemies of EAB have helped to slow population growth.

Management of Tree Infrastructure

Bozeman's urban forest consists of approximately 21,000 trees, 47% of which are ash. The following sections provide the necessary knowledge and steps to be taken to prepare Bozeman and manage Bozeman's ash tree population though the EAB infestation.

Tree Inventory

As of 2014 Bozeman has inventoried approximately half of its publicly owned trees. This is a good start, and completing the inventory is essential for planning and managing it once EAB arrives. First, the city needs to know how many ash trees it has since all of its management decisions and budgets will be based on this number. The inventory is a database that is key for budgeting, limiting liability, and managing the urban forest. The existing inventory incorporates many of the categories below, and it will be beneficial to also add categories particular to EAB.

Planned Maintenance

Once it is decided which ash trees will be retained, the rest of the trees will eventually be removed. Some of the ash trees that are in poor condition or are in conflict can be removed prior to the emergence of EAB. Once EAB arrives, the infested trees will need to be immediately removed. Trees not yet showing signs of infestation will be treated to delay their removal. All of this planned maintenance should be documented in the inventory. It allows for the plan to continue being executed regardless of personnel changes.

This section of the inventory will document the trees that will be preserved though the infestation and will help prevent any errors or loss of the city assets. If a tree is to be treated in order to delay its death due to workload constraints, this is where it will be documented.

Completed Maintenance

The ash trees that are removed are documented to keep track of budgeting for future years of the EAB infestation. Each removal should document the resources expended, such as how many people, equipment required, and time spent, including the stump removal.

Trees that receive treatments must be documented accordingly for the same budgeting reasons. In addition, it aids in scheduling the next treatment or when to next inspect the tree for signs infestation.

Inspections

Regular inspections will lessen liability. For example, if a tree were regularly inspected and documented with photos to be structurally sound, yet it failed and caused damage, the city could use the inventory records to show their diligence in monitoring tree infrastructure.

Condition

Documenting the condition of a tree in the inventory will aid in making management decisions.

Open Planting Spots

Knowing how the number and location of appropriate planting spots may be the most important aspect in moving forward after EAB runs its course. In Bozeman, it will be fairly obvious which streets or parks are in need of trees, but it will be important to plant trees systematically throughout the entire city using the inventory.

Detection

Detecting the presence and monitoring the severity of the EAB infestation is an essential part of this plan. Multiple detection methods should therefore be employed. Emerald ash borer traps, which are baited with pheromones, are installed in ash trees to detect and monitor the infestation. The continued use of traps should be implemented because it will further the possibility of early detection, and the possibility will exist to suppress and contain the infestation. The traps are not time consuming or overly expensive. This this method should be aided by "branch sampling." Branch sampling requires the removal of two live branches (2-6" diameter)

from the south side in the mid height of the canopy. The bark is removed from the branches with a knife. Any visible signs of EAB: feeding galleries, D-shaped exit holes, or EAB in the larval or beetle form are noted. This method is being utilized now and should be continued. However, it is time consuming and labor intensive. It should be used but not as the sole monitoring method because of the limited labor and money the forestry division possesses.

Many cities and states have indicated that tree mortality did not occur until years three through five of EABs arrival. (Siegert et al., 2007; McCullough and Mercader, 2012). This highlights the need for consistent detection because most likely by the time tree mortality occurs or the presence of "D" shaped holes in the trunk due to EAB are detected, the EAB damage is extreme and successful treatment of the tree is all the more difficult.

A point person in the department should be designated to be a reliable and qualified resource for the community and to provide identification when EAB is reportedly suspected. This way our efforts are coordinated and a protocol is being developed. This person will coordinate with Montana State University's detection efforts, Belgrade, and any other significant land owners in the Gallatin Valley monitoring for EAB. The importance of a diligent and consistent monitoring effort cannot be understated. Upon detection, our response plan can be implemented immediately.

After the arrival of EAB, monitoring should continue to keep track of the severity of the infestation. With consistent monitoring techniques, a graph of EAB population levels can be created. The city will reach its desired ash tree population and continue to treat the remainder of its ash trees for the amount of years needed. During this period, the city will want to see EAB levels decline and ideally reach zero.

Management of EAB and Achieving Goal Species Diversity

The newly created Urban Forestry Management Plan for Bozeman sets goals for the urban forest to increase species diversity and age diversity. Planning for EAB creates an opportunity to achieve those goals in a timely manner. The current species distribution is heavily weighted by ash trees (47%). Progress can

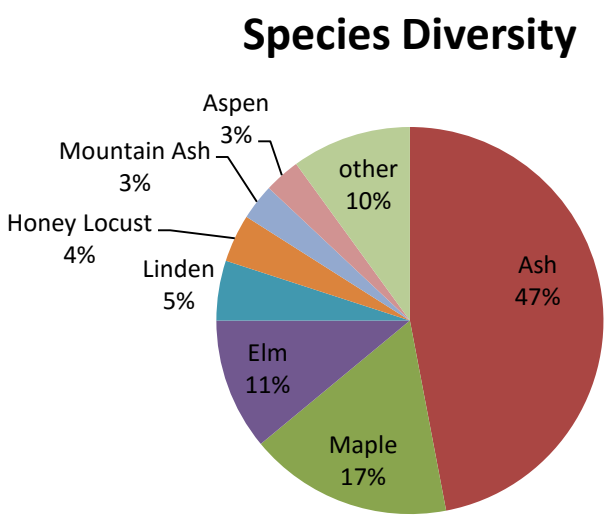


Figure 3

be made to achieve the goal of having no more than 20% of any one genus. Some ash trees will be lost in our urban forest due to EAB, and this loss will address our lack of species diversity. However, species diversity is achieved through appropriately planting new trees, which will be key in creating a sustainable urban forest and improving its health.

Economics of Ash Trees and EAB

Urban trees offer the community many economic benefits, which must be calculated to make fiscally sound decisions on how to manage EAB. Costs to consider include the cost of treating ash trees to preserve them through the outbreak (or until the city is ready to remove the tree) and the cost of removing the tree and grinding the stump.

There are approximately 10,000 ash trees in Bozeman, and they comprise 47% of the urban forest. This plan will work with the 10,000 ash tree number until the tree inventory is completed. These 10,000 trees have an importance value of 60% because many of the ash trees are mature. The tree genus that has the second highest importance value is maple, which has a 15% value. As can be seen in the figure below, there are a disproportionately large number of ash trees.

Bozeman

Importance Values of Public Trees

12/4/2014

Species	Number of Trees	% of Total Trees	Leaf Area (ft^2)	% of Total Leaf Area	Canopy Cover (ft^2)	% of Total Canopy Cover	Importance Value
Ash	9,887	46.97	37,990,095	69.35	8,048,809	66.21	60.84
Maple	3,662	17.40	7,481,142	13.66	1,697,280	13.96	15.01
Littleleaf linden	1,072	5.09	642,247	1.17	161,335	1.33	2.53
Honeylocust	928	4.41	714,104	1.30	219,156	1.80	2.50
Elm	762	3.62	2,321,848	4.24	466,694	3.84	3.90
European mountain ash	708	3.36	789,985	1.44	303,266	2.49	2.43
Common chokecherry	632	3.00	311,339	0.57	160,071	1.32	1.63
Quaking aspen	456	2.17	860,005	1.57	206,880	1.70	1.81
Oak	428	2.03	228,683	0.42	61,433	0.51	0.99
Crabapple	428	2.03	282,501	0.52	130,998	1.08	1.21
Total	21,050	100.00	54,777,826	100.00	12,156,409	100.00	100.00

Table 1, Figure 4

The vast majority of the mature trees are in the downtown area, as reflected in "Percent of Species that are >12 inches" pie chart. This means 83% of Bozeman's mature trees are ash, leaving Bozeman in a very tenuous position. Ash trees provide more than $1.4 million in annual benefits, with the average individual tree providing $145 in annual benefits to the Bozeman community. Figure 6 details the value of Bozeman's ash trees.

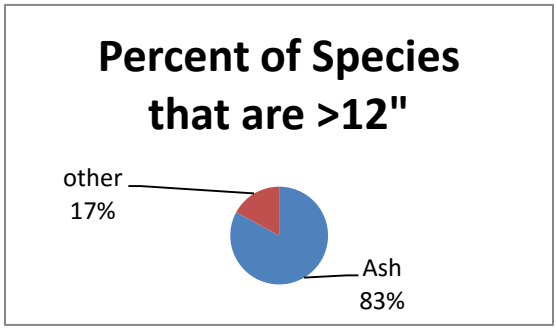


Figure 4

Bozeman

Total Annual Benefits of Public Trees by Species ($)

12/4/2014

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Ash	154,799	31,287	23,155	147,525	1,081,053	1,437,820	(N/A)	61.7

Bozeman

Annual Benefits of Public Trees by Species ($/tree)

12/4/2014

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
Ash	15.66	3.16	2.34	14.92	109.34	145.43	(N/A)

Table 2, Figure 5

The cost of removing ash trees is substaintial. The City of Kalispell is seeking bids to remove the above-ground portion of 24 elm street trees killed by Dutch Elm Disease. They budgeted $24,000 for this, or $1,000 per tree. In the end, they ended up paying $750 per tree for the removal of the above-ground portion. Using the budgeted numbers of Kalispell, Bozeman would spend $10 million to remove its 10,000 ash trees, not including stump griding and replanting.

Management of Ash Trees 10 Inches in Caliper and Over

Fifty percent of Bozeman's ash trees have a caliper over 10 inches. For the sake of calculations, this report will assume the cost of removing an ash tree, including a stump with a caliper more than 10 inches, is $850. The cost of removing an ash tree with a stump with a caliper under 10 inches will be $125. Note that this is a one-time cost.

Economically, it is worth it to treat trees with a caliper over 10 inches that are in good condition and in an appropriate location for the service life of the tree or the duration of the outbreak. Trees with a caliper smaller than 10 inches most likely are not worth treating because of the long lifespan ahead of them and the number of years the tree will need treatments. Also, these smaller trees do not offer the benefits the bigger ones do, and they can be replaced with a tree requiring less maintenance and offering similar benefits. The city should use the 10-inch caliper number as a general rule. There will be property owners with public ash trees with a caliper of 9 inches or smaller in front of their properties who may want their ash trees treated. In these cases, technically, it would be the property owners' responsibility to treat the trees if they did indeed want to retain them. The city will want to adopt smaller publicly owned ash trees that present merit for treating. There will be costs if the trees die, and the benefits lost may outweigh the cost of treating the tree. These trees will be considered on a case-by-case basis by the city official. Coordination and communication will be crucial between the entities.

If the city budgets $100,000 per year for the removal of ash trees, this will remove approximately 118 trees every year. There will also be a cost associated with purchasing replacement trees and installing them. This cost will not be calculated into the cost of EAB scenarios because it is unclear who will assume that cost.

Preventative treatment is a viable option for saving an ash tree. With the correct timing and chemical, one treatment will last for two years. (More on this topic in "Treatment Options.") Treating a tree with a caliper over 10 inches will cost $52. This application is administered every two years for a cost of $26 per tree per year.

Figure 7 shows management options available to the city. As can be seen, the more healthy trees that are treated, the less money that will be spent over time. In other words, it is less expensive and tree benefits are retained by treating and saving our ash tree population. This is because the removal cost is more than treating the trees, even over time. Moreover, the benefits of the city's mature trees are retained by treating every mature ash tree that is in good condition and in an appropriate location. The "Benefits-Costs" line shows the benefits of ash trees minus the cost of treating them through the life of the tree or the duration of the outbreak. Seven percent of Bozeman's mature ash tree population is either in poor health or a poor location; these trees will not be treated and will be removed. By treating the remaining 93% of mature ash trees, Bozeman comes out ahead by $42 million over 44 years.

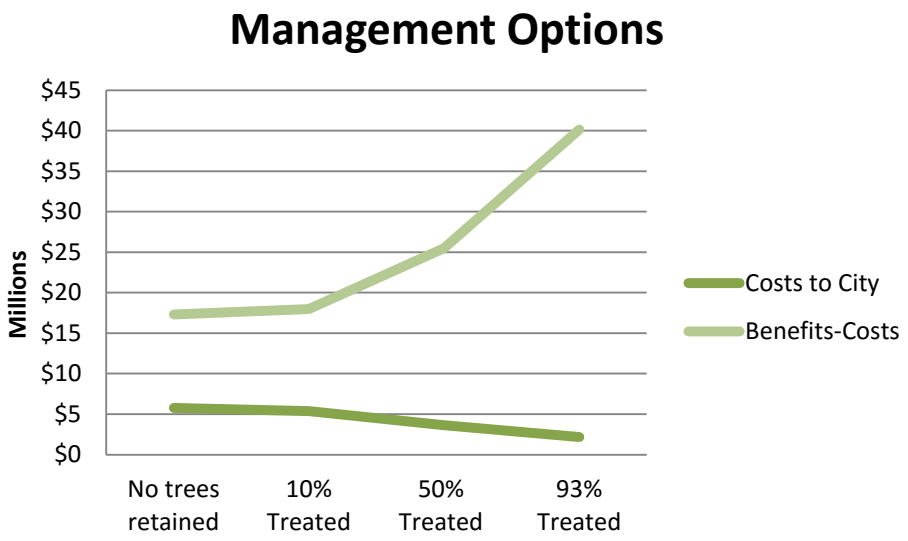


Figure 6

The example scenarios below take into account the cost for managing EAB though its infestation cycle. The following are taken into account:

- Treatments are calculated for 12 years in every scenario.
- The removals will not all happen in one year, so treatments will need to be administered to all trees except for the trees scheduled for removal. In other words, the city is dictating when the tree dies, not EAB.
- Only trees with a caliper of 10 inches or greater are tabulated
- Tree benefits are experienced until a tree dies and are calculated at $223 per tree per year because only the mature trees are taken into account.
- Tree costs and benefits are calculated for 44 years in every scenario because in the "no trees retained" scenario, that is the length of time it would take to remove all of the city-owned ash trees at $100,000 per year.

*Charts of maintenance schedules are in the appendices.

* After the ash tree population has been reduced to the goal number, the remaining ash trees are treated for years to starve the remainder of the EAB population and control the insect.
There are some variables to be considered with the outcome of these options:

- With the "no trees retained" option, we are left with no ash trees and 10,000 open planting spots. The replacement trees will eventually offer benefits that are not calculated here. There is no guarantee the replacement tree population will have a greater species diversity. A mass public education program must be undertaken to prevent Bozeman from being in the same predicament when the next disease outbreak or insect infestation occurs.
- With "10% retained," we are left with 500 ash trees and many of the same considerations as with "no trees retained"
- With "50% trees retained," Bozeman still faces a major replanting effort. The ash tree population changes from approximately 50% to 33%.
- With "90% of ash trees retained," we are left with canopy cover. It is understood that Bozeman is retaining the 90% that are in the best condition and retaining much of its mature tree population.

As can be seen in the scenarios presented, by far the least expensive way to manage EAB is to retain 90% of our mature tree population. Moreover, retaining 90% of our current mature ash tree population retains the benefits our urban forest provides. The 10% of Bozeman's mature ash tree population that would be removed is represented by trees in poor condition or inappropriate locations. **Losing mature ash trees that are in good condition and planted in appropriate locations is not an option for Bozeman from an economic and liability standpoint.**

Management of Ash Trees 9 Inches in Caliper and Under

The management of ash trees with a caliper of nine inches and smaller is largely a removal schedule as they are infested, or if they are infested. (The picture above is a 7-inch caliper ash tree, provided to give the reader a reference for the trees being described in this section.) The reasoning for this approach is that ash trees with smaller calipers:

- Do not offer the same benefits larger trees do
- Have a life expectancy that is much longer and potentially require a longer period of treatments
- Do not present as large of a public hazard upon death as larger trees
- It is not realistic for the city to treat more than 5,000 trees for many years.

Ash trees with smaller calipers that die will still need to be removed and replaced in a timely manner; however, the city's liability is more manageable. After the city removes the tree, the homeowner or HOA responsible for replacing the tree can then take appropriate actions.

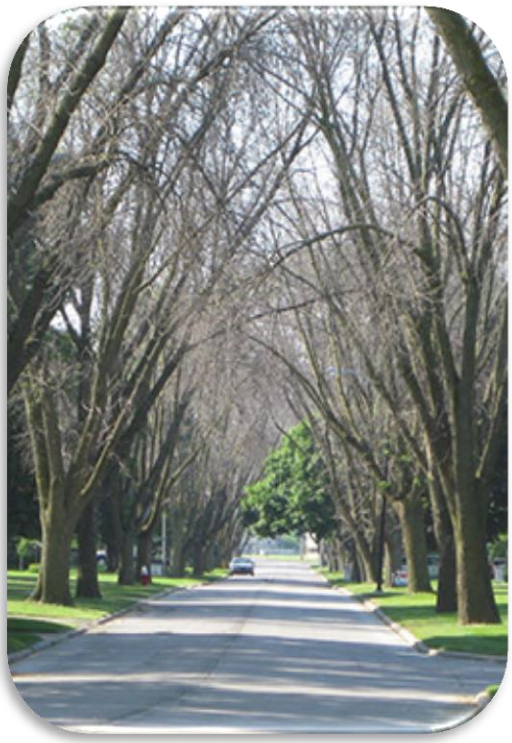
The potential exists for the city to lose all of its 5,000 smaller-caliper ash trees; however, at this point in EAB theory, the potential is small. There are many reasons for this theory.

First, some percentage of homeowners will decide the publicly owned ash tree in front of their property is worth treating and preserving through the outbreak or for the lifespan of the tree. In these cases they can petition the city to adopt their tree into the treatment cycles, and the city can accept their tree or determine the tree does not fit into their goals of managing EAB. More than likely, it will be in the city's best interest to treat the tree because it will avoid animosity and be cost effective. The alternative is that if the tree did indeed die, the city would be left with the cost to remove the tree and stump, a loss in tree benefits, and possible problems with replanting.

Second, a management program exists entitled **Sl**ow **A**sh **M**ortality (SLAM), whereby treating a percentage of the ash trees leaves the remaining ash trees at minimal risk of being infested. SLAM is a project involving many state and national organizations and makes the case that by treating around 20% of the entire ash tree population, EAB cannot establish a critical bug population to cause tree mortality. This is because ash trees can survive a very low level of EAB infestation. The amount of damage done to the vascular system is not enough to kill a tree. In implementing this management program, there is the variable that you do not know what percentage of the privately owned ash tree population will be treated. Bozeman's EAB Plan recommends treating approximately half of its ash tree population, and this would equate to approximately 25% of the entire ash tree population in the city. Some property owners will treat their ash trees, but the percentage of privately owned ash trees that would be treated is difficult to determine. Also, how consistent and diligent property owners will be as to treating their trees over time is hard to predict. Using these numbers, SLAM management principles would be applicable and losses would be minimal. This report does not employ SLAM management practices for a variety of reasons but mainly because too much is at risk with not treating some of Bozeman's large-caliper ash trees and it is not the most current management approach. However, if SLAM management principles are valid, it's all the better, and Bozeman's losses will be minimal to non-existent by employing this plan's recommendations.

The third reason the city probably will not lose its entire small ash tree population is that it is possible that property owners will choose to hire privately owned tree care companies to treat the publicly owned trees near their property. This scenario might occur if the city chooses not to adopt the tree into their treatment cycle and the property owner still deems the trees worth the investment. The city might choose to adopt the tree into their treatment cycle in future years if the tree reaches the caliper requirement.

If the city did indeed need to remove its entire 5,000 small-caliper ash tree population, it would cost the city almost $700,000. This number spread out over 15 years averages almost $45,000 per year. If the city implements the updated Bozeman Urban Forestry Management Plan and proactively implements this EAB Plan, this report does not recommend extra budgeting for the removal of ash trees with smaller calipers. This is due to the reasons stated above. It is possible losses will be minimal and efficiencies created by the Bozeman UFMP will better equip the Bozeman Urban Forestry Department to "do more" with the allocated funds.



Removals

Ash trees in poor condition or in bad locations do not fit into the criteria for treating and will most likely be infested, die and need to be removed upon the arrival of EAB. Efficient and timely implementation of the removal component of the EAB plan is crucial for reasons of public safety and also for controlling the EAB infestation.

Dead ash limbs are particularly susceptible to failure because of their grain. Many reports of limb failure exist where seemingly no weather event played a role in triggering the failure. This is alarming in the fact that dead ash trees may fail at any time with no warning. For this reason, from a liability standpoint, dead ash trees that present hazards must be removed immediately. The City of Bozeman Urban Forestry Department currently has 78 mature ash trees slated for removal due to poor condition and in addition, approximately 400 ash trees that are in poor condition and/or bad locations. These trees will eventually be on the schedule for removal, and keeping current or ahead of schedule on the existing removals will prepare Bozeman for the arrival of EAB. On average, 1% to 2% of a tree population will phase from fair condition to poor condition and the service life of the tree will be over. This would represent approximately 100

ash trees per year. Anticipating ash tree removals due to poor condition should be accounted for when managing a tree population. This is especially true in light of preparing for the arrival of EAB.

EAB will prefer to attack already stressed trees. Herein lies an element of strategy. Once EAB arrives, Bozeman will want to delay the planned removal schedule of dead or dying ash trees until late summer and fall. This way, if the wood is disposed of properly, the city will be killing off all these bugs that have bored into trees in poor condition. These trees are known as "sink trees." Some ash tree population managers have intentionally girdled ash trees slated for removal in hopes of attracting EAB, then killing them with the removal of the tree. This is not necessarily recommended in this plan because Bozeman will have enough work without creating potentially more removals. Ash trees already in poor condition should be considered sink trees. Of course, public safety will take precedent over strategy, and dead trees that pose a risk should be removed immediately, no matter the time of year.

Quarantine

Wood from removed, infested ash trees should be dealt with in a coordinated way. When the city removes an infested tree, a yard should be designated for storing this material. Branches and smaller-caliper brush are chipped and should be aged before considered safe for repurposing or disposing of normally. Trunks containing EAB larvae also carry the risk of spreading the bug, so a single spot is chosen to limit further dispersal of EAB. The city may want to open this yard for homeowners and tree services to dispose of infested logs.

Transporting ash firewood or logs becomes a major concern. Gallatin County will need to implement a "no transportation of ash wood" outside of the county. The city will coordinate with the county to execute such actions. Fines could be implemented for violating such quarantines. Bozeman may want to partner with Belgrade to coordinate the disposal of ash tree trunks.

If EAB was to move into Montana but not Bozeman, the city will want to establish added measures of monitoring transported ash wood. Many of these actions have more to do with "community engagement." One step might be licensing all firewood dealers selling wood within city limits. Again this would require a community engagement aspect to inform the community to buy firewood from a safe source.

Contracting Out Removals vs. Keeping Removals In-House

Contracting out removals will likely present a cost-efficient approach to dealing with EAB-related removals. These are removals that might be unplanned, due to an EAB loss, or that do not fit into the department's already increased workload. Contracting out removals will also enable

the Urban Forestry Department to keep up with their pruning rotation and normal workload activities.

Ash trees that will inevitably be removed or are scheduled for removal prior to the arrival of EAB will fit into the normal workload of the Forestry Department and will likely be best kept in-house.

Contracting Out Tree Treatment vs. Keeping Treatments In-House

Thousands, if not tens of thousands, of ash trees will be treated for EAB prevention every year once EAB arrives. Bulk pricing for treating trees with Tree-äge (emamectin benzoate) will inevitably be an important cost-saving measure. The City of Bozeman has historically contracted out its pesticide applications. This would be an acceptable and possibly cost-saving approach for treating the public ash trees. This is because contractors will likely be treating private trees and can create an efficiency by treating public trees while already in the area. If the city does contract out treating ash trees, it will want to make sure the contract has the ability to be flexible to add or subtract trees from the stated amount. This will allow for effective treatment to be timed with EAB's life cycle, which will maximize treatment effects. Also, if treatments are contracted out, it is essential the timing of the treatments be correct. The city will want to ensure the work is well-defined with its targeted application dates.

Some time will be saved if the city decides to treat its own trees because the department will set out to treat certain streets and sections of town, and they will not need to put much time into coordinating these efforts. If the work is contracted out, the city will need to spend a certain amount of time marking the trees to be treated, the trees' calipers, and locations. These details will be important for writing the RFP.

If the city does plan on treating its own trees, a couple considerations need to be addressed:

- The Urban Forestry Department will need to get one of its arborists or its urban forester licensed by the State of Montana to apply pesticides.
- Injection equipment and the appropriate insecticide will need to be purchased.
- The city will need to allocate three two-person crews for four weeks to treat 2,250 trees every year in the middle of summer. This presents a loss in productivity in the heart of the working season for the department.

It is likely there will be homeowners who have publicly owned ash trees in front of their property and want them saved but the trees don't fit into the criteria of trees the city is planning on treating. In these cases, three options are presented here: the homeowner must have them treated by a private company and pay for the service out of pocket, the city assumes responsibility for treating the tree, or the tree is left to be infested. If the tree dies, it is the city's responsibility to remove it. A decision must be made, most likely on a case-by-case basis, whether or not to treat

it. If the tree is close to the 10-inch caliper, in a good location and in good condition, the tree will likely be a good candidate for saving to preserve the benefits of canopy cover and avoid the costs of removing the tree. The city will most likely have to remain flexible and have the ability to adjust to situations like these with a possible added workload.

Insecticide Treatment Options

Treating ash trees to prevent attacks or further attack from EAB is an effective approach to controlling the spread of EAB and saving the tree. There are different methods of treating trees including soil drenches, basal trunk sprays, and trunk injections. Each method requires two to four weeks for uptake to protect the entire tree against EAB. All methods are systemic and effective for protecting an ash tree from an EAB infestation; each has positives and negatives.

Soil drenches

- Applied directly into ground
- Should not be applied to excessively wet ground as can result in poor uptake due to dilution
- Should not be applied to excessively dry ground because of resulting poor uptake
- Should not be applied where flowers are present to prevent injury to pollinators
- Should not be applied where the water table is shallow or there is risk of contaminating bodies of water

Trunk injections

- Soil conditions are not a factor in the effectiveness
- Drilling is required to administer chemicals, creating injury to trunk
- Requires specialized injecting equipment
- Absorbed and distributed around the tree more quickly

Basal sprays

- Spray the lower 5-6 feet of trunk
- Easy and quick to apply
- Does not wound the tree
- Does not enter the soil
- Sprayer must be calibrated to ensure proper dosage.

There are three chemicals that can be injected into a trunk: azadirachtin, emamectin benzoate, and imidacloprid. This report does not address the technicalities of each chemical; rather, it gives recommendations as to the most effective and cost-conducive approach. During periods of low infestation, any treatment application can be considered with an emphasis towards efficiency and the cheapest method. Trunk injections of emamectin benzoate (EB) are the safest and most effective way to treat ash trees and should be used during heavy periods of infestation. Recent

studies show no long-term damage has resulted from drilling sites where chemicals have been administered. A trunk injection of EB is the only method of protecting ash trees for two years, and in some recent studies, EB was effective for three years. Emamectin benzoate has shown to provide the highest level of control in side-by-side studies. This treatment option could be used through all stages of the EAB infestation and most likely will be the cost-effective approach considering it can be applied once every three years during low infestation periods. It should be noted the label states treatments are good for two years, so three is not a guarantee. Emamectin benzoate is derived from a bacterium and has a low toxicity to mammals. Emamectin benzoate is immobile in soil and has a low potential to bioaccumulate.

Upon detection of EAB, treatment should begin with the trees in the immediate area first and spread out from the point of detection. Treatments may be administered to trees showing less than 30% dieback. In these cases, the tree's vascular system is only partially damaged and limiting further infestation will result in a viable tree.

Biological control

The USDA has tested and developed protocols for the introduction of three biological control insects to help slow the population increase of EAB (EAB Management Plan for Boulder County, 2015). *Oobius agrili*, *Spathius agrili*, and *Tetrastichus plannipennisi* are insects known to exist in EAB's native range and parasitize either the EAB eggs or larvae. These insects vary a bit in their efficacy but complete multiple lifecycles in one year's time, helping to reduce EAB either during the egg or larval phase of development. Although biological control can reduce EAB densities, these biological control agents have not been effective in significantly reducing EAB populations below damaging levels.

Funding/Budget

Healthy trees (demonstrating little or no symptoms) will be targeted for treatment. Bozeman must have the proper budgeting in place for treating trees. The city will not be able to keep up with removals if EAB dictates when the tree dies. By treating the trees not showing signs, the city determines when or if the removal is to take place, depending on the management decision for the individual tree. This proactive approach preserves the budget and dramatically lessens the liability of having dead ash trees without the capacity to remove them.

The City of Bozeman is fortunate to be planning for EAB ahead of its arrival; many towns in the Midwest did not have this luxury. As detailed above, by far the most economically beneficial approach to dealing with EAB is to preserve as many ash trees that are 10 inches in caliper and over, in good condition, and growing in appropriate locations. This approach will cost the least and offer the most benefits. In Bozeman's case, they will come out ahead some $40 million.

Ash trees in poor condition can be removed as soon as they fit into the work schedule. It is prudent to remove problem ash trees rather than waiting until EAB necessitates it. This will lessen the budgeting and workload impacts once EAB arrives. It will also address species diversity problems and create new planting spots, as this is good management for any urban forest.

In planning for EAB, all of the actions fit into the recommendations made in the Bozeman Urban Forestry Management Plan. These actions focus especially on maintaining the appropriate removal schedule of ash trees in poor condition or in bad locations, completing the inventory, detection efforts, and planting new trees with appropriate species diversity. Implementing Bozeman's UFMP will lessen the immediacy of this plan because it will create a healthier and more sustainable urban forest. Moreover, implementing Bozeman's UFMP could save Bozeman millions of dollars by creating a sustainable urban forest by the time EAB arrives, and accordingly, the full scope of this plan would never need to be implemented. Bozeman's UFMP recommends creating a superintendent position in the Urban Forestry Department and filling it appropriately. This step is crucial to the implementation of the Bozeman UFMP and to the implementation of this EAB plan, especially for executing the community engagement component. This position also will coordinate with Montana State University and Bozeman School District to aid in detection efforts and community awareness. Lastly, a single person must be responsible for coordinating and executing EAB activities. The one line item for budgeting in anticipation of EAB is in detection efforts. It is essential to secure funds to implement this plan prior to EAB's arrival in Bozeman. Again, this plan is executed assuming the UFMP has been adopted and funded. With the Bozeman UFMP fully executed, it is possible and likely that the budget recommended in the EAB plan will never need to be fully implemented.

Action	**Anticipated expense**
Detection	$500/year
Implementation of BZN UFMP	$120K increase to $570K/year

Once EAB is detected in Bozeman, additional funding will be needed to implement the EAB plan. This includes treatments, removals, and community engagement. A year-by-year breakdown and totals are available in the appendices.

Action	**Anticipated expense**
Monitoring	$750/year during infestation and beyond
Treatment cycle	Avg. $100,000/year for 12 years
Removal of trees >10 inches caliper	$100,300/four years and $23,800 on the fifth year
Removal of trees < 9 inches caliper	$6,250/year for duration of outbreak
Community engagement	$3,000/year for duration of outbreak

Response Plan

Upon detection of EAB, a response plan should be implemented immediately. Many of the steps will happen simultaneously. For example the community awareness component and determining the size and severity of the infestation will occur first and at the same time.

Proposed response plan:

1. Determine size or area of infestation and relative severity. If population is very low and detection is in year one, continue to two. If population is detected in more than one location of Bozeman and is beyond year one, continue to step three.
    - Sample trees using a variety of tools to determine which trees are infested and the intensity. Do this in all trap locations and inform all detection partnering organizations.
2. Population of EAB is very low; implement EAB Course of Action Plan.
    - Attempt to suppress population by removing infested tree(s) and bringing them to designated area.
    - Targeted use of insecticides on public ash trees in area. Treatments schedule is on a two-year rotation.
    - Alert homeowners in immediate area to treat privately owned ash trees.
3. Community awareness component once EAB has arrived:
    - Enact preplanned communication strategy.
    - Prepare for all questions and critics of plan.
    - Engage news agencies to run stories on EAB.
4. An established population is detected; implement full treatment of ash trees.
    - Treatment schedule for ash trees
    - Removal schedule for ash trees
    - Monitoring schedule: note changes, spread, and impacts
    - Continued monitoring and detection efforts: address as necessary

Re-evaluate

One part of the overall strategy is being able to adapt as conditions in the urban forest change upon the arrival of EAB. The superintendent of the Urban Forestry Department must be able to revise the strategy based on new information without needing approval from city government. Some of the practices will work well while others will not be effective approaches to creating a healthier urban forest. Questions that must be asked, perhaps on a quarterly basis, include:

- What is working well?
- What needs improvement?
- What lessons are being learned?

Most likely, new information and technology will be developed between the time this report is adopted by Bozeman's City Commissioners and the arrival of EAB. The plan must be

implemented and budgeted for, and there must be a mechanism to update the plan with developments in technology and experience.

Management of Tree Infrastructure Recommendations

Issue	Recommendation
Tree inventory	-Complete tree inventory. -Add "open planting spots" to inventory.
Detection	-Implement a consistent detection effort by designating a point person in the department to inspect traps and reports from the community. -Coordinate detection efforts with MSU and State of Montana.
Budget	-Budget necessary money for detection efforts, removals, and treating trees.
Who will perform work	Make decisions as to how much, if any, and what work will be contracted out.
Potential loss of 83% of mature trees	-Upon detection of EAB in Bozeman, treat all ash trees that have a caliper of 10 inches and over with most effective treatments. -Treat trees that are in good condition and are growing in a good location. -Treat every third year during periods of low infestation and every other year during periods of moderate to high infestation. -Trees are split into two groups of treatments to keep a consistent budget and workload. -Special accommodations will be considered for property owners with boulevard ash trees that do not fit into the criteria for the city to treat but are close.
Species diversity and age diversity	-Remove ash trees in poor condition. -Remove ash trees in bad locations. -Implement sink tree removal techniques. -Plant new trees with good species diversity and do not plant ash. -Keep current with existing removal schedule.
Planting new trees	-Expand city tree planning programs to people who have lost ash trees. -Plant a new generation of trees with appropriate species diversity using recommendations in Bozeman UFMP.

Community Engagement

Urban forestry starts with community engagement and culminates in community engagement. This is because it is the community that builds, supports, and realizes the benefits from the urban forest. It is the community that must be informed and educated by the City of Bozeman on ways to build a healthier urban forest and protect their own ash trees.

In a sense, the city is partnering with the community to manage the ash tree population. Both must manage their urban forest in concert for either one to be successful in executing their plans. For example, the city must rely on the public to report suspected beetles or infested trees. Efforts will be maximized if both the city and private land owners coordinate efforts for EAB treatment and management. It will be the city's responsibility to coordinate and network with all organizations, including landowners, MSU, Belgrade, Bozeman School District, interest groups, conservation groups, etc. A clear and consistent message must be communicated to all entities.

Public Education

In preparing for EAB the public should be educated about the risk of EAB and the elements of a healthy, sustainable urban forest. By creating a healthy urban forest, Bozeman is preparing itself for EAB. This plan's immediacy is critical: the work done now will minimize the impacts in the future and create a healthy urban forest for future generations. Education and public outreach is the focus of Bozeman's Urban Forestry Management Plan.

Once EAB is detected in Bozeman, the public should be informed with a clear and consistent message. This public announcement must be completely ready to be broadcast at any moment. The Public Service Announcement should have the following elements:

- Clear and concise scientific information
- What Bozeman is doing and why
- Description of effective EAB treatments and relevant costs.

Bozeman should anticipate questions and concerns about the EAB Plan. Surely, whoever is administering treatments to the trees will have encounters with the public, and this team should have adequate resources to properly address public concerns. The Urban Forestry Department should be equipped with a planned message to handle potential conflicts with the public. Educating the public now, before EAB's arrival, can minimize many of these concerns. Bozeman's superintendent of urban forestry should be able to synthetize constructive criticism and make adjustments to the plan. Much unfounded information exists surrounding EAB, and the City of Bozeman should focus on the most efficient and practical management techniques.

Once EAB is detected in Bozeman, public meetings will be beneficial. During the development of this plan, a well-attended public meeting was held and members of the public were very engaged. These meetings should inform the public of the dangers of EAB, what the city is doing, and what management options homeowners have. By engaging the public, the city will also gain support for the plan and the department. This furthers the goal of creating a healthy urban forest and maximizing the benefits urban trees provide. Property rental agencies should be informed so they can contact all of their property owners to make management decisions.

The media will be beneficial in Bozeman communicating information about EAB. Public service announcements (PSAs) should be written and proofed, and a list of all media outlets that can publicize a PSA should be compiled ahead of time. The news channels and newspaper should be

engaged to run stories on EAB, and the superintendent should be ready to respond to media inquiries. Any additional strategies for communication should be planned ahead of time so they can be executed in a timely and efficient manner.

Management of Private Trees

The public will need to be educated on the city's plan to coordinate and maximize management efforts. In any given management option scenario, the city will reach a desired ash tree population and treat the remainder of its ash trees on a more conservative treatment cycle for a number of years. During this period it is extremely important that privately owned ash trees are treated similarly. It is crucial to continue monitoring and detection efforts during this phase of the plan. Problems that could arise during this period of eradication include:

- New property owners may not have ash tree management plans or knowledge of EAB.
- Absentee owners or property owners of rental units may not manage their trees.

By this point in the plan, the vast majority of ash trees that have not been managed will most likely have died and these "variable" trees will be less of a factor. Contacting rental agencies in Bozeman and alerting them of the management options they have will possibly diminish the risk of these "variable" trees. Depending on when EAB arrives, it is possible that Bozeman's 47% ash species diversity will have moderated itself through proper proactive management of the urban forest and EAB will be less of a factor.

There will be privately owned trees in Bozeman that will die as a result of infestation and present a considerable public hazard. Again, these trees will possibly be on rental lots and on absentee owners' lots. This presents a dilemma: should the City of Bozeman be able to enforce the timely removal of a dead privately owned ash tree? From a public safety perspective, probably. From a property rights perspective, which is prevalent in Montana, the answer is not so clear. There must be a balance between public safety and perceived government overreach. The city could run a survey, accessible from the city website, asking this question prior to the arrival of EAB. Or this question could be presented to the city commission, and maybe they will have a clear understanding of what the appropriate actions should be. If the city does determine a need to implement an ordinance enforcing the removal of dead ash trees, a subsidy could be created to help those who cannot afford to have an ash tree removed from their property. Moreover, it is possible the State of Montana will be a resource for aid to the public in need of ash tree management.

There is an interest to preserve as many mature ash trees as possible, both public and private, that are in good condition. If Bozeman's species diversity has not changed by the time EAB arrives, a cost-share program for treating privately owned trees would be in Bozeman's best interest. This would work if Bozeman contracts out its treatments by negotiating a bulk treatment price; or if

conducting its own treatments, these cost-share trees could be incorporated into the treatment cycle.

Political Support

Decision makers in Bozeman will play a crucial role in the management of EAB. A "State of the Forest" report to the city commissioners will be essential while the EAB plan is being implemented and its effectiveness is being evaluated. The more the city commissioners know about the conditions on the ground, the better partners they will be in creating a healthy urban forest population. This will also help their political goals by being informed about a pertinent issue related to the urban environment. Also, the more they are informed by periodic commission briefings, the easier it will be to make management decisions because of their knowledge of the gravity of the situation.

Online surveys should be conducted during the implementation of the plan to alert the commissioners as to the public's support and willingness to save our forest through proactive management.

Tree Replacement

When the city ultimately loses or removes hundreds or thousands of street trees, the responsibility of replacing these trees comes into question. City ordinances state the property owner must keep a certain number of trees planted in their boulevard, so it will be the property owner's responsibility to replant. Of course, there are some extending circumstances here:

- It is possible that local nurseries will not be able to keep up with demand and there will not be quality nursery stock.
- A property owner might not have the money to replace one or many trees.
- The property owner might not be aware of their responsibility to replant.

The city will play a very important role in guiding the species diversity of the new plantings. Increasing species diversity will also be important to minimize impacts of future insect pest invasions in the urban environment. Certain provisions the city might consider are:

- Providing incentives for planting new trees:
    a. Discount or eliminate the tree tax for one year.
    b. Expand tree planting programs for people who have lost ash trees.
    c. Expand the use of the city nursery for replanting ash trees.
- Making a timeline for when trees must be replanted:
    a. Extending the timeline for people who cannot afford to replant for one year. Requirements to qualify for an extended timeline could be that the property owner is currently on a Medicaid, MHK, WIC or other assistance program.

Community Engagement Recommendations

Issue	Recommendation
Detection/Monitoring	-Coordinate detection efforts between citizenry, MSU, Belgrade, and other interest groups. -Implement a strategic and consistent detection effort. -Respond to community reports of beetles or infestations.
Education of EAB and elements of a health urban forest	-Engage public to create a healthy sustainable urban forest in preparation of EAB. -Conduct the community engagement program outlined in the BZN UFMP.
Alerting community of arrival of EAB	-Enact preplanned strategic communication plan.
Planting programs	-Enact public planting effort outlined in BZN UFMP.
Additional precautions	-Consider ordinances enforcing timely removals of dead trees. -Consider regulating or certifying firewood dealers selling firewood in Bozeman.

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Appendix 1. Cost breakdown of management options

Management Option	Removal Cost. $850/tree, *one time	Treatment Cost.* $26/tree/year for duration of EAB infestation	Tree Benefits that are retained for the duration of the outbreak. $	Total cost $	Benefits-Costs
No trees retained	4,250,000	1,547,666	23,068,458	5,760,266	17,308192
10% of trees retained	3,811,400	1,547,666	23,331,598	5,359,066	17,972,532
50% of trees retained	2,106,300	1,547,666	29,146,992	3,653,966	25,493,026
90% of trees retained	425,000	1,742,146	42,329,860	2,167,146	40,162,714

*note cost of removal includes stump grinding