Harbord Village EAB Managament Plan

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Executive Summary:

The Emerald Ash Borer (EAB) is considered to be one of the worst invasive pests in North America, and is causing serious damage to ash trees in Ontario. The EAB infestation in Southern Ontario is expanding at a rate that is difficult to control given our current resources, and the insect's cryptic nature makes it difficult to detect. Rapid tree mortality rates mean that there are often significant losses before any actions can proceed. This is a challenge to forestry professionals and municipalities charged with the management of publicly owned ash trees and the public goods and services these trees provide.

In order to deal with EAB in the Harbord Village area, an EAB Management Model was developed in conjunction with the University of Toronto, using the Neighbourwoods protocol. The goal of this model is to suggest best management practices for local ash trees, based on the community's directives, the severity of EAB infestation, and overall forest condition. The model is flexible and is adjusted based on local interests, values, and priorities, so as to reflect to best possible match between suggested actions and actual community preferences.

Here we present our preliminary findings and recommendations for the pro-active management of Harbord Village's ash tree resource. Due to confirmed EAB infestations in nearby areas, we suggest that Harbord Village act as if EAB is already established within the neighbourhood. Highly valuable trees be preserved through injection of the insecticide TreeAzine™, while those of little value, and in poor condition be pre-emptively cut down and replaced. Other, intermediate management options are also explored for moderately valuable trees, including underplanting. In some cases, it may be to the community's best interest to leave a tree, knowing that it will succumb to EAB within the next 5 years, at which point it will have to be removed and replaced.

Tree replacement must be based on canopy losses and not on individual tree losses if Harbord Village is to maintain the benefits and local services provided by the urban forest canopy. 100% canopy replacement may not be possible due to space and budgetary constraints, however we recommend that a minimum of 10% canopy replacement be considered. Future plantings should consider tree diversity, ecosystem function, and long-term growing conditions.

We provide the following specific recommendations:
- **Preserve highly valuable trees** in fair, good, or excellent condition through insecticide injection. 45 trees in Harbord Village should be treated (9 of these are privately owned), at a total projected cost of $38,350 over the next 10 years.
- **Cut** 26 trees immediately, **underplant** another 7 trees, and **leave** 38 to be removed at a later date.
- **High risk** ash trees should be dealth with immediately before they become a greater risk due to death from EAB.
- **Tree replacement** should be based on at least 10% canopy replacement, meaning a minimum of 105 New trees planted within the next 10 years
- **Monitoring** of ash trees should be conducted at least every 2 years, and yearly for trees that are being preserved. The EAB management plan should be re-assessed in its entirety in 5 years.
- **Overall budget** for this project will be just under $145,000 over 10 years, with a cost to the city of $113,250, and to the community of about $30,000.
- **Community funding** may be available to help the Harbord Village Residents Association support local residents with the costs of tree injection, removal and replacement, and should be explored.

Table of Contents:

1. Introduction

1.1 Purpose

Harbord Village is a historic community known for its aesthetic appeal, large trees, and quiet streets. Much of these qualities are enhanced by the large trees lining the area's streets and in laneways and backyards. The community has long since been active in urban enhancement, including urban forest projects, for example the "tree our village" campaign, and the completion of a complete tree inventory using the Neighbourwoods protocol, in 2009. The impending loss of all of the community's ash trees to Emerald Ash Borer presents a significant setback in these community forestry efforts, and poses a real challenge for the community in fulfilling its commitment to "strengthening and preserving the stability, distinctive character and quality of life of our neighborhood (HVRA 2012)."

Harbord Village has the opportunity to lead the way in urban forest community stewardship because of its extensive mature forest resource, and highly active community. Through a partnership with the University of Toronto, the Harbord Village Residents Association has commissioned this Emerald Ash Borer Management Plan in order to be best prepared for the EAB infestation. This plan is focused on maintaining the core values of the community and the tree canopy in the face of ash tree loss due to the invasive Emerald Ash Borer. We hope that this document can help both community members and the city of Toronto to have a clear picture of the local ash tree situation and of the potential cost for proactive ash tree management.

1.2 The Emerald Ash Borer

Emerald Ash Borer (*Agrilus planipennis*, hereafter EAB) is an invasive insect that is believed to have arrived in Michigan from Asia in the late 1990's (OMNR, 2010). EAB targets all ash species with a nearly 100% tree mortality rate within two to three years of initial infestation. It was first detected in Canada in Windsor, in 2002, by forest health monitoring staff from the Ontario Ministry of Natural Resources (OMNR) and Canadian Food Inspection Agency (CFIA). In 2007, EAB was confirmed in the vicinity of Sheppard Avenue East and Highway 404, and has since been detected throughout the east, west, and northern parts of the city (City of Toronto, 2012). As of 2011, much of south-western Ontario has been quarantined by the CFIA due to the increasing spread of the EAB infestation. Adults typically disperse at a rate of about 100m per year when ash trees are present, however dispersal can be up to 5km annually, and dispersal ranges over 19km per year have been reported (Kovacs et al, 2010). To date, there is no known method of eradicating EAB from the landscape, and therefore management efforts have been focused on slowing the spread of insects, and on managing ash trees within infested zones (OMNR, 2010).
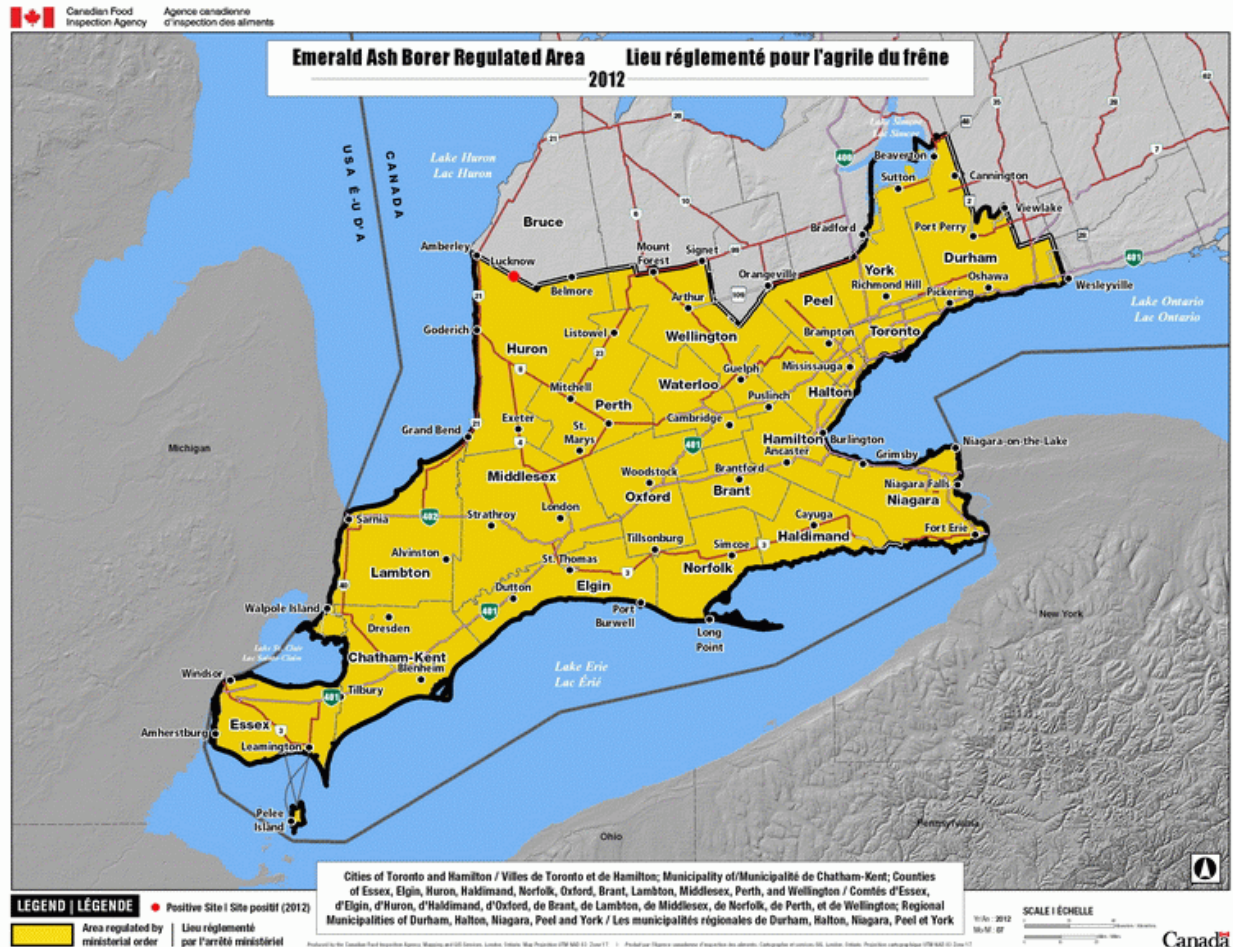
Figure 1.1: EAB quarantine zones for Southern Ontario (CFIA 2012).

The Emerald Ash Borer is pictured in figure 1.2a. Adults are small (8.5-13.5mm long), slender metallic green beetles, with flattened heads and black compound eyes that cover most of the side of the head. EAB's life cycle is believed to be one year, although new evidence suggests it can take up to 2 years to reach maturity (OMNR 2012). Adults lay single eggs in bark crevices from late May through July. Eggs hatch in about 20 days and larvae feed aggressively on the cambial layer beneath the bark until cooler temperatures arrive in October or November. The larvae, pictured in figure 1.2b, are longer than adults (26-32mm long) and cream-colored (OMNR, 2012). Larvae will overwinter in the tree and pupate in the following spring. Adults begin to emerge in late May through June, by boring through the bark, leaving distinctive D-shaped exit holes in the tree. Mating occurs 7 to 10 days after emergence, with an average multiplication factor of 70 eggs per female (OMNR, 2012; CFIA 2012).

a)

b)

Figure 1.2: The Emerald Ash Borer, a) when mature and b) pictures next to the larval stage (CFIA, 2012).
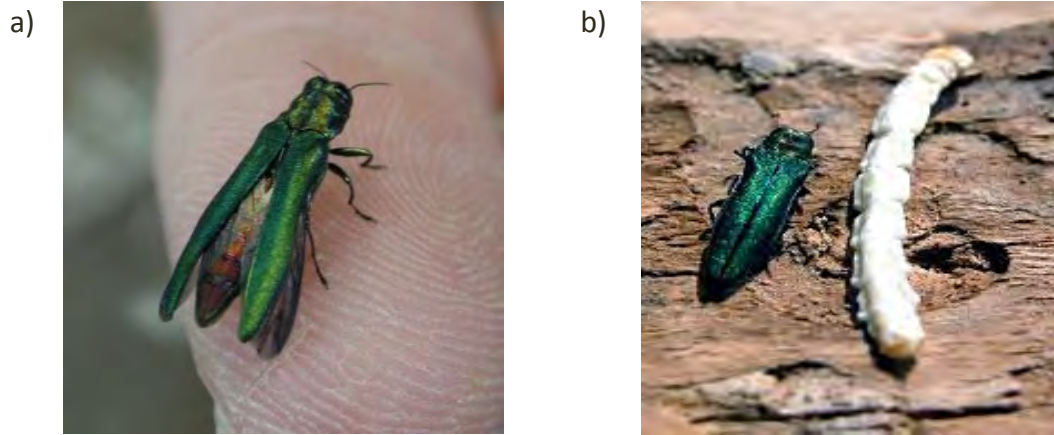
Infested ash trees display a range of symptoms, including crown dieback, defoliation, high levels of woodpecker activity, and signs of drought (OMNR, 2012). EAB kills trees by girdling trunks and cutting off the flow of nutrients in the cambrial layer just below the bark. Larva feeding creates vertically oriented, shallow, tunnels just beneath the bark that meander with abrupt turns and are packed with frass (sawdust-like waste), when enough of these feeding galleries are present, the tree's circulation is completely cut off, and the tree dies (OMNR, 2012). A telltale sign that EAB has infested an ash tree is the presence of the D-shaped exit holes left by emerging adults. These exit holes may be found anywhere on the tree branches or trunk, especially in June and July (OMNR, 2012), but if detected at eye level are likely a sign that the tree is too severely infested to save. Appendix I outlines the signs of EAB infestation in ash trees.

1.3 Ash trees in Harbord Village

Ash trees are common in urban areas because of their high salt and pollution tolerances, and ability to grow rapidly in a large variety of soils (Gucker, 2005). There are a total of 116 ash trees in Harbord Village, which is approximately 5.5% of the area's trees. In Harbord Village, 97 ash trees are owned by the city, 18 are owned by private residents, and only one tree is jointly owned (Figure 1.3). Ash contributes approximately 4% of the forest canopy,[1] and this is unevenly spread among the blocks, with some areas completely devoid of ash, and others with over 14% ash canopy. As of 2012, 7.76% of these ash trees are in excellent condition (7 trees are city-owned, and 2 are privately owned), while 39.66% ash trees are in very poor condition (city owns 38 of these, and 8 are jointly or privately owned; Figure 1.4 and Figure 1.5). Overall,

[1] This is based on estimated canopy widths of all non-ash species (only ash were measured in 2012). Because these estimates are likely higher than actual canopy widths, the % contribution of ash to the canopy is probably an underestimate.

more than 57% of ash trees are in poor and very poor condition. It is likely that the large amount of trees in poor and very poor condition is due to EAB infestation in this area.

Figure 1.3: Ownership of ash trees in Harbord Village

- Private (18) — 15.52%
- City (97) — 83.62%
- Joint (1) — 0.86%
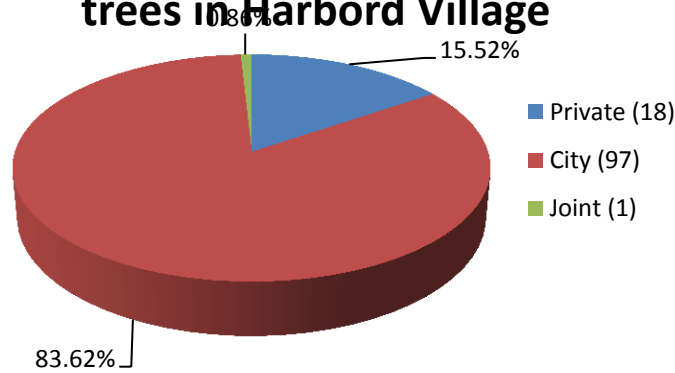
Figure 1.4: Health condition of ash trees

- Excellent (9) — 7.76%
- Good (14) — 12.07%
- Fair (26) — 22.41%
- Poor (21) — 18.10%
- Very poor (46) — 39.66%
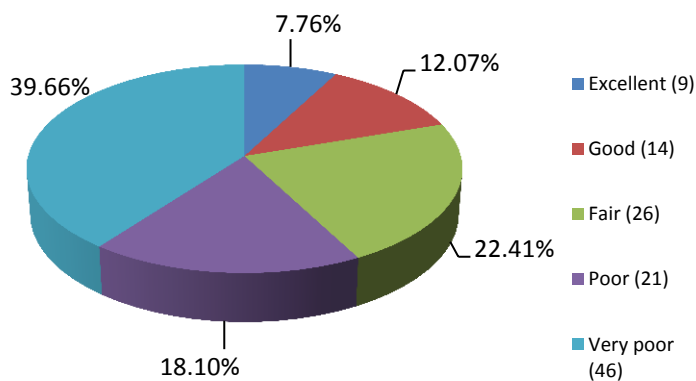
Figure 1.5: Condition of ash trees by ownership

- Joint
- City
- Private
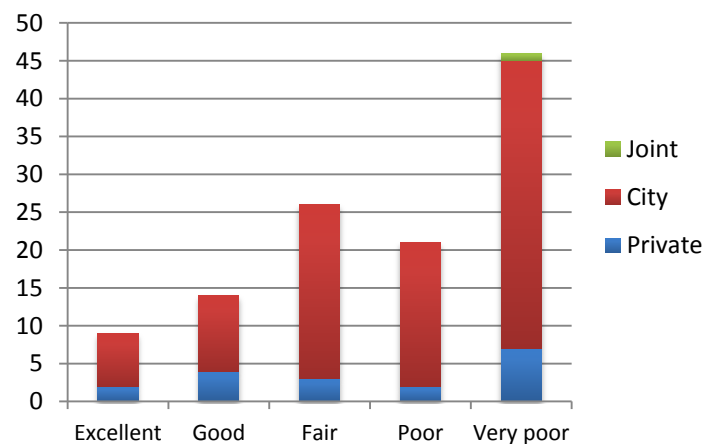
Tree size is typically measured by the Diameter at Breast Height (DBH). Figure 1.7 illustrates the number of ash trees in each DBH class. Harbord Village has number of large ash trees (DBH>45cm), 1 of which falls into the largest DBH class: class 6 (>76cm; see table 1.1 for the DBH class categories) and all of which are privately owned. Because most ash trees are street trees on Spadina Avenue, the DBH of 78.44% of Harbord Village's ash trees is below 30cm (class 1 and class 2). Interestingly, DBH Class 1 and 2 have a very high number of excellent and very poor trees. This may be because most small trees are street trees, and highly stressed by local conditions (resulting in very poor condition), or may be newly planted saplings (accounting for those in excellent condition).

Table 1.1: DBH classification

DBH class	DBH (cm)
1	<15
2	15-29
3	30-45
4	46-60
5	61-76
6	>76

Figure 1.7: Number of ash trees by DBH class
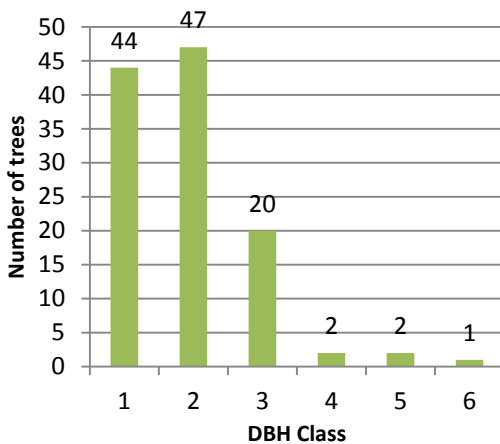
Figure 1.8: Condition of ash trees by DBH class
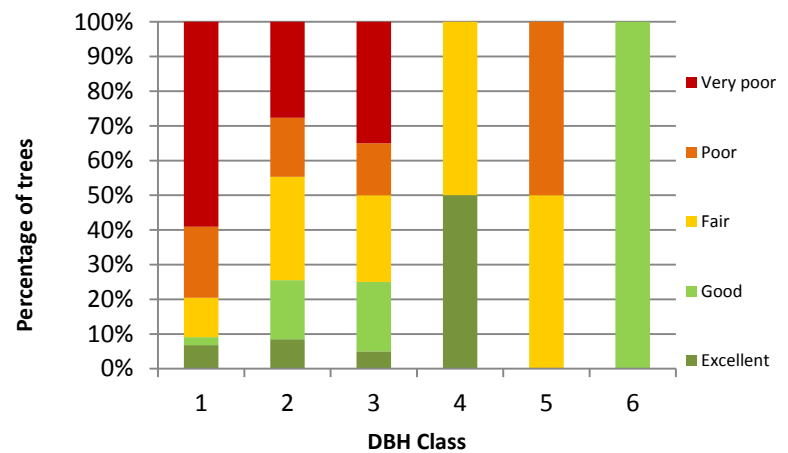
1.4 EAB in Harbord Village

Confirmed presence of EAB: Although we did not confirm EAB infestation in any ash trees within the Harbord Village area, one adult beetle was located during our survey, likely from block 16 or 21. In addition, because the Neighbouring University of Toronto Campus has a confirmed widespread EAB infestation, it is highly possible that EAB has already infested some ash trees in the Harbord Village area.

Signs of EAB infestation on in Harbord Village: The major indicators of EAB in ash trees are defoliation, limb death, and high levels of woodpecker activity (as they feed on EAB under the bark). The City of Michigan has noted that trees with more that 20% leaf-loss (hereafter Defoliation) had completely died by the following year if not injected right away (Wilson, 2010). With this in mind, we examined defoliation levels among the area's ash trees: 16 ash trees are currently showing greater than 25% defoliation (only 1 is privately owned, 15 are city trees), and can be expected to succumb to EAB by next year if not treated. This is a projected loss of 13% of the Neighbourhood's ash trees, and 35% of the ash canopy. 33 trees are showing less

than 25% defoliation, and 70 are showing no defoliation at all. These 103 trees may still be saved by injection should their overall condition and value deem them eligible. The levels of defoliation have increased since 2009, despite a reduction in the number of ash trees due to tree removal and mortality (figure 1.9). The most defoliated trees appear to be the smallest trees (DBH class 1), which may be a sign of other pressures in addition to EAB. Because the majority of small trees are city trees, this may reflect poor rooting conditions, or other pressures associated with roadside conditions on Spadina Rd. and Bloor St.

In addition to defoliation, complete limb death and woodpecker activity can also indicate the presence of EAB. Heavy EAB infestations can result in the complete death of entire limbs before other areas of the tree are affected. In Harbord Village, 26 ash trees are showing signs of branch death (or 22% of all ash). This has not changed significantly since 2009, however pruning and other tree maintenance activities may have removed dead branches before we were able to take note of them (figure 1.10). Ten of these trees are owned by private citizens, representing 1/3 of the area's private ash tree population. While woodpecker activity in Harbord Village was only able to be confirmed in 3 cases, the level of bald spots on ash trees (which may be due to woodpecker activity, among other things) was quite high. In total, 47 trees showed moderate to severe balding, nearly all of which were city trees (N=42).

Figure 1.9: Ash tree defoliation levels in 2009 and 2012
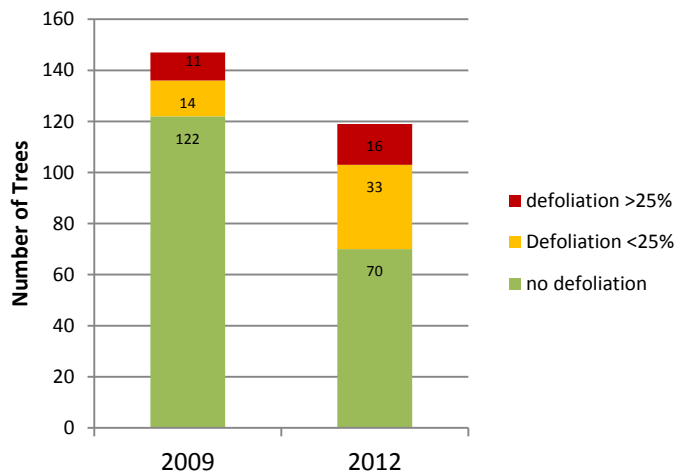
Figure 1.10: ash trees with large dead or broken branches by severity level (1 is less severe, 3 is most severe)
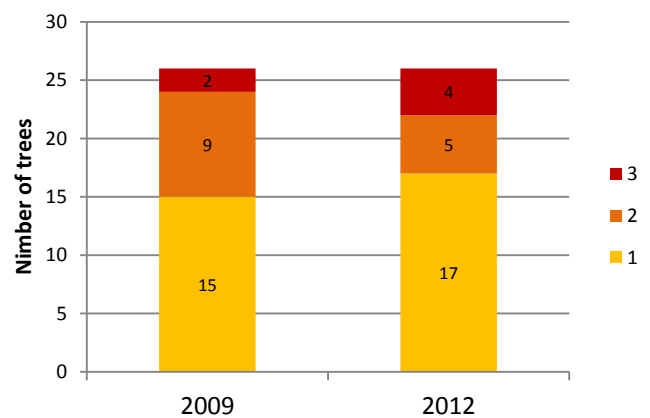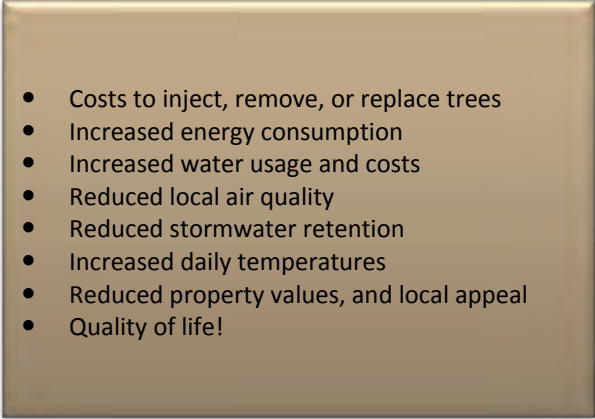
While Harbord village appears to be in the early stages of EAB infestation, the severity of the EAB infestation on the University of Toronto's St. George campus is beyond what was initially expected at the outset of this study. Tree loss is expected to increase exponentially in the coming years, and it is essential that Harbord Village be prepared for this infestation. While many trees are already exhibiting signs of decline, swift and decisive management can help to mitigate the further loss of ash trees and the services they provide to the community. The proposed management plan hopes to provide a proactive approach with the goal of preserving the most valuable trees, and offsetting tree loss through strategic removal and replacement.

2. Emerald Ash Borer Management Options

Although EAB has not been confirmed in Harbord Village, the discovery of a live emerald ash borer during tree inspection, and the confirmed infestation of at least 8 trees on the nearby University of Toronto St. George Campus, is a reason to assume that EAB is present and abundant in Harbord Village. Because of its cryptic nature, early detection of EAB is very difficult, and by the time symptoms are confirmed, tree condition is usually so poor that treatments are ineffective. Therefore, a proactive and pre-emptive approach is recommended for the Harbord village area.

To date, there is no way to eradicate EAB from the landscape, therefore current management actions are aimed at slowing the spread of this insect, managing risk, and preserving highly valuable individual trees. Regardless of the actions taken, costs will be incurred sooner or later (see Box 2.1). A proactive approach, while initially costly, will preserve many tree services, and prevent service and financial losses in the future. Conversely, a reactive approach, which would reduce initial and long term spending to only what is necessary to mitigate risk, would result in large losses of tree services, reductions in property values, increased temperatures, energy costs, and water consumption, and also increased pressure on other municipal departments for management of infrastructure due to increased temperature, erosion, and stormwater runoff (McPherson & Simpson, 1999; Akbari et al, 2001; Pandit & Laband, 2009; Dobbs et al, 2011).

- Costs to inject, remove, or replace trees
- Increased energy consumption
- Increased water usage and costs
- Reduced local air quality
- Reduced stormwater retention
- Increased daily temperatures
- Reduced property values, and local appeal
- Quality of life!

There are four basic approaches to invasive pest management, outlined in table 2.1. Because of the severity of the EAB infestation, doing nothing is no longer an option. In addition, if the Harbord Village community hopes to preserve the visual heritage of the area and the services provided by its large canopy, proactive management will be necessary. Because of the severity of EAB infestations (nearly 100% mortality within 5 years of initial infestation), there are limited action options available, and we can safely assume that trees will die if they are not treated. The reactive management approach focuses on leaving trees until they are dead, whereas tools such as underplanting, injection, and pre-emptive removal are more typically used during more active and pro-active approaches.

Table 2.1: Management approaches

Approach	Financial impact	Social impact	Methods	Control actions	Tree replacement
Do nothing/reactive management	Low at first, increasing as EAB infestation progresses.	High: large loss of canopy all at once	- Remove risk trees, or trees as they die - No surveys or outreach	- none	Minimal, as budget allows
Active management	Costs spread over time	Moderate: all trees will eventually be lost, just spread over time	- Manage impacts of EAB, with the goal of offsetting and staggering costs. - Limited public outreach	- Monitoring, - tree removal, - Minimal injection (only for high value trees)	In priority areas, and then as budget allows
Pre-emptive/pro-active management	High initial cost, decreasing over time	Moderate, but can be low if properly planned	- Emphasis on surveys, - public education, - tree protection, - private landowner incentives	- emphasis on tree protection (injection), - private landowner incentives, - pre-emptive removal	Can include underplanting in high risk areas
Aggressive management	High costs, offset by retention of large trees, and money saved through tree services.	Minimal	- Intensive management: Try to save the majority of trees, focus on maintaining canopy.	- surveys, - injections, - incentives to private landowners	Only where trees cannot be saved

2.1 Surveys and detection

There are various detection and survey methods that can be used to detect EAB in areas where it has not been previously located, or to determine the level of infestation and to locate infestation hotspots. However detection of EAB at low population levels is still not reliable. Since EAB is known to be within the St. George Campus area (Harbord Village's immediate neighbor to the East), action should not be dependent upon the results of detection surveys. While detection is important for confirmation, it is not necessary for proactive action and planning in the face of an EAB infestation.

For Harbord Village, the time for monitoring is past. While surveys should continue to determine the level of infestation, and the efficacy of management actions, surveys should be conducted in conjunction with, and not as a precursor to, active ash tree management.

2.2 Inventory

It is essential that an inventory be maintained so that tree location, condition, and values can be quickly identified in the face of infestations such as EAB or other disease outbreaks. The Harbord Village tree inventory was completed in 2009 using the Neighbourwoods inventory protocol, outlined in appendix II. It is also useful to collect information specific to the stressor in question, and for this study additional criteria on EAB infestation was gathered (see appendix II).

Inventories can affect the level of analysis performed, and many different management tools require differing levels and forms of information. For example, the *i-tree* program,

commonly used to calculate a tree's value in dollars, requires information on hourly pollution levels, the amount of light reaching a given tree, and daily temperatures, in addition to basic information such as species, size and location. It is important that the inventory technique employed gathers information best suited to the assessment tool you intend to use. Box 2.2 lists some other tree assessment tools available online.

> ## Box 2.2: Some open-access urban forest assessment tools
>
> - LEAF tree benefits estimator:
>   helps to estimate the money saved by non-ash trees on residential properties.
>   http://www.yourleaf.org/estimator
> - The i-tree program suite:
>   Quantifies both the structure and value of urban forests, in US$.
>   http://www.itreetools.org/
> - The Canadian Forest Service Ash Protection Model:
>   Tracks the costs of different ash tree management options over a 30-year timeframe. Other tree benefits can be included as desired.
>   http://gmaps.nrcan.gc.ca/apm/index.php

6.3 Preservation

The identification of trees for preservation is conducted in a variety of ways for different municipalities. Regardless of the criteria, it is essential that clearly defined, easily quantified criteria are determined according to the specific values and goals of the property. In Canada, both EAB protection techniques available (TreeAzine and Confidor) require the bi-annual injection of pesticides directly into the base of a tree's trunk. TreeAzine™, or Azadirachtin, is a bio-pesticide (naturally derived and neem oil-based), which has been shown to effectively protect trees for EAB for a 2-year period. This product seems to have the least detrimental effects on a tree's health, although long-term data is still unavailable. Other products are available in the united states, however they have not yet been approved for use in Canada. More information on TreeAzine can be found at the BioForest Technologies Inc. website: http://www.bioforest.ca/index.cfm?fuseaction=content&menuid=18&pageid=1026.

6.4 Tree removal and replacement

In addition to the high risk trees, trees that are beyond preservation will have to be removed and replaced as they die from EAB. Tree replacement is subject to the discretion of the landowner, but we suggest that the commonly used "one-to-one" approach, while the most cost effective, may not preserve all of the services and values of the area's forest. We suggest that canopy-based replacement in conjunction with underplanting would better mitigate the loss of tree services, and increase the campus' green capital over time.

There are several tree removal and replacement options, listed below:

1. "CUT" - Pre-emptive removal: Pre-emptive removal reduces the maintenance costs of trees that are likely to die very soon, reduces liability concerns, and allows for earlier establishment of any replacements planted. In addition, this will stagger some of the tree removal costs, preventing a spending "spike" in the near future if many trees die all at once.

2. "LEAVE IT" - Leave the tree unattended and remove when dead: this will postpone the removal and replacement costs for the tree, and may help maintain some larger trees in the immediate future. If all trees are left unattended, however, the death of all trees within the next 3-8 years will mean a large spike in tree removal and replacement costs in the next several years, and the amount of trees to be dealt with all at once may overwhelm management resources.

3. "UNDERPLANT" – Plant a replacement tree in anticipation of the original tree's eventual removal: this technique allows us to offset the loss of services provided by the large tree by pre-emptively replacing it before it has died. This will allow for the replacement tree to grow to a more substantial size before the original tree is lost, and will also provide extra green leaf area as the original tree declines. In this way, the costs of tree removal and replacement are spread out, and the loss of services is reduced.

4. "One-to-one replacement"- Every tree removed is replaced by another tree: While this retains the number of trees, it cannot maintain the canopy lost by the removal of larger trees. Since leaf area is the major contributing factor to most services provided by urban trees, the loss of canopy can have significant environmental and financial implications. For example, the loss of ash trees in Michigan state resulted in an overall increase in energy costs (up to 12%), a 33% increase in water costs, increased temperatures, drought, and reduced air quality (Wilson, 2010). It is estimated to take 10 to 15 years for replacement trees to begin to provide these services again, and up to 20 years for trees to reach an optimal functional size (McPherson et al, 1997), and so the removal of a large tree and the replacement with a small tree will result in the net loss of services while replacement trees grow to sufficient size.

5. "Canopy replacement"- This replacement method seeks to replace the leaf area lost by the removal of a tree by planting enough new trees to completely replace the lost tree's leaf area. This increases the replanting costs substantially, and is often limited by the amount of space available, but it has the benefit of eliminating much of the losses associated with large tree removal. In addition, tree services will appreciate over time: as replacement trees grow, the canopy cover will exceed the canopy lost originally, resulting in a net benefit in tree services. Canopy replacement is the best option for high value trees and in situations where canopy cover is important. It can also help in achieving canopy cover and biodiversity targets if implemented properly.

Figure 2.1: The dangers of one-to-one tree replacement as illustrated in an Ottawa suburb, 2012. It will take 10-15 years for the new tree pictured here to begin providing similar services to the original tree, and even longer for these services to reach a level equivalent to what was lost.

3. Methods: The Neighbourwoods EAB management model

The Harbord Village tree inventory was used to locate all ash trees in the area. All trees were re-visited, and the inventory was updated using the Neighbourwoods protocol (appendix II) to ensure that assessments and recommendations were based on the most current, accurate data. In addition to the Neighbourwoods tree condition assessments, information associated with EAB and tree value was collected, and photographs were taken for every ash tree. This data was entered into Microsoft Excel, and trees were mapped using ArcGIS. A model was then developed to assess all ash trees on three main axes of interest: the tree's overall condition, the tree's condition in relation to EAB infestation, and the tree's value relative to the community's interests. The model suggested management options for each tree based on its ranking on these three axes, and these suggestions were mapped and verified before final recommendations were made. Figure 3.1 outlines the general process of the Neighbourwoods EAB management model, and the following sections describe the process in more detail.
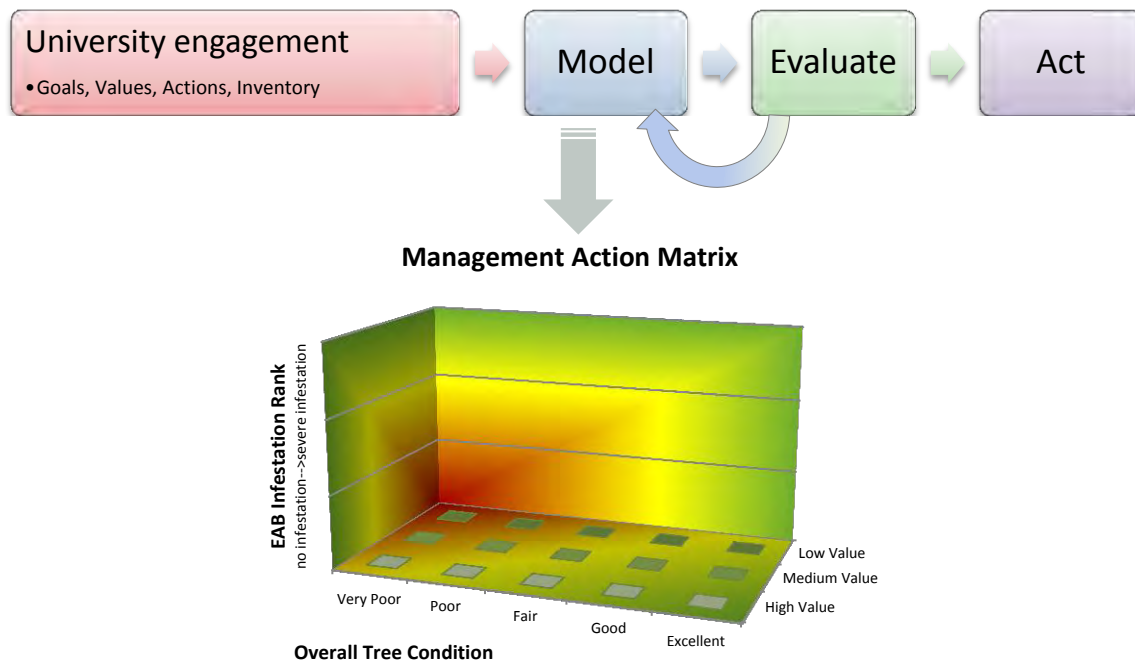
Figure 3.1: the EAB Management Model process involves 4 basic stages. First, the community is engaged to determine goals, values, and preferred management actions. The tree inventory is also updated during this process. Next, data is entered into the model, which provides suggestions for tree management according to the Management Action matrix. Outputs are evaluated and the model is adjusted (step 3), until a final action scenario is agreed upon.

3.1: Data gathering and the Neighbourwoods protocol:

The Neighbourwoods protocol, developed at the University of Toronto, allows for the quantification of relatively subjective tree condition factors with fairly little training, and is therefore ideal for projects that rely on community or student involvement. Appendix II lists some of the criteria gathered using this protocol, as well as a sample field data sheet.

In addition to the traditional criteria, specific EAB assessment factors were included in the inventory (see appendix II). Because Harbord Village is within the EAB quarantine zone for Southern Ontario, we assume that EAB is, or will, infest all ash trees in the immediate future. While other sampling and detection methods are valuable tools for identifying infestation hotspots, our assumption that all trees will eventually become infested with EAB, makes detection within individual trees unnecessary. For this reason, the additional criteria related to EAB symptoms is used to assess the *degree to which* a tree is showing EAB-related stress, and is not to be used as a substitute for other more reliable detection methods. In addition to the Neighbourwoods ratings for defoliation and the number of dead or broken branches, we look for the presence of D-shaped exit holes at eye level, and for woodpecker activity; and rate the level of peeling bark in the branches, balding of the trunk, and the degree to which epicormic shoots contribute to the tree canopy. While all factors except the exit holes may also be contributed to other stressors in ash trees, they are highly correlated with EAB infestation and tree decline (CFIA 2012).
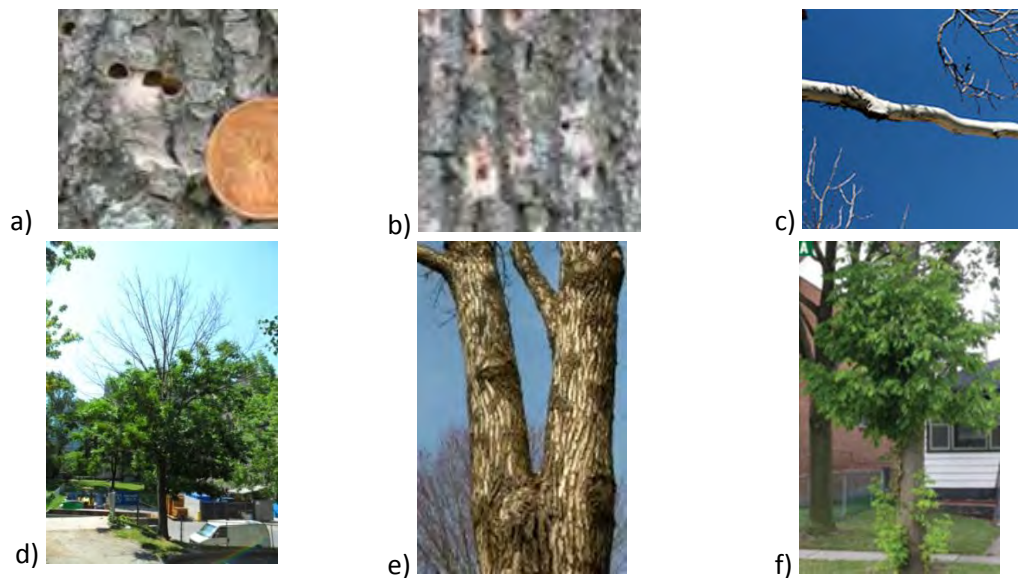

Figure 3.2: signs of EAB related stress in ash trees: a) D-shaped exit holes; b) woodpecker and other animal feeding; c) peeling bark in the branches; d) defoliation from the top-down; e) trunk balding; and f) epicormoc shoots.

3.2: Tree assessment

3.2.1: Tree condition and risk:

Tree condition and risk was assessed using the Neighbourwoods standards, and adjusting for factors specific to ash trees. Trees were sorted into 5 condition categories: Excellent, Good, Fair, Poor, and Very Poor according to the Neighbourwoods standards. Similarly, Tree risk was assessed using the Neighbourwoods scoring system, and then adjusted according to the tree's location. For example, a tree with high-risk features located near a playground retains its High Risk status, whereas a similar tree located in a woodlot far from human activity may not require the same attention, and would have its risk status adjusted down to "moderate."

Table 3.1 factors associated with high risk trees

Score	Definition	Criteria
0	tree is not considered a risk at this time	One or more of: - Sum of risk scores is 0 - DBH is less than 25cm
1	tree is considered a potentially low risk, try to improve condition through selective pruning.	One or more of: - Poor branch attachment = 3 - Rot or cavity in the trunk =3 - Sum of risk scores is less than 4
2	Tree may pose a moderate risk, and should be examined again next year, try to improve condition through selective pruning.	One or more of: - Dead/broken branches =3 - Sum of EAB scores greater than or equal to 4
3	Tree is considered a potentially high risk. Have an arborist evaluate immediately	One or more of: - Lean = 3 - Crack = 3 - Sum of risk scores is greater or equal to 6

3.2.2: EAB infestation score

A score of 0 to 3 was assigned to each ash tree describing the severity of the signs of EAB infestation. This score is not a reflection of the tree's overall condition, but of how likely it is that the tree has been infested with EAB, and how severe this potential infestation may be. Table 3.2 outlines EAB infestation scoring: Trees with an EAB score of 3 have signs of heavy EAB infestation, and are considered beyond saving; trees with a score of 2 may survive for a few more years, however it is not likely that injections will preserve them; and therefore trees with scores of 0 or 1 are considered the only candidates for injection.

Table 3.2: EAB Infestation Scoring criteria

Score	Definition	Criteria
0	No signs of EAB	Sum of EAB scores less than or equal to 3.
1	Some minor issues associated with EAB	One or more of: - Defoliation = 1 - Peeling Branches = 1, 2 - Bald spots on trunk = 3 - Epicormic shoots = 2 - Dead/broken branches = 1 - The sum of EAB scores is between 3 and 5
2	some major issues that are associated with EAB	One or more of: - Defoliation = 2,3 - Animal feeding = E - Peeling branches = 3 - Epicormic shoots =3 - Dead/broken branches =3 - Sum of EAB scores greater than or equal to 5
3	confirmed EAB infestation	D-shaped holes have been found at eye level (D_shaped_holes = "E")

3.2.3: Value scoring

Traditionally, tree value is calculated using dollars for the services a tree provides. However, these methods often have difficulty accommodating non-market values such as aesthetic or cultural importance, and often leave out important considerations beyond the primary concerns of the model. In addition, because dollar values and interest rates are in constant flux, this form of valuation is often time and location specific. To avoid these complexities, we have expanded the Neighbourwoods protocol to include a value scoring system for 6 key tree services and functions: Canopy contribution, Importance to biodiversity, Historic and cultural heritage value, Aesthetic value, Size value for atypically large trees, and Utility value (which encapsulates the various functions the tree performs within the city such as pollution absorption, storm water runoff mitigation, temperature reduction, or energy savings through shading of buildings). Value scores are calculated by the model based on data input from the Neighbourwoods inventory, on a scale of 0 (no value) to 3 (very high value) for each category, and then summed and weighted according to the client's preference. Harbord Village value preferences we weighted according to table 3.3.

Table 3.3: Value rankings for Harbord Village, where 4 is the most important, and 0 is not at all important.

Value Ranking	canopy	biodiversity	heritage	aesthetic	utility	size
Rank (1-4)	3	1	1	4	2	3

Value estimates such as canopy and biodiversity contribution are based on more local areas, such as the functional blocks within the inventory to ensure an even representation across the managed space. This can be further divided into local areas, such as parks, courtyards, etc. as is appropriate when considering the benefits of individual trees. Detailed scoring of these values can be found in Appendix III.

Table 3.4: Definitions of value categories within the Neighbourwoods EAB Management Model

Value category	Model Definition	Criteria Summary
Canopy Function	The contribution of a tree to the canopy cover in the local area. Factors such as local canopy cover targets can be considered here.	Based on Crown Projection Areas (CPA) for all trees, ranked relative to their contribution to the total CPA for that block.
Biodiversity Function	The contribution of the tree to diversity in the area.	Based on the relative contribution of each tree to the CPA. The total CPA for that species within the block. An ideal species distribution would include no more than 20% representation for ash species in a given area.[2]
Heritage or cultural Value	Tree is an important part of the area's history, and should be preserved for this reason alone. (This is entered manually for individual trees, as per the area's history.)	The Ontario urban forest council defines Heritage trees as: "a noble specimen because of its size, form, shape, beauty, age, colour, variety, genetic constitution, or other distinctive features; a living relic that displays evidence of cultural modification by Aboriginal or non-Aboriginal people including strips of bark or knot- free wood removed, test hole cut to determine soundness, furrows cut to collect pitch or sap, or blazes to mark a trail; a prominent community landmark; a specimen associated with a historic person, place or event or period; a representative of a crop grown by ancestors and their successors that is at risk of disappearing from cultivation; a tree associated with local folklore, myths, legends or traditions; a specimen identified by members of a community as deserving heritage recognition."[3]
Aesthetic Function	Trees that are important just because we like how it they look, of the environment they help to create.	This may include trees along important paths, park areas, in gardens, etc., as well as trees that are an important part of the landscaping or ambiance of the local area. This is given on site to each tree
Utility function	This refers to the services that the tree provides to people. This includes decreased local temperatures in summer, wind speeds in winter, storm water runoff, air pollution, light and noise levels, and energy and water consumption, as well as services such as carbon sequestration and water transpiration.	Utility value is calculated by the computer, and considers many values as well as potential drawbacks associated with each tree. Factors such as tree size, location, the porosity of the surrounding area, canopy volume and thickness, as well as potential and existing conflicts with structures and other trees are considered as per appendix….
Size function	This relates to the value added for large trees. The presence of large trees can increase property values, as well as local activity and attitudes.	Based on Relative DBH (R_DBH) or relative height (R_Height) for that species, and for that area.

3.3: The Model and Action Matrix

The model uses the scores calculated above to produce recommendations for EAB management based on specific action inputs tailored to the client's needs and means. First, all trees rated as "High Risk" are identified for immediate evaluation by management, then all special case trees are evaluated individually. Special cases are dependent on the community's needs, and can include heritage or dedicated trees, or trees where future construction plans will call for its removal regardless of management decisions. The final stage of the model involves the "Action Matrix," which consists of suggested actions for trees given their rankings along the three axes of: *Tree Condition*, *EAB Infestation Rank*, and *Overall Value*. The action matrix is adjusted depending on the scenario in question. The default matrix was used for Harbord Village (Figure 3.4).

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[2] Kenney et al. 2011
[3] Ontario Urban Forest Council, 2012
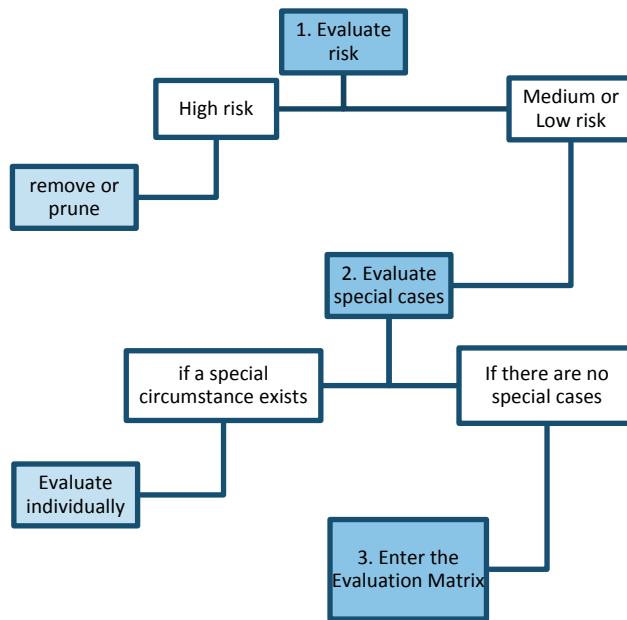
Figure 3.3: Basic decision tree for the EAB management model. All trees that enter the Action matrix in step 3 are evaluated depending on their rankings in the three axes of EAB infestation rank, condition, and Value.

condition_EAB	Treatment		
	High_value	Med Value	Low_value
Excellent_0	Inject now	Inject Yr 2	Leave it
Excellent_1	inject now	Inject now	Leave it
Excellent_2	Inject now	Underplant	Leave it
Excellent_3	Underplant	Underplant	Leave it
Good_0	Inject Yr 2	Inject Yr 2	Leave it
Good_1	Inject now	Inject now	Leave it
Good_2	Inject now	Underplant	Leave it
Good_3	Underplant	Underplant	Leave it
Fair_0	Inject Yr 2	Inject Yr 2	Leave it
Fair_1	Inject now	Inject now	Leave it
Fair_2	Underplant	Underplant	Leave it
Fair_3	Underplant	Underplant	Leave it
Poor_0	Underplant	Underplant	Leave it
Poor_1	Underplant	Underplant	Leave it
Poor_2	Underplant	Underplant	Leave it
Poor_3	Underplant	Underplant	Leave it
Very poor_0	Underplant	Underplant	Leave it
Very poor_1	Underplant	Underplant	Cut
Very poor_2	Underplant	Underplant	Cut
Very poor_3	Cut	Cut	Cut

Figure 3.4: The Action Matrix evaluates a tree's ranking along the three axes of : Value score (High, Medium, Low), Condition (Excellent, Good, Fair, Poor, Very Poor), and EAB infestation rank (0 through 3); and assigns an action based on the contents of the appropriate cell within the matrix.

3.4: Cost Forecasting and Spending Timeline

The initial costs for the first year of management are presented directly in the model output, and are adjusted according to current prices and preferred canopy replacement factors. In addition, a timeline of costs is produced for each subsequent year, using the discount rate of 3%.

Injection costs were estimated from the average of quotes for injection costs provided by the tree care specialists listed in Appendix IV. Because injection must be repeated bi-annually, and injection costs increase as tree size increases, injection costs were estimated for subsequent years using an estimated tree growth factor of 0.69cm/yr. increase in DBH. No tree growth standards are available for ash trees in the Toronto area, therefore we derived our growth standard using DBH data from the University of Toronto database for the years 2003, 2008 and 2012 (Figure 3.5). While this means we have a limited sample size and less than ideal scientific conditions, it does provide a relevant and current estimate of ash tree growth for the immediate area.

The equation shown on the chart is $y = 0.0037x^3 - 0.0609x^2 + 0.3116x + 0.2211$ with $R^2 = 0.9567$. The y-axis is labelled "Average growth rate (cm/yr at DBH)" and the x-axis is labelled "DBH (cm)".
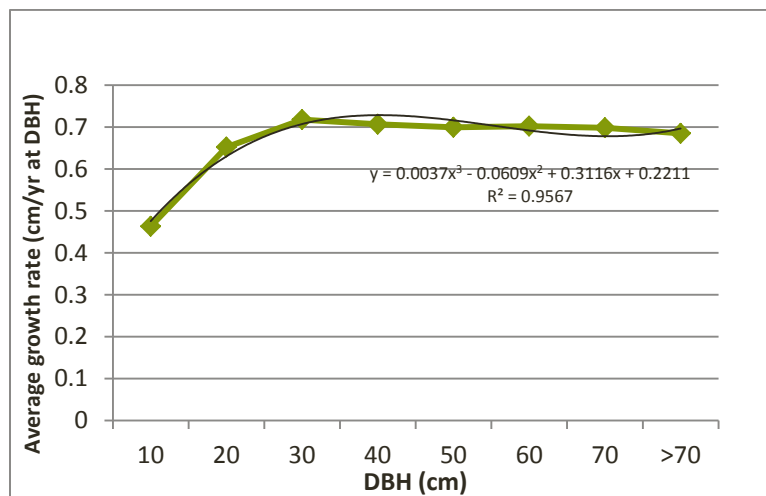
Figure 3.5: Ash tree Growth rate for the City of Toronto

Tree removal costs were estimated based on an average cost of $600 for a 30cm DBH tree with no significant hazards nearby. Tree removal depends on many factors, including tree size, condition, and location, which can all influence the amount of risk to workers and the time necessary to properly remove the tree. In addition, because ash re-sprouts readily, many trees will have to be stumped, an additional cost not calculated here.

Tree replacement costs tree replacement can be done on a one-to-one basis (i.e.: replace a tree with one other tree), or can be calculated according to the number of trees necessary to replace the canopy lost (and therefore to replace the services performed by the original tree). For Harbord Village, a tree replacement ratio of 0.1 (or replacement of 10% of the original tree canopy) was used in consideration of budgetary and spatial limitations within the community.

Table 3.5: Costs used for the Harbord Village EAB management plan.

Treatment	Cost
Injection cost	$6.20/cm at DBH
Tree removal cost	$22/cm at DBH
Tree Replacement cost (includes tree and planting)	$500/ replacement tree
Annual tree maintenance	$2/cm at DBH

3.5: Management timeline

The model output also produces a potential timeline which can help planners to anticipate future costs and long-term budgetary needs. Because EAB is already present on the property, we assume that all trees will die within the next 5 years unless treated (this includes a potential for 2 years EAB-free, and then 3 years to die once EAB has infested the tree). There is a lot of uncertainty involved with invasive pest outbreaks, and the accuracy of predictions decreases as time from present increases. For this reason, the timeline produced by the model is to be used for budget and resource projections only, and actual management actions should be adapted to present conditions.

The model's timeline is based on the knowledge that ash trees typically succumb to EAB infestations within 3 years of initial infestation, while trees that are already showing serious signs of EAB infestation (such as defoliation of more than 25%, or woodpecker feeding) will typically die within the following summer (Wilson 2010). Table 3.6 outlines the "tree death timeline" within our model.

Table 3.6: Projected tree death timeline based on past experience with EAB infestation of urban ash trees, and assuming that it takes no more than 4 years for the tree to completely die.

EAB ranking at yr. 1	0	1	2	3
Projected lifespan	No signs of infestation yet. Expect that tree may stay bug-free for 2 years, after which it may die within 4 years.	Infestation is just beginning, dead by year 4	Infestation is too far gone, dead by year 2	Consider it already dead, as EAB has infested nearly the entire tree.

Table 3.7: The EAB Management Model hypothetical action timeline

Action	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Notes
Inject now	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject every odd year
Inject yr. 2	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Evaluate in fall	Inject in spring	Inject every even year
Underplant	Plant replacement tree if EAB>1	Remove tree if EAB = 2 Plant if EAB =1	Plant remaining replacements	Remove tree if EAB = 1		Remove remaining trees					Plant replacement in yr. 1, remove trees as they die
Leave it		Remove tree if EAB = 2	Replace trees	Remove tree if EAB = 1	Replace trees	Remove remaining trees	Replace trees				Remove trees as they die, replace as needed
cut	Remove tree	Replace tree where possible									Remove trees in yr. 1, replace as needed in yr. 2
High risk	Evaluate in fall, prune or remove as necessary	Re-evaluate									Should be evaluate, and pruned if possible, if not, remove immediately
Special case	Evaluate in fall										Evaluate and treat as needed
Total expected activities:	- Inject 1st batch of trees - Tree evaluations - Underplanting - Tree removals	- Inject 2nd batch of trees - Tree evaluations - Replacements - Tree removals	- Inject 1st batch of trees - Tree evaluations - Tree removal - Tree replacement	- Inject 2nd batch of trees - Tree evaluations - Tree removals	- Inject 1st batch of trees - Tree evaluations - Tree removals	- Inject 2nd batch of trees - Tree evaluations - Tree removals	- Inject 1st batch of trees - Tree evaluations - Tree replacement	- Inject - Evaluate	- Inject - Evaluate	- Inject - Evaluate	

4. Management recommendations

4.1: Summary

4.1.1: Reducing net canopy and service loss

In order to spread out costs and labour over the 10 year timeframe, and minimize loss of functional tree canopy, we recommend a proactive approach. Harbord Village stands to lose over 5,530m^2 of ash canopy - or 4% of the entire tree canopy in the area- to EAB. This represents a significant loss of urban forest services, including increased energy and water usage, increased summer temperatures, decreased winter temperatures, lower air quality, and reduced property values and local appeal. If proactive management is not undertaken, the cost of removing trees as they die will be in excess of $56,300, and the cost to replace lost canopy would be aproximately $1.4 million (Table 4.1). In some areas, as much as a 14% canopy reduction can be expected, increasing local summer temperatures by as much as 2%, and therefore increasing electricity demands by between 2-4% (Akbari et al, 2001; Dobbs et al, 2011).

The EAB management model presents Harbord Village ash trees within the matrix according to their relative value, condition and EAB rankings (Figure 4.1). Overall, 46 of the 116 ash trees are considered of high value, and 7 of these are in excellent condition. These high value trees are most important in providing the services valued by the community, but not all can be preserved due to their condition or the level of existing EAB infestation. In total, 45 trees should be injected, and 26 will require removal within the next 10 years. In order to replace 10% of the canopy lost, 105 trees will need to be replanted.

Table 4.1 : Comparison of tree replacement scenarios

Scenario	Net ash Canopy lost (m^2)	% ash tree canopy lost	# replacement trees	Cost of replacement	Preserved canopy	Cost of preservation	# removed trees	Cost of removal
Do nothing	5530	100%	0	Loss of $1,382,481.90 In trees	0	0	116	$56,303
Proposed model (10% canopy replacement)	2018.5	36.5%	105	$142,168	3287	38,350	71	$27,232
Proposed model with 100% canopy replacement	0	0%	1121	$651,250	3287	$38,350	71	$27,232

The proposed management plan focuses on a 10% canopy replacement scenario. This scenario will preserve 3287.2 m^2 or 59.44% of the ash canopy, and replace an additional 4.05%. This will reduce the net canopy loss to only 2018.5m^2 (or 40.56% of the ash canopy). The cost of this plan will be approximately $143,000 over the next 10 years. These costs are split between the city and the local community according to table 4.2. If Harbord Village seeks to completely offset the loss of canopy (0% canopy loss), 1121 trees will have to be planted, at a planting cost of approximately $651,250 spread over 10 years (an additional $511,720 to the original budget). Spending tends to be higher in the immediate future as trees are cut down and replaced, and level out in later years as injection expenses take over.

Not only does the proposed plan reduce canopy losses, but it spreads costs over time, and lowers overall spending in the long run. Figure 4.2 compares the projected spending for our proposed plan with the estimated costs of a reactive management scenario -- which involves removing trees as they die, and replacing them the following year.
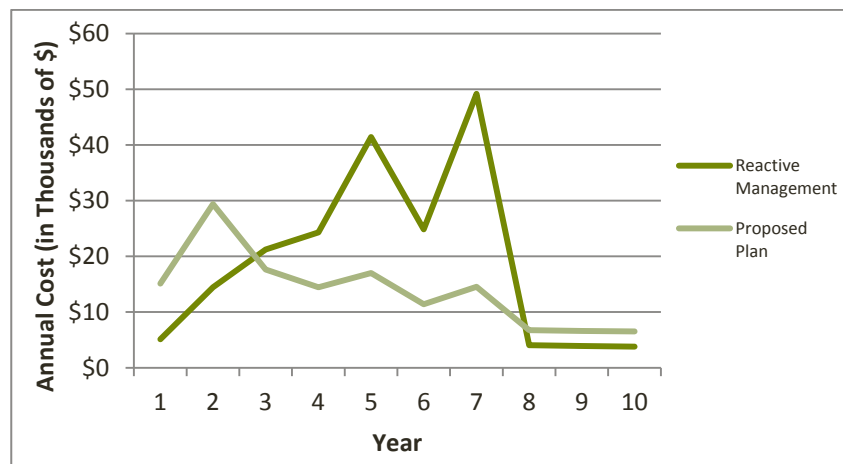
Figure 4.2: Comparison of yearly projected EAB management spending between the proposed management model and a reactive management scenario

4.1.2: Timeline and Budget

The cost of this plan will be approximately $143,000 (Net Present Value) over the next 10 years. These costs are split between the City and the Harbord Village community according to Table 4.2. As is consistent with the pro-active approach, spending will be higher in the immediate future as trees are cut down and replaced, but will level out in later years as maintenance and injection expenses take over (Figure 4.3). Table 4.3 gives a summary of the proposed action timeline for the Harbord Village area, and a complete timeline for individual trees can be found in Appendix VI. While these timelines are tentative and do not account for survival probabilities, they can be helpful in anticipating the expected costs and management demands as the EAB infestation progresses on campus.

Table 4.2: Summary of Management costs according to the ideal model.

	First Year	Over 10 Years
Overall Manageemnt costs	$15,116	$143,168
Cost to City	$10,720	$113,251
Cost to Harbord Village Residents	$4,396	$29,917

Figure 4.3: Management costs of the proposed model overall, and to both managing bodies.

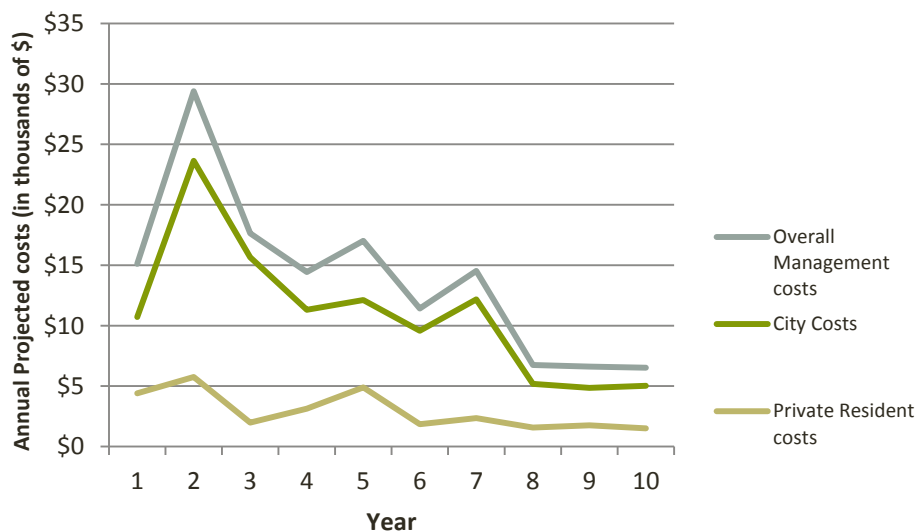*Table 4.3: Proposed budget and timeline for according to the Harbord Village 10-year EAB Management plan.*

Overall Management Plan

	Year	1	2	3	4	5	6	7	8	9	10	10 Year total
Inject	# trees	20	25	20	25	20	25	20	25	20	25	45
	Cost	$4,173	$3,947	$4,094	$3,916	$4,011	$3,876	$3,924	$3,828	$3,834	$3,772	$39,376
cut	# trees	26	13	0	18	0	14	0	0	0	0	71
	Cost	$8,327	$6,428	$0	$8,109	$0	$4,935	$0	$0	$0	$0	$27,799
plant	# trees	2	36	23	0	24	0	20	0	0	0	105
	Cost	$1,000	$17,661	$11,032	$0	$10,638	$0	$8,174	$0	$0	$0	$48,504
maintain	# trees	68	48	84	73	82	77	83	91	96	91	793
	Cost	$1,617	$2,241	$3,047	$2,847	$2,873	$2,948	$2,870	$3,123	$2,978	$2,944	$27,488
Total yearly costs		$15,116	$30,278	$18,173	$14,872	$17,522	$11,760	$14,968	$6,951	$6,812	$6,716	**$143,168**

City tree Management plan

	Year	1	2	3	4	5	6	7	8	9	10	10 Year total
Inject	# trees	15	21	15	21	15	21	15	21	15	21	36
	Cost	$2,790	$2,968	$2,751	$2,962	$2,707	$2,947	$2,659	$2,924	$2,608	$2,893	$28,207
cut	# trees	21	13	0	15	0	13	0	0	0	0	62
	Cost	$5,478.00	$6,428.49	$0.00	$6,504.00	$0.00	$4,703.55	$0.00	$0.00	$0.00	$0.00	$23,114.04
plant	# trees	2	27	23	0	17	0	18	0	0	0	88
	Cost	$1,000.00	$13,304.12	$11,031.63	$0.00	$7,437.56	$0.00	$7,620.70	$0.00	$0.00	$0.00	$40,394
evaluate	# trees	60	39	71	62	72	64	71	77	83	77	676
	Cost	$1,452.00	$1,648.54	$2,346.12	$2,185.36	$2,342.94	$2,213.45	$2,262.04	$2,416.51	$2,391.12	$2,277.79	$21,536
Total yearly costs		$10,720	$24,349	$16,129	$11,651	$12,487	$9,864	$12,542	$5,340	$4,999	$5,171	**$113,251**

Private Tree Management plan

	Year	1	2	3	4	5	6	7	8	9	10	10 Year total
Inject	# trees	5	4	5	4	5	4	5	4	5	4	9
	Cost	$1,383	$980	$1,344	$955	$1,304	$930	$1,265	$904	$1,227	$878	$11,169
cut	# trees	5	0	0	3	0	1	0	0	0	0	9
	Cost	$2,849	$0	$0	$1,605	$0	$232	$0	$0	$0	$0	$4,685
plant	# trees	0	9	0	0	7	0	1	0	0	0	17
	Cost	$0	$4,357	$0	$0	$3,200	$0	$553	$0	$0	$0	$8,110
evaluate	# trees	8	9	13	11	10	13	12	14	13	14	117
	Cost	$164.50	$592.72	$700.82	$661.19	$529.98	$734.94	$608.01	$706.98	$586.93	$666.40	$5,952
Total Yearly costs		$4,396	$5,929	$2,044	$3,221	$5,035	$1,896	$2,427	$1,611	$1,813	$1,545	**$29,917**

4.2: Dealing with EAB in Harbord Village

No ash trees in Harbord Village have been found to have D-shaped exit holes at eye level, which would confirm an EAB infestation beyond manageable levels. However, an individual insect was located in Harbord village during our survey, and 8 trees have been confirmed to be severely infested with EAB on the neighbouring University of Toronto property. Given the severity of the infestation nearby, and the long-range dispersal ability of EAB, we therefore suggest that although EAB is not confirmed in the community, action be taken as if it is already present.

4.3: Dealing with high risk trees in Harbord Village.

There are 4 high-risk ash trees located in areas that make them a safety concern. These are listed in Table 4.4 and pictured in Map 4.1. One of these trees is privately owned, and another is owned jointly by the city and a private resident, but all have a high value to the community. All high risk trees need to be dealt with immediately, but not all need to be removed. In many cases, selective pruning, bracing, or cabling may be able to preserve the tree. High risk trees that are also high value should be visited by an arborist as soon as possible, and any actions that can mitigate risk should be considered. If nothing can be done, the tree will have to be removed and should be replaced immediately to reduce the loss of services provided by the original tree.

Table 4.4: High risk trees and preliminary management recommendations

Tree #	Address	Ownership	Location	Condition and value	Reccomended Action
3.133	630 Spadina Ave.	Joint	FY	Very Poor High Value No signs of EAB	Underplant: Tree is highly valueable but in poor condition.
4.27	546 Spadina Ave.	City	FY	Very Poor High Value Some signs of EAB	Prune and leave: tree's condition can be improved with proper pruning. There is too little space to underplant, so tree should be left as long as possible and then removed and replaced.
4.206	77 Robert St.	Private	BY	Poor High Value Some signs of EAB	Prune and inject now: tree has a large, poorly attached branch and a severe lean, but is otherwise in good condition. Proper pruning can preserve this highly valuable tree.
5.8	302 College St.	City	ST	Very Poor High Value Strong signs of EAB	Cut and replace: because tree is high value it should be replaced immediately.

4.4: Special cases

Special case trees can include those that are dedicated trees, heritage trees, or trees that are scheduled for destruction due to urban development. In the case of Harbord Village, there are only 2 special case trees, both which have particular significance to the owners. Special case trees will have to be treated on a case-by-case basis, and managed at the owner's discretion. We recommend that they are assessed immediately and appropriate management actions decided upon. Table 4.5 lists the special case trees in Harbord Village, both are on private property and of high value to the community. We recommend that some financial assistance be provided to the owners in order to help maintain the services these trees provide.

Table 4.5: List of special Case trees in Harbord Village and our recommendations.

Tree #	Address	Ownership	Significance	Condition and value	Risk	Action
6.184	235 Major St.	P	Large tree, owner is preserving at all costs	Excellent High Value No signs of EAB	No risk	Inject in year 2. This is one of the largest ash trees in the area, and a major source of shade and leaf area in the immediate area. It is not showing signs of EAB and so injection can wait until next year.
8.124	80 Robert St.	P	This is a LEAF backyard tree, planted at owners request	Good High Value No signs of EAB	No risk	Inject in yr. 2. This tree is in good condition and of high local value. It does not have signs of EAB, so can likely be injected in the second year

Map 4.1: High risk trees (red triangles), special case trees (yellow stars), in the Harbord Village area.

4.5: Tree preservation

Trees that are in fair condition, with relatively little signs of EAB infestation are considered for preservation. In general trees greater than 20cm DBH can be effectively treated in the long-term, while smaller trees may not be as easily protected. For this reason, alternative options, such as underplanting, should be examined for trees smaller than 20 cm DBH. These smaller trees may also be treated temporarily until replacement trees have grown to sufficient size.

Tree preservation can be divided into even and odd years to stagger costs. Trees that should be treated immediately are those that are either very important or that have an EAB score of 1 (this indicates that the symptoms of EAB are manageable now, but will likely be too extreme in the following season). Trees with an EAB score of 2 are likely too far gone to be effectively preserved, but may be treated with the understanding that preservation success is low. Tree preservation costs would total $38,350 over 10 years if TreeAzine is used, with an initial budget of $2,790 for city and $1,382 for private tree owners. A list of trees selected for preservation in even and odd years is provided in Appendix V.

Table 4.6: Summary of Tree preservation actions according to the Model outputs.

	odd years	even years	Total
Overall	20	25	45
City	15	21	36
Private	5	4	9

4.6: Tree removal and replacement

In addition to the high risk trees, high value trees that are beyond preservation will have to be removed and replaced. Low value trees, and those in very poor condition will also have to be removed. Any tree left unattended is likely to die within the next 5 years (depending on the current level of EAB infestation it may be sooner, however we estimate that all trees in the area will have EAB within 2 years, and will die within the following 3 years), and will also have to be removed. Tree replacement is subject to the discretion of the landowner, but we suggest that a one-to-one approach, while the most cost effective, may not preserve all of the services and values of the area's forest. We suggest that canopy-based replacement in conjunction with underplanting would better mitigate the loss of tree services, and increase the community's green capital over time.

The model factors in the following management actions based on tree condition, location, and value:

1. "CUT" - If a tree is deemed to be in very poor condition, or has severe signs of EAB infestation, we recommend the pre-emptive removal of the tree.

2. "LEAVE IT" - Leaving a tree is recommended for low-value trees; large trees that cannot be preserved, but still have high value; or trees with special circumstances that make it's pre-emptive removal redundant (such as planned construction which will destroy the tree).

3. "UNDERPLANT" – If a tree is valuable, but not suitable for preservation, underplanting is considered where space is available.

Tree replacement options can be either one-to one, or based on preserving a proportion of the canopy. The EAB model was set to preserve 10% of the original canopy, in consideration of financial and spatial constraints for Harbord Village, and the number of replacement trees was adjusted manually where space was too limited. Canopy replacement is the best option for high value trees, and in situations where canopy cover is important.

Table 4.7: Summary of Harbord Village trees selected for removal, underplanting, and those that can be left until they die.

	Remove	Underplant	Leave
overall	26	7	38
city	21	7	34
Private	5	0	4

Map 4.2. : Harbord village Ash Trees and proposed treatments: inject year 1 (bright green), inject year 2 (blue), underplant (yellow), leave (orange), and Cut (Red).

4.5: Additional reccomendations:

Monitoring: Timelines provided are necessarily only estimates of the trajectory of the EAB infestation in Harbord Village. Until EAB is effectively controlled, all ash trees will require regular monitoring, and the management plan will have to remain adaptive to the increasingly unpredictable nature of the situation. Specifically, we recommend that all injected trees be re-assessed the fall prior to injection in order to allow for time to alter any plans before their subsequent injection the following spring. Similarly, all remaining ash trees should be re-assessed every 2 years in order to allow time for management adaptations should the EAB infestation not progress as expected, and a complete re-evaluation of all Harbord Village trees should be conducted in year 5, allowing for an updated management plan.

Urban Forest Planning: Despite tree losses to EAB, overall benefits to the community can be enhanced with proper forest planning from this point on. The first step would be to replant as much canopy as possible, and to choose appropriate replacement trees. Highly invasive trees such as Norway Maple and Tree of Heaven should be avoided, while other less invasive, or native trees should be planted with consideration to local diversity and ecosystem function. A list of potential native replacement trees is provided in Appendix VIII.

When re-planting in Harbord Village, the 10:20:30 guideline should be used as a bare minimum for diversification. This standard stipulates that the local tree community should consist of no more than 10% of any one species, 20% of any one genus, and 30% of any one family (Subburayalu & Syndor, 2012). Because invasive pests and diseases such as EAB can wipe out more than one species or genus at a time, we recommend that the more diverse a forest is, the more resilient it will be to future attack. Considerations of tree function within the larger ecosystem can also help to build an adaptive and resilient urban forest.

The strategic placement of trees can also help increase the functional abilities of the forest. Some tips to increase the energy efficiency of the community through strategic tree planting are presented by McPherson et al. in 1997: Energy efficient landscapes include a diversity of shade trees, shrubs, and vines. Large trees to the West and Sout- West are the best at reducing summer cooling costs through shading, and deciduous trees with dense canopy and an open understory are best placed on the East side of buildings. For protection from winter winds, evergreen windbreaks to the North and North West can be useful (McPherson et al, 1997). A functional and sustainable urban forest requires that we consider the long-term growth of the trees we are investing in. Proper rooting areas, irrigation and soils can go a long way in reducing maintenance costs, promoting the rapid development of functional trees, and ensuring that these trees reach their maximum potential.

Trees with dense canopy provide the best shade:
sweetgum (Liquidambar styraciflua),
Tulip poplar (Liriodendron tulipifera),
black oak (Quercus velutina),
pin oak (Quercus palustris),
dogwood (Cornus florida),
red maple (Acer rubrum),
Eastern Red Cedar (Juniperus virginianus),
Southern shagbark hickory (Carya carolinae septentrionalis)

5. Afterwards: Wood utilization and disposal

5.1: Further research

This is the first test of the Neighbourwoods EAB Management Model, and therefore we expect that subsequent trials may highlight areas for improvement. We recommend that this model be run with other datasets and in other municipality in order to test model robustness and generalizability. Furthermore, a test of the model's value assessments in relation to other tree valuation models will allow for the quantification of the model's accuracy relative to established standards. In addition, the development of this model has highlighted various knowledge gaps that could be filled. These gaps include:

Urban ash tree growth and yield curves for Toronto and Southern Ontario: As of yet, there are no accurate growth rate curves for ash species in this area. The growth rate used here (of 0.69cm increase in DBH per year) was derived from growth data gathered at the St. George campus between 2003 and 2012. It is a good approximation of current growth rates, but more work would be required to make a robust and defensible growth rate prediction.

Tree value evaluation standards for urban area. Our model adds tree values in order to the relative importance of a tree to the community. However, some standards lack scientific support either because they are subjective in nature (such as aesthetic value), or extremely difficult to define (such as biodiversity value, which has no established standard for urban areas).

In addition, research into species specific pollution mitigation capabilities, and social surveys to more accurately gage the true values that local people place on the urban forest could help to increase the usefulness of this model.

5.2: Outreach and education

Public outreach related to the community's proactive approach to the EAB situation can bring positive attention to Harbord Village and its residents, and may inspire other communities to take similar actions. Possible outreach activities can include:

- Publicizing Harbord Village's actions regarding EAB. The effective use of media and informative signage can help to raise support and awareness for the community's efforts.
- Informing residents of local EAB management activities posters, signs, and public speakers.
- Ash tree identification and promotion of the importance of urban trees. The EAB situation is an opportunity to raise awaremess about the importance of urban forests.

Labeling trees selected for preservation or removal (for example thorugh posters placed directly on trees, figure 5.1) can help put a real-world face to the EAB crisis, and bring attention to the value of the community's trees.

Figure 5.1: In some US communities, ash trees were identified with humourous labels, and the community response was overwhelmingly positive.

5.3: The use of ash wood:

The surplus of wood for dead ash trees presents a unique opportunity to the community. Wood can be mulched and used to improve the condition of other neighbourhood trees and gardens, or it can be used in partnership with the University of Toronto for research and development purposes. For example, the Faculty of Forestry is currently experimenting with the generation and use of "biochar" (biologically derived charcoal) as a fertilizer. Initial studies suggest that biochar may also be able to mitigate and even offset the negative impacts of some forms of pollution such as road salt. Ash wood can be used by the university as the primary material for biochar creation, and this biochar can be used within Harbord Village to further forest resource research, with the potential of improving conditions for local plants along the way.

Other wood products, such as flooring and furniture can be made out of ash wood, since EAB only causes damage to the trees' cambium, and not its usable wood. In addition, should important trees have to be removed; the loss of this tree can be reduced if it is converted into a celebrated community artifact such as a sculpture, or furniture for a park. A similar approach was taken in Ottawa, when a large tree of significance to the community was removed due to EAB. This tree was used to create the sculpture (figure 5.2), which is now on display at a local college. Urban wood can also be used to make unique furniture due to its interesting growth patterns. A local Toronto company, Urban Tree Salvage, has had great success in re-using urban wood for high end furniture (visit: http://urbantreesalvage.com/).

Figure 5.2: Ash wood can be re-used within the community in various ways: a) a sculpture made form a heritage ash tree in Ottawa and b) unique furniture made from re-cycles urban trees by Urban Tree Salvage.

6. Conclusions

While the benefits of a large, healthy and resilient urban forest canopy are difficult to quantify, there is ample evidence that the urban forest -- of which Ash contributes up to 14% in some areas of Harbord Village – is not important to the city's infrastructure, but also provides a great deal of benefits to local residents. In addition to the pollution absporption capacity of urban forests, their ability to reduce stromwater runoff, flooding, and drought, and the many ways in which shade trees save residents money through water and energy use reductions, urban trees have been linked with better overall human health, reduced incidence of ADHD symptoms in children, increased concentration in schools, reduced crime and overall increased neighbourhood safety, as well as increased worker productivity and workplace satisfaction (Wolf, 2004). If these boons to human well-bring are projected forward to their indirect effects on local consumption and productivity, the economic importance of a healthy urban forest become clear.

Because ash trees are so dominant in the urban landscape, their loss to EAB can have devastating consequences on our community and local infrastructure. Ash trees are an important species in many forest types in the Great Lakes region (Gucker, 2005), and urban trees can be a seed source for the regeneration of this resource once EAB has moved on. In addition, the abundance of Ash trees in Harbord Village suggests that action be taken immediately to preserve what we can, and manage the rest to offset any loss of tree services due to EAB. Pro-active action can not only mitigate losses to the community, but can also help to re-design a better, more resilient urban forest in Harbord Village.

EAB presents us with an opportunity to design a better, more resilient local forest. Pro-active management, as outlined in this proposal, can help to mitigate tree service losses while at the same time providing the opportunity to improve local forest structure. It is integral that tree replacement be focused on canopy, rather than the one-to-one approach, and that at least 10% of the canopy is replanted for every tree lost. A focus on planting the right tree in the right place, on improving local growing environments, and on encouraging diversity and ecosystem function should be the top priority of any responsible urban forest management plan when faced with a crisis such as EAB.

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8. Appendices:

I.	Signs of Emerald Ash borer Infestation
II.	The Neighbourwoods Protocol and additional factors for the EAB Management Model (plus sample field data sheet)
III.	Value Scoring
IV.	List of Tree Care Providers
V.	List of Management actions for all trees
VI.	Recommended ash tree actions according to the proposed EAB management plan
VII.	Proposed Action and Budget Timelines
VIII.	Replacement tree options