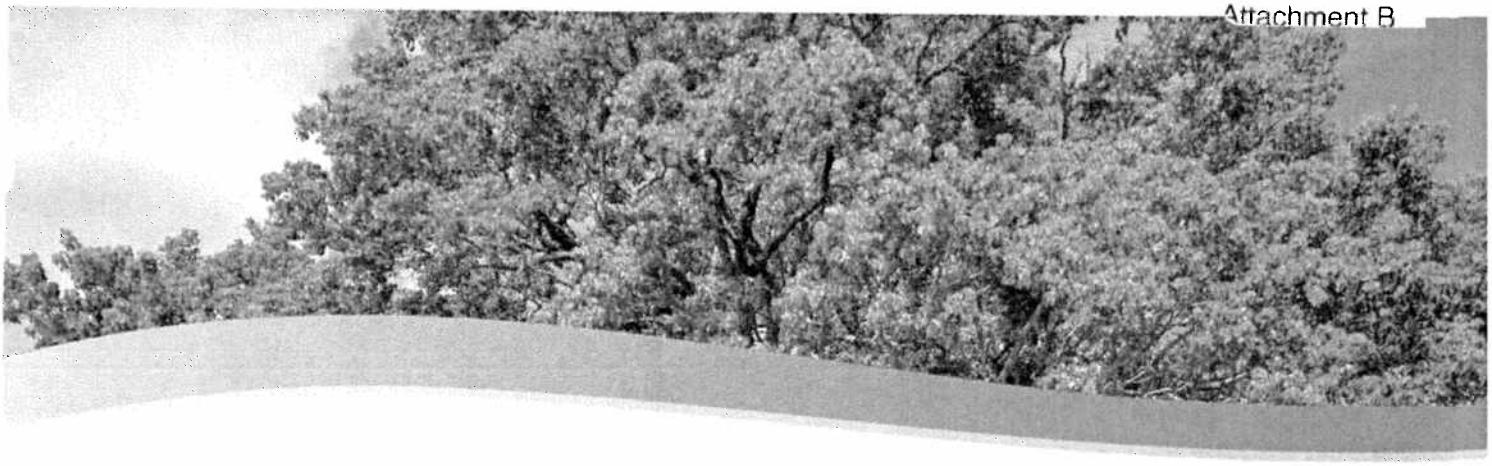

EMERALD ASH BORER STRATEGY

City of Markham, Ontario

November 14, 2012

Prepared for: **City of Markham**

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Executive Summary

Markham, Ontario currently faces a serious threat to a large portion of its public and private green infrastructure. The emerald ash borer (EAB), *Agrilus planipennis Fairmaire*, is an invasive and exotic pest which has infested ash trees throughout Markham and surrounding communities, resulting in the demise of large numbers of ash trees. At this time, it is estimated that approximately 50-100 million ash trees have already been killed due to EAB, with over 17 billion trees at risk in the United States alone. The impact to the urban forest is greater in scope than Dutch elm disease, and progression is rapid, now spreading across Ontario, Quebec, and 17 US states.

The EAB larvae feed on the inner bark, disrupting the tree's ability to translocate water and nutrients. It is believed that EAB arrived in the United States from its native Asia on solid wood packing material carried in cargo ships or airplanes. **EAB is a very serious pest with the potential to destroy all ash trees if left uncontrolled.** Trees are key components of the urban environment and contribute greatly to the quality of life in Markham. They provide residents interaction with nature, relaxation, and recreation in ways that enhance a sense of community. In most communities, particularly in highly urbanized areas experiencing expansive growth such as Markham, residents view trees as great assets. However, providing adequate maintenance for public trees within a budget is a common concern for communities, especially in populations affected by EAB.

Markham Forestry staff has been on active alert for the presence of EAB for several years, initiating partnerships with government agencies such as the Canadian Food Inspection Agency and York Region, as well as updating its tree inventory to assess the condition of trees impacted by EAB. The City of Markham Forestry Section is now developing a comprehensive strategy to protect the best candidate ash trees, and manage the large number of tree removals and replacements that will be necessary as EAB kills large numbers of ash trees. Decisions must be made regarding removals of trees that either cannot be protected because their level of infestation is too high, or should not be protected because the cost of protection exceeds the tree's value to the community. Recent experience throughout North America shows that management options decrease as infestation progresses. This strategy includes recommendations for public lands including mowed and maintained areas of parks and street boulevards. Public woodland recommendations will be made in conjunction with York Region consultation in the near future. Recommendations for privately owned ash trees within Markham will be made at a later date with community consultation. Privately owned trees occur on residential sites, campuses, commercial properties, and in privately held woodland settings.

The inventory completed by City of Markham Urban Forestry staff in 2012 indicates that Markham's current publicly owned ash tree population along streets and in manicured areas of parks stands at 16,738 trees.

A 2012 study of Markham's tree population on both public and private lands in the Urban Growth Boundary (UGB) indicates that approximately 283,950 ashes occur on both public and private lands. This study, known as an Urban Forest Study shows that ash comprise 9% of the total number of trees and 9% of the City's total leaf cover. The Urban Forest Study is a complex, peer reviewed method of measuring and analyzing trees in a community and calculating the benefits that these trees provide (Nowak, 2003).

EAB has started to kill ash trees within the City, and tree mortality will increase rapidly over the next few years. Decisions must be made about which trees are the most economically feasible and of high value to

the community to be considered for protection. Additional decisions must be made about how to deal with the large number of ash trees that will die. Trees will need to be treated repeatedly for the next 15 years, or after the threat of EAB has passed. Untreated ash trees will need to be removed over a 10 year period. The most hazardous will be removed first, and then systematic removals may occur along blocks to increase efficiency and mitigate costs.

With such a large scale removal planned, the City also needs to give strong consideration to replanting enough trees to compensate for the impact of the loss of so many trees. The 2012 Urban Forest Study that measured the benefits that urban trees provide to Markham indicates that ash trees in Markham's UGB have a value of approximately $ 47 million dollars. Replanting the ash component of the City's urban forest is a critical part of maintaining the value of the urban forest.

The City plays a leading role as the responsible steward of its urban forest, to take steps to cost-effectively and efficiently protect or remove public ash trees. This report recommends short and long-term planning strategies that will help plan for, minimize, and spread out the potential impact of EAB on Markham's urban forest and forestry program. The total cost of the 15 year strategy is estimated to be $15.4 million dollars which includes treatment, removals, wood disposal, replanting, and ongoing monitoring and program costs. The bulk of the program occurs is the first 7 years, at a cost of $13.3M when removals and replanting will occur.

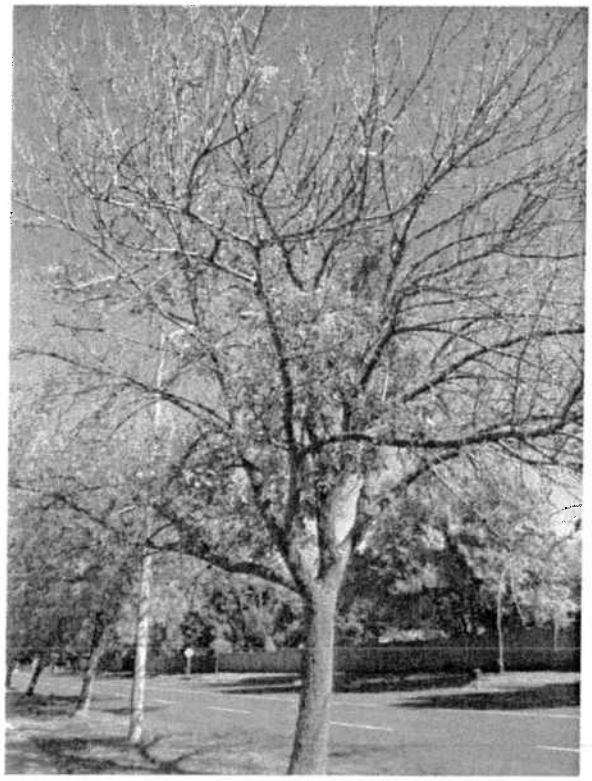


Figure 1. Infested Ash Tree.

Review of Current Knowledge of EAB and Management Strategies

EAB Background and Biology

EAB is currently the biggest threat to Markham's urban forest. The emerald ash borer is an invasive species from Asia that kills all ash trees, including *Fraxinus americana* (white ash), *F. nigra* (black ash), *F. pennsylvanica* (green ash), *F. profunda* (pumpkin ash) and *F. quadrangulata* (blue ash). Mountain ash (*Sorbus* spp.) does not belong to this genus, hence it is not at risk. EAB has already destroyed 50 to 100 million trees in Canada and the United States, and is expected to decimate approximately 7.5 billion ash trees in the United States alone. First detected in Detroit, Michigan and Windsor, Ontario in 2002, the borer has spread aggressively, with infestations identified in Norfolk County, City of Toronto (2007), Mississauga, Oakville, Brampton, Vaughan and Ottawa (2008), Hamilton (2009) and recently in Richmond Hill (2011).

EAB has firmly established itself throughout the northeastern United States and southern Ontario, reaching as far as Montreal, Quebec by 2011. The borer is believed to have been transported to North America in wood packaging material or dunnage on merchant ships, and then migrated to urban trees. Its spread was subsequently facilitated by the movement of infested firewood and nursery stock. The life expectancy for an infested ash tree is normally three to five years, but serious decline can be seen in as little as one year, as seen from this photo taken in London, Ontario in 2009. The previous year, these ash trees appeared to be in good condition, with full canopies.

It is important to understand the dramatic mortality curve of EAB infested trees. While symptoms may appear relatively insignificant at the onset of the infestation, trees die within just a few years, creating operational challenges for municipalities trying to keep up with removals.

Figure 2. Ash trees showing serious decline in one year in London, Ontario

The Canadian Food and Inspection Agency (CFIA), is the federal agency responsible for regulating introduced Forestry and Agriculture pests through the Plant Protection Act. The CFIA has the lead role for the management and regulation of the EAB. CFIA update Link:

http://www.inspection.gc.ca/english/corpaffr/newcom/2011/20110325e.shtml

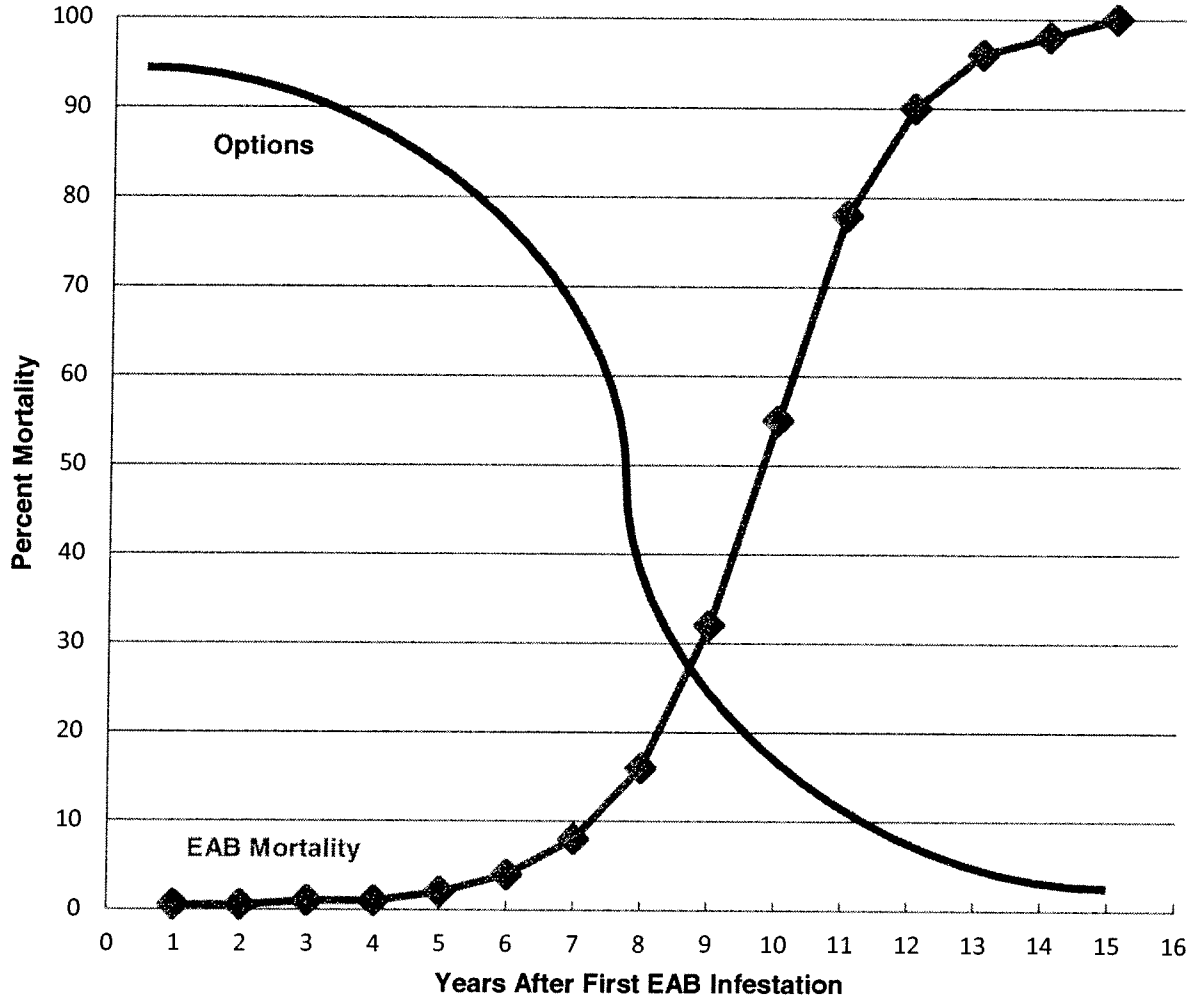


Chart 1. The inverse correlation between ash mortality and management options: as the mortality rate increases, management options decrease.
Source: Jim Zwack, Technical Director, Davey Tree Expert Co., based on data from Dan Herms, Ohio State University.

Identification of the Insect

Agrilus planipennis (Fairmaire)

The adult beetle is a dark metallic green, 8.5 mm to 14.0 long and 3.1 to 3.4 mm wide. The head is flat and the vertex is shield-shaped. The eyes are bronze or black and kidney shaped.

Mature larvae are 26 to 32 mm long and creamy white. The body is flat and broad shaped. The posterior ends of some segments are bell-shaped. The abdomen is 10-segmented. The first 8 segments each have one pair of spiracles and the last segment has one pair of brownish, pincer-like appendages.

Maturing insects emerge from late May until early August, feeding on leaf margins. Females lay eggs deep into bark crevices on lower main branches. After eggs hatch, the larvae tunnel through the bark creating serpentine galleries, while feeding on the phloem and outer sapwood along the entire bole and larger branches (greater than 2.5 cm in diameter) in the crown. In addition to infesting mature trees, the insects will also attack young saplings. Fully grown larvae overwinter under the bark, or sometimes in pupal cells made of outer sapwood. There is one generation per year, but some larvae can remain in the tree for two years. The intense tunneling the larvae create obstructs the tree's ability to transport water and nutrients from its roots to its canopy, causing dieback and eventually death. Trees typically lose between 30 and 50% of their canopies during the first year of infestation. Once mature, the new adults chew 3.5 to 4mm diameter, D-shaped holes to emerge from the tree.

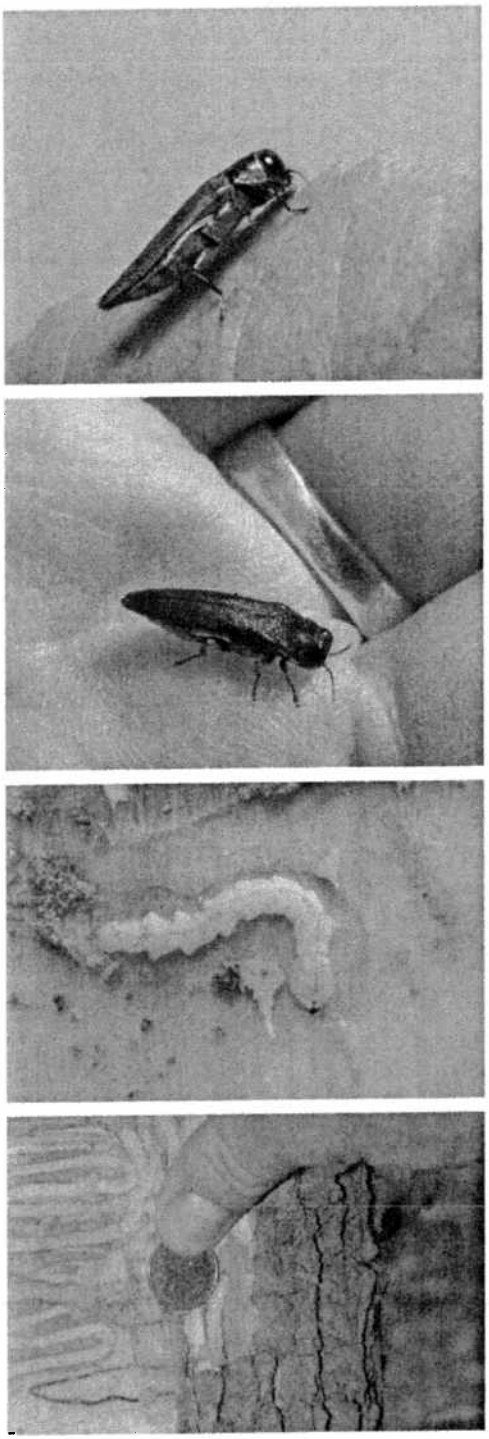


Figure 3. Emerald Ash Borer. *From top*, adult beetle feeding on ash leaf; adult beetle on hand; larva; larva and serpentine galleries.

EAB Life Cycle

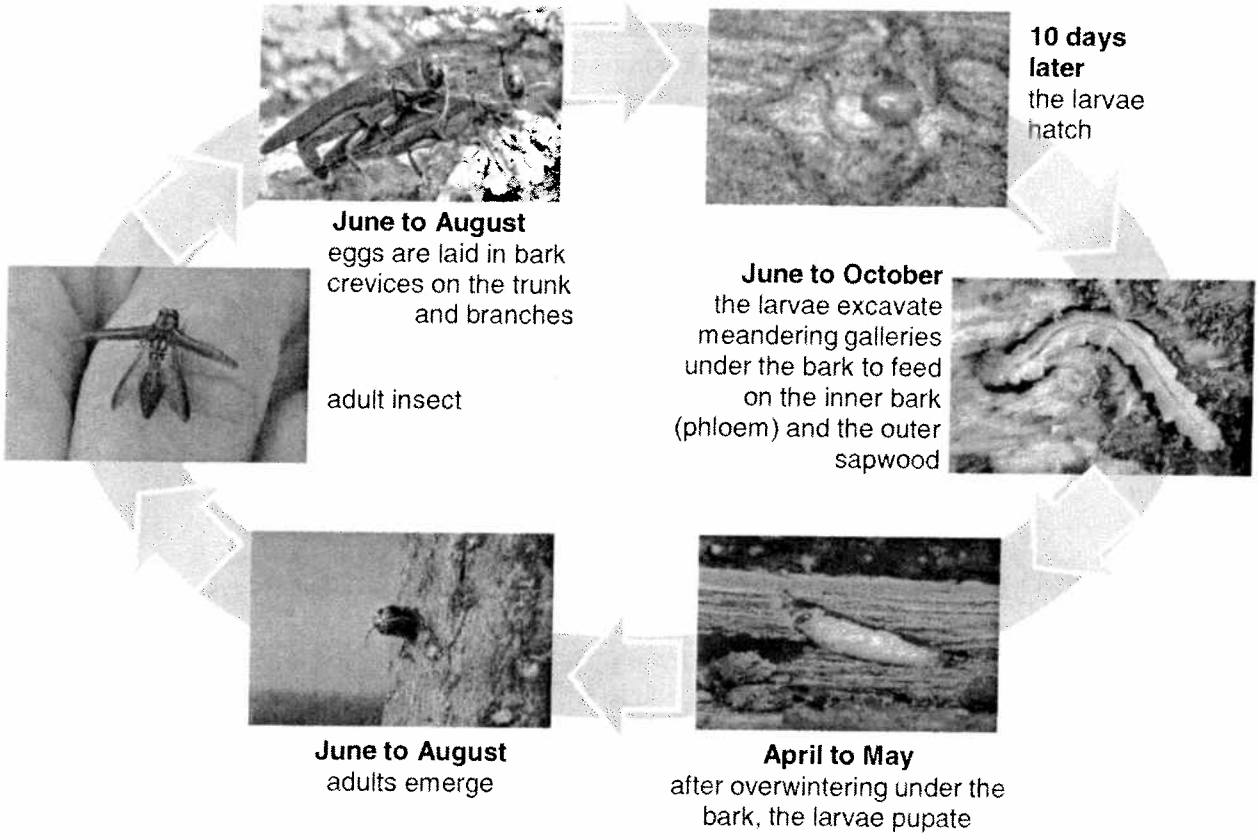


Figure 4. The EAB life cycle: from egg to adult beetle.

Symptoms of EAB infestation

Initial symptoms include yellowing and/or thinning of the foliage and longitudinal bark splitting. The entire canopy may die back, or symptoms may be restricted to certain branches. Declining trees may sprout epicormic shoots at the tree base or on branches. Removal of bark reveals tissue callusing and frass filled serpentine tunneling. The S-shaped larval feeding tunnels are about 3.5 to 4mm diameter. Tunneling may occur from upper branches to the trunk and root flare. Adults exit from the trunk and branches in a characteristic D-shaped exit hole that is about 3.5 to 4mm diameter.

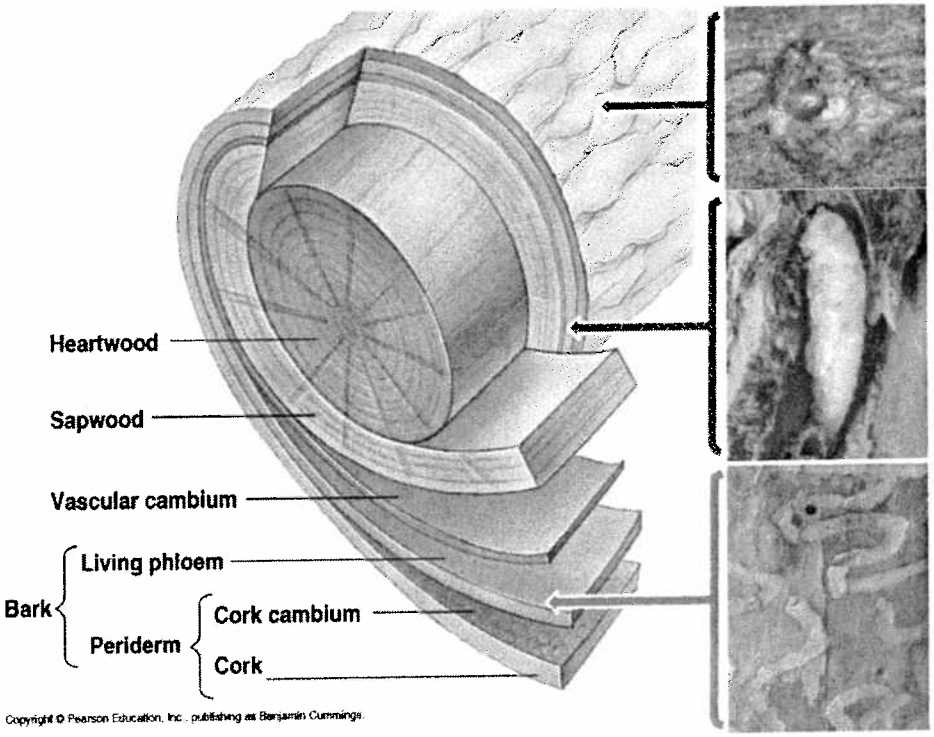


Figure 5. Parts of the tree stem affected by the EAB.

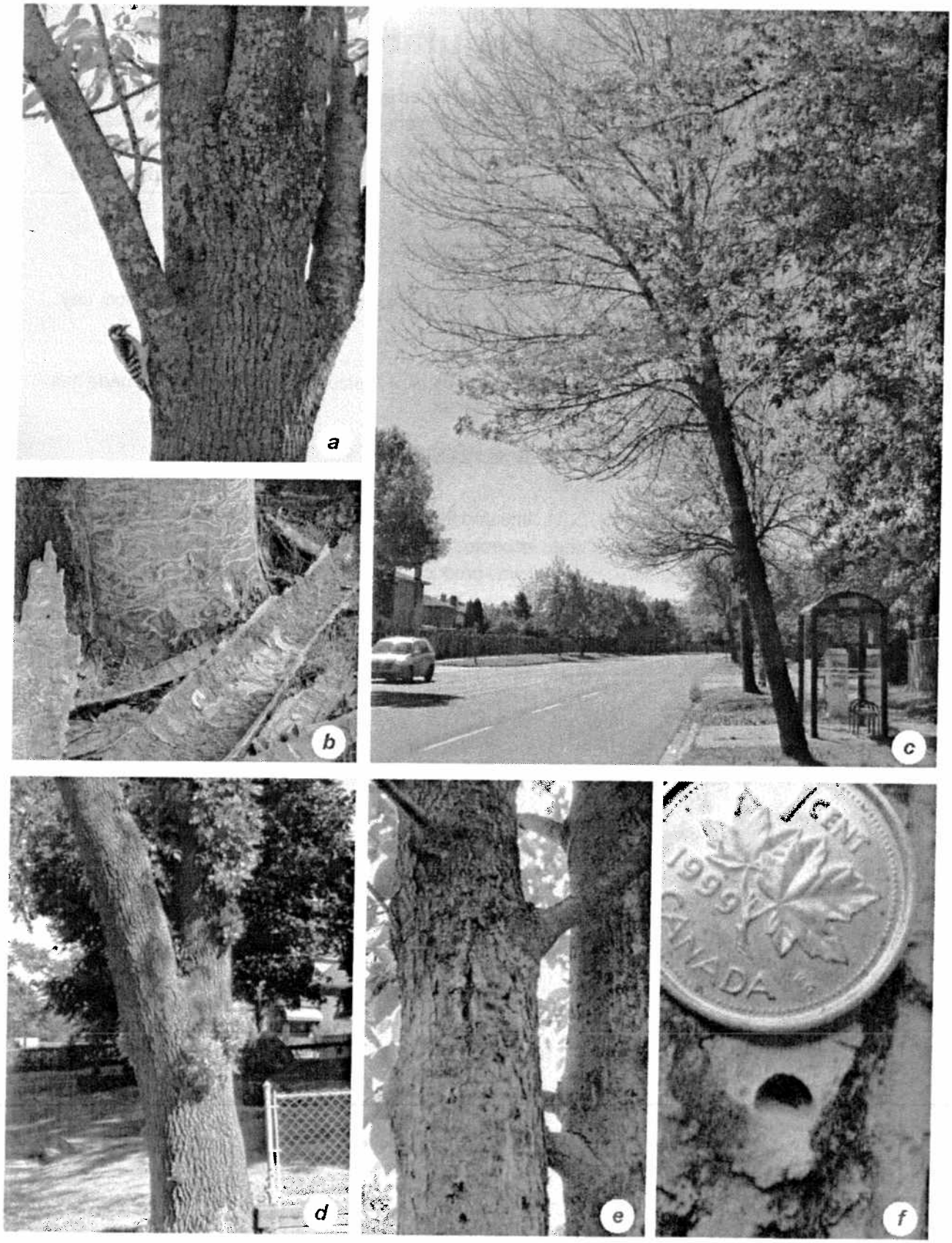


Figure 6. Symptoms of EAB infestation: *a*, woodpecker activity; *b*, larval galleries; *c*, crown thinning; *d*, epicorm ic shoots; *e*, vertical cracking; *f*, D-shaped exit hole.

EAB Quarantine and Regulated Areas

Markham is located within the EAB quarantine area established by the Canadian Food Inspection Agency (CFIA) in 2008, after the presence of EAB was confirmed in York Region. The quarantine restricts the movement of infested wood and nursery stock in an attempt to impede the rapid and artificial spread of the borer caused by human activities. More precisely, the EAB quarantine prohibits the removal of the following items from the quarantine area:

- The living emerald ash borer in any development stage.
- Firewood of all species.
- Ash trees, nursery stock, logs, lumber, wood, bark, firewood, and wood or bark chips from any species in the genus *Fraxinus*, other than seeds.

To slow the spread of the infestation, the Federal Minister of Agriculture and Agri-Food Canada has issued a ministerial order that covers the areas affected:

http://www.inspection.gc.ca/plants/plant-protection/insects/emerald-ash-borer/ministerial-orders/eng/1337373086853/1337373166199

There are provisions from the March 23, 2011 "Infested Places Order" that permit the movement of treated wood products if the product has been inspected and approved for transport. The order also permits the movement of ash nursery stock that was produced outside of the quarantine area to be moved through the area if it is in enclosed containers. The full "Infested Places Order" is also found in Appendix H.

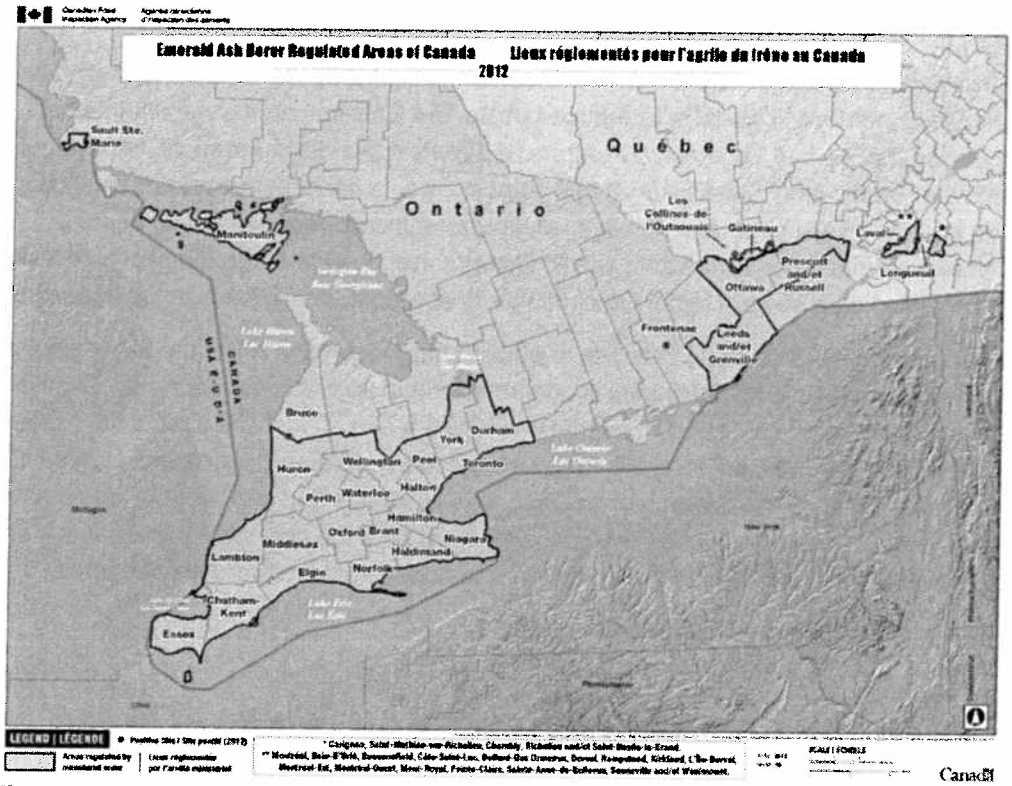


Figure 7. CFIA EAB quarantine map.

Management Strategy Options

Managing EAB impact to the urban forest is one of the most critical challenges currently facing North American forestry departments. Typical of introduced pests, the EAB has no natural enemies of significant population, hence has aggressively entrenched itself in the North American ecosystem. It is essential to note that eradication of the EAB, at this point in time, is no longer possible. The first symptoms of an infestation are generally visible a full year after the adult insects have become established. There are limited pesticides available in Canada that provide control; however, the decision to treat should be based on a several factors, including efficacy, cost, and impact on the ecosystem.

There is a full spectrum of EAB control strategies in place throughout North America. Strategies range from cutting down all ash trees once the insect is confirmed within 25 km of a community, to developing a chemical treatment approach on selected trees that involves the use of pesticides requiring repeated injections throughout the serviceable life of the tree. Despite many different approaches, the common element of current strategies is the combination of both tree injections and removals. These plans aim to treat only healthy, well-structured ash trees that are of high value to the community and canopy cover, while removing those trees that are in poorer condition and provide fewer community benefits.

The reported strategies can be categorized as follows:

Option A: Removal of all ash trees

This strategy proposes the removal of all of a community's ash trees once the EAB has been detected , presuming that chemical treatments are not cost-effective, safe or effective. While this strategy is uncommon in 2012, it was the only option available to many communities early in the EAB battle, before the efficacy of chemical options was understood.

Good forest management practices rarely advocate the removal of single species without a plan for replacing it, either by replanting with desirable species or encouraging natural regeneration. Without proper planning, the proliferation of unwanted, invasive species, such as buckthorn, will increase dramatically.

The price tag for ash tree removals must also consider expenses beyond the initial cost of removing the tree and stump. Replanting costs should be factored in, as a municipality should anticipate the loss of the full range of ecological benefits that the tree provided. For a community with a significant population of mature ash trees, the loss in terms of cooling, stormwater reduction, and energy saving potential can be considerable.

Option B: Chemical treatment of all ash trees

Limited options are available in Canada for controlling EAB. The Pest Management Regulatory Agency (PMRA), a department of Health Canada, extensively evaluates and approves pest control products for Canada according to the Pest Control Products Act. Only three pesticides have been approved for use against the EAB in Canada:

- TreeAzin™, a systemic bioinsecticide with the active ingredient azadirachtin, an extract from the neem tree native to India
- Confidor®, an imidacloprid product

- ACECAP®, an organophosphate based on acephate

Option C: Targeted ash tree removal in conjunction with targeted chemical treatment

This strategy combines both removals and chemical treatment to affect effective control of EAB damage. It also corresponds with the best management practices described by the Coalition for Urban Ash Tree Conservation, an organization composed of twenty-one universities and colleges, non-profits, private institutions and public agencies to promote the protection of ash trees where economically practicable. Notable universities include Ohio State University, Michigan State University, the University of Wisconsin, and Purdue University, all of whom are at the forefront of EAB research.

In the organization's February 2011 "Emerald Ash Borer Management Statement", the Coalition states:

> In view of the unprecedented scope of this problem, a broader, integrated approach that conserves ash canopy and preserves existing benefits that living ash trees provide may make more sense. The challenge of managing EAB is determining how to incorporate sound, science-based methods of management into existing knowledge for the benefit of our citizens and the environment.

The full text of the report can be found in Appendix G.

The principles of sound, science-based methods of management should be primary factors in developing EAB programs, including using tree inventory data, assessing infestation levels, selecting a proper balance of treatments to minimize removals, and finding effective and environmentally safe chemicals that control the EAB. Ongoing monitoring and assessing of treatment efficacy is also critical.

The fundamental premise of this strategy is that a program that balances removal and preservation can be effective through assessment and planning; that a sound EAB action plan depends on a proactive analysis of information, including tree inventory data, infestation levels, and chemical treatment effectiveness, among others.

Option D: Do nothing approach

This last strategy does not remove trees proactively or treat them with chemical pesticides. While initially economical, significant costs will still incur as dead and dying trees will require removal and replanting. Costs may in fact, be even higher, as a large number of trees will need to be removed during a shorter period of time than if proper planning had taken place. The economics of supply and demand will see tree removal costs escalate during peak demand periods, given the limited number of contractors providing services to municipalities as well as private property owners. Additionally, this approach has the highest probability of risk for potential harm to people and damage to property. The City's liability will increase dramatically as over 16,000 ash trees begin to die resulting in dropping of brittle branches. City of Markham Supervisor of Forestry records notes that the June 22, 2012 windstorm of only 40km/hr resulted in 74 of the 75 resident calls for broken limbs and trunks were related to EAB-infested ash trees.

Treatment Options for Canada

TreeAzin™

At this time, TreeAzin™ has been the commonly used product for municipalities, having attained Emergency Registration by the Pest Management Regulatory Agency in 2008, with full registration in October 2012. TreeAzin™, containing active ingredient azadirachtin, is available in a liquid formulation developed by the Canadian Forest Service, in conjunction with BioForest Technologies Inc. The product is injected into the trunk using BioForest's proprietary technology, the EcoJect® System. Trunk injections are the preferred method for pesticide application as it limits exposure of the product. The pesticide has an Emergency Registration by the Pest Management Regulatory Agency (PMRA) for EAB control in ash trees. The label states "This formulation is to be used only with the EcoJect® System for tree injections against emerald ash borer (*Agrillus plenipennis Fairmaire*) in ash (*Fraxinus*) trees. Treatment interval is every two years. Additionally, TreeAzin™ is approved by the Organic Materials Review Institute (OMRI) for use on organic crops. TreeAzin™ controls EAB by inhibiting larval development and preventing adult emergence as well as lowering fecundity, and is indicated for both preventative and remedial use.

- TreeAzin™ is recommended by BioForest for application on infested ash trees which have retained at least 70% of their canopy. Tree canopy should be in good to fair condition to facilitate effective uptake and translocation of the pesticide throughout the tree.
- TreeAzin™ label notes Environmental Hazards of toxicity to aquatic organisms, so care must be taken to avoid application in proximity to aquatic environments.
- TreeAzin™ has been widely used across Ontario and Quebec including the cities of Oakville, London, Toronto, Ottawa, Burlington, and Montreal. Oakville was the first municipality to treat ash trees with TreeAzin™ in 2008. Follow up monitoring of treated trees shows good efficacy at this time.

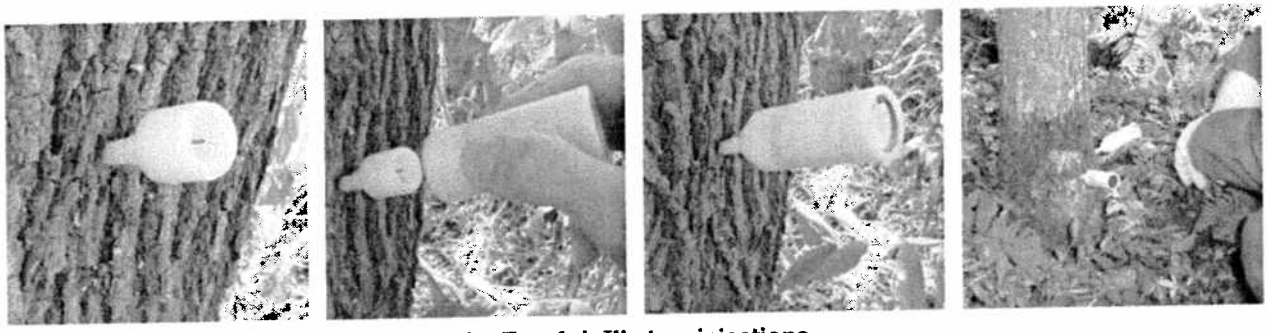


Figure 8. BioForest's EcoJect® System for TreeAzin™ stem injections.

Confidor®

In 2011, Bayer CropScience obtained Canadian registration of Confidor® 200SL by the PMRA, containing active ingredient imidacloprid 17.1%. Imidacloprid is well known as an effective product for insect control, and is one of the most widely used pesticides for agricultural crops worldwide. Imidacloprid is considered one of the most effective treatments for EAB in North America; widely used in the United States. The efficacy trials conducted by researchers from the Canadian Forest Service and BioForest Technologies Inc. in 2005, proved product efficacy, stating "one, low-volume trunk injection of Confidor® Trunk Injection 200SL at 0.25g ai/cm DBH in June provides effective control of emerald ash borer larvae". Each trial was designed with 10 control trees, in conjunction with 10 injected trees. Trials were conducted A subsequent mid-September 2005 trial by the same research team concluded "effective control of emerald ash borer larvae the next season in trees which have no apparent crown damage at the time of treatment".

Other noteworthy results include:

- 90% of the trees injected with Confidor® had no new exit holes compared to 0% of the controls
- 90% of the trees injected with Confidor® had no galleries or larvae compared to 30% of controls
- Numbers of galleries were reduced 94% and larvae 88% following treatment with Confidor®

Confidor® was registered in 2011, under an Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) program with a Restricted designation (*see box*).

Environmental Hazards noted on the label state that the product is highly toxic to aquatic invertebrates, and is toxic to bees. Bees can be exposed to residues in floral pollen and/or nectar resulting from tree injections.

The Davey Resource Group and The Davey Institute, conducted product demonstrations of Confidor®, using the Arborjet QUIK-jet system in August 2012 at two Ontario sites. Applications were performed by licensed applicators, evaluating uptake time for material; wound closure (to be evaluated in 2013); movement of active ingredient within canopy (to be evaluated in 2013); and equipment delivery system. Product efficacy over time will also be documented.

Wounds created by trunk injections have been the focus of research regarding wound closure. Dan Neely, in his Tree Wound Closure article in the Western Arborist Spring 2012, states:

> Martin and Sydnor (8) compared closure rates of wounds 10 mm (about .4 inch) in diameter in 12 tree species at two locations. Most wounds closed within 10 to 20 weeks. Green ash had the most rapid wound closure rate... Injection or implantation wounds by themselves are not especially

NATURE OF RESTRICTION: This product is to be used only in the manner authorized. For use only by Certified Applicators or persons under their direct supervision, only for those uses covered by the Certified Applicator's certification. This product can only be used in conjunction with a federal, provincial or municipal government control program. Directions for Use states: CONFIDOR® 200 SL Systemic Insecticide may be used as directed on ornamental and landscape trees such as in residential areas, rural lands, farms, business and office complexes, shopping complexes, multi-family residential complexes, golf courses, airports, cemeteries, parks, ravines, playgrounds, and athletic fields. CONFIDOR® 200 SL Systemic Insecticide also can be used in commercial forestry production, nurseries, greenhouses, and in federal, provincial, county and local forests and recreational areas.

damaging to trees. Trees have physiological functions and morphological structures to repair wounds.

Two articles regarding wound closure are found in Appendix D.

The Davey Institute is involved with long-term EAB product efficacy trials in the United States, including the Cleveland trial in collaboration with Ohio State University. DRG supports consideration of alternative registered products as a core principle of Integrated Pest Management (IPM) principles. Existing research trial information in both the US and Canada confirm imidacloprid provides good efficacy against EAB, in addition to being a key tool in the battle against Asian Long-horned Beetle (ALB). United States trials also confirm TreeAge as another preferred product, although not registered for use in Canada, providing up to 3 years of control.

Monitoring of the sites will be ongoing, and Davey Resource Group will provide updates of product demonstration results.

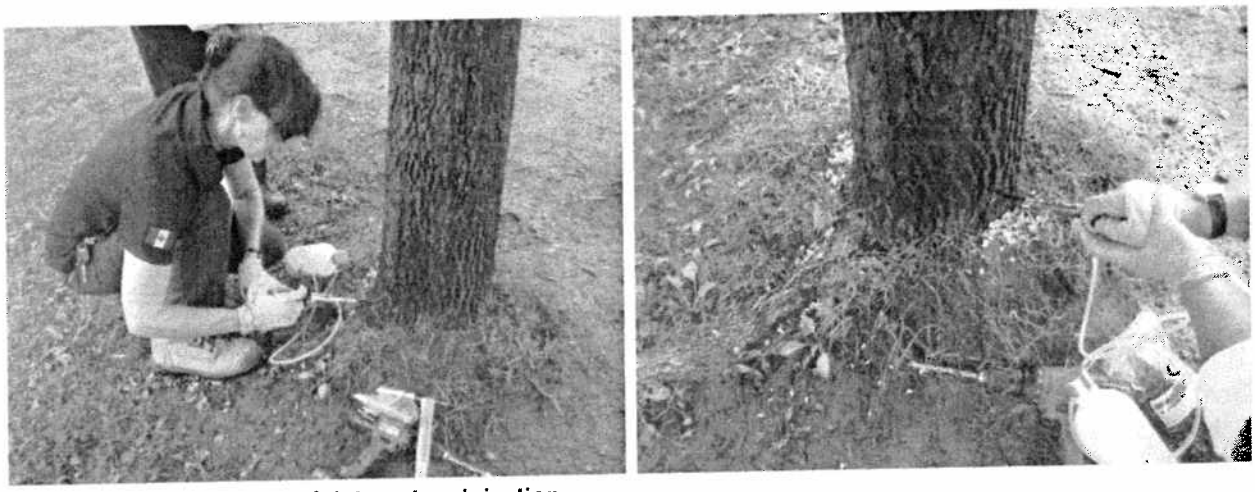


Figure 9. Technicians administer a tree injection.

ACECAP®

ACECAP®, with active ingredient acephate 98.9%, is manufactured by Creative Sales, Inc. At this time, ACECAP® is not a product of choice by Canadian municipalities, and it is unknown whether any Canadian municipality has used ACECAP®, resulting in good control of EAB. Label instructions read:

> Emerald Ash Borer: apply implants from early April - early June. Insecticide controls for Bronze Birch Borer and Emerald Ash Borer may be more effective if overall tree stress symptoms are reduced. Fertilize trees being attacked in fall or early spring and water regularly, especially during dry periods, and mulch around the tree base to increase moisture retention. Application to trees already heavily infested may not prevent the eventual loss of the trees due to existing pest damage and tree stress.

All chemical treatment regimens will require reapplications at indicated intervals: once every two years for TreeAzin™ and annually for ACECAP® or Confidor®. These reapplications may need to be continued for up to fifteen years, perhaps more if the tree's serviceable life—the span of time in which it provides

meaningful societal benefits-is longer. This fifteen year estimate is questionable at this time, as there is insufficient scientific history for this pest to determine longevity of a treatment program.

Product labels for TreeAzin™, Confidor® 200SL, and ACECAP® are found in Appendix C.

Predators, Pathogens and Parasitoids

Successful management of Emerald Ash Borer (EAB) will ultimately require the use of natural enemies. Natural enemies will be important control agents because of the limited options for chemical control of EAB, labour intensive application methods, and costs. Natural enemies may be either predators, pathogens or parasitoids. The benefit of natural control, is persistence in the environment as long as the host is present. Recent research into natural enemies of EAB is proving promising for managing EAB populations effectively, however natural enemies come with their own limitations which must be overcome to prove practical control options.

Predators are typically generalists, preying on insects that they are able to access. Woodpeckers are the most common and effective example. Research conducted by the United States Department of Agriculture (USDA) Forest Service show that three common woodpecker species consumed 16% of the larval EAB population in test plots. This low level of mortality is unlikely to increase, since EAB are but one of many wood-feeding insects that woodpeckers consume. Insect predators also exist, however their impact on the larval populations is unknown at this time. The broad range of insect prey has been demonstrated through studying the predatory wasp, *Cerceris fumipennis*. This wasp provisions its larvae with adult insects, of which EAB is one of nearly 90 species (see www.cerceris.info). Although predators are natural enemies of EAB, their broad palate precludes them from playing a primary role in the reduction of EAB populations.

Figure 10. *Cerceris fumipennis*

Pathogens are more specialized to their insect hosts, meaning they attack a narrower range of hosts, but are less mobile than predators. The main pathogens known to affect EAB include fungi, microsporidia and nematodes.

Figure 11. Auto-contamination trap.

Researchers at the Canadian Forest Service (CFS) in collaboration with the Institut national de la recherche scientifique – Institut Armand-Frappier (INRS-IAF) are developing entomopathogenic fungi that attack EAB. Researchers grow host-specific fungi in the laboratory, and are developing effective ways to transmit the fungal spores to the EAB. Once the fungal spores contact the insect host, the fungus penetrates the insect's body and produces enzymes which kill the emerald ash borer by feeding on it. Dr. Robert Lavallée deployed 20 auto-contamination traps in Montreal in 2012 for EAB, and CFS scientists Barry Lyons and Kees van Frankenhuyzen have research projects currently in the Sarnia area. Researchers are working to overcome the challenges of bio-control agents. Their host-specificity limits the ability to upscale production because producing the pathogen requires a living host. The poor ability to disperse requires human facilitation, namely through packaging and transportation, which can reduce the pathogen's virulence, and necessitates innovative auto-contamination traps.

Figure 13. ***Left to right, Spathius agrili; Tetrastichus planipennisi; Oobius agrili.***

Like pathogens, parasitoids are also specialists, but have the advantage of being able to disperse. Parasitoids of EAB are wasps whose larvae feed on EAB eggs, larvae or pupae, eventually killing it. Researchers from the United States and Canada have identified several parasitoids of EAB from China, the most promising being *Spathius agrili*, *Tetrastichus planipennisi* and *Oobius agrili*. Studies from the United States have demonstrated that these parasitoids can establish after being released, which is essential for long-term control of EAB. A native parasitoid, *Phasgonophora sulcata,* has been identified by researchers at the University of Toronto and the Canadian Forest Service. In one Ontario location, *P. sulcata* had a parasitism rate of 40%. However, there are risks associated with introducing foreign organisms into new environments, which have to be measured and understood before parasitoid introductions can be implemented on a broad scale. Producing parasitoids to a level that can effectively manage EAB populations is also a challenge, just as it is for pathogens. Despite these limitations, however, parasitoids have the potential to be the most significant bio-control agents against EAB because of their host-specificity, their ability to disperse broadly and their ability to establish populations.

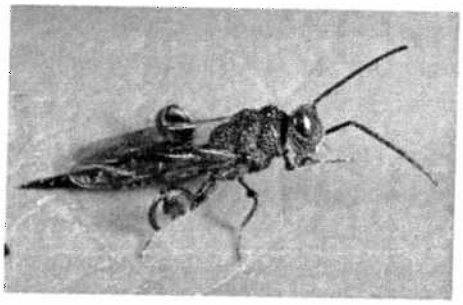


Figure 12. ***Phasgonophora sulcata***

Research being conducted on natural enemies by governments and academic institutions in Canada and the United States are promising. The information gained from this research is already being applied in the development of practical bio-control agents. With continued investigation and testing, there will soon be natural enemies available that can be used as a component of EAB management plans.

Management Strategies in Other Locations

In the decade since its detection, communities have developed a wide variety of responses to the EAB threat, depending of fiscal resources, community input, and the willingness of the community to tolerate risk. A major factor contributing to the range of these responses is their timeliness: the communities first impacted were trailblazers by circumstance without precedence from which to learn, and were also deprived of the treatment developments yet to come. Later responses differ according to the resources, both fiscal and physical—i.e. money, staffing and equipment—that were capable of expending.

York Region, Ontario

The first detection of Emerald Ash Borer (EAB) in York Region was in Vaughan in 2008. It was apparently well established by that time, and subsequent surveys have shown that the infestation has spread to many municipalities within the Region, including Richmond Hill, Markham, Newmarket, Georgina, East Gwillimbury, and King. It is estimated that there are approximately 2.1 million ash trees in York's woodlands, 70% of which are located in East Gwillimbury and Georgina. York Region also has approximately 700,000 ash trees in its urban forests (public and private lands), representing 8% of the total number of trees.

York Region published a comprehensive and detailed EAB management plan in 2011. The Region has decided on an active management plan, comprised of monitoring, protection, tree removal, tree replacement, communication and private land incentives. The Region's EAB management plan emphasizes maintaining the woodland canopy and mitigating the long-term ecological and environmental consequences of the EAB invasion. Monitoring activities will focus on detection and delimitation, relying on the completion of a complete inventory. Protection efforts (i.e., treatment with TreeAzin™) will be extended only to high value and/or heritage trees, though the criteria of high value and heritage trees were not outlined. The Region has provided itself several options for removal, with the main objective being limiting liability due to hazard trees along streets and trails. Tree replacement in York Region will rely on an urban forest management plan and identifying highly vulnerable sites in the York Regional Forest and along the Regions rural rights of way. Communications will be carried out using pamphlets and handouts, and the internet. The York Natural Planting Partnership and the Backyard Tree Planting Program are programs that assist landowners with planting trees and shrubs on their properties; maintaining these programs will help mitigate the losses in the urban canopy.

With the relatively recent detection of EAB in York Region, the public is only now beginning to understand the ultimate impacts of the infestation. Current concerns are focused on the protection of ash trees. The Region's EAB management plan does not recommend treating woodland trees or those on rural rights of way, but does respect the autonomy of lower-tier municipalities in choosing treatment or not. The examples of Richmond Hill and Newmarket represent municipalities that have chosen to treat ash trees for EAB, while Vaughan has chosen not to treat ash trees. A Markham resident wrote a letter to the Markham Economist & Sun ("Saving tree would be money well spent", August 20) in response to an article explaining the Region's approach to treating for EAB. He uses an economic argument to encourage private residents to have their street ash trees treated, which shows that the public is aware of the value of street trees and appreciates them enough to have them protected.

The York Region EAB management plan provides cost estimates for each phase of the plan. The total 10 year budget for the Region's plan is $11.7 million divided between monitoring, protection, tree removal,

tree replacement, communications and landowner incentives. Monitoring is estimated to cost $400,000 over 10 years. Protection costs are projected to be $200,000 over 10 years, providing protection to approximately 200 trees. Tree removal costs are estimated at $3.5 - $4 million over 10 years. Tree replacement is expected to cost $5 - $6 million over 10 years. Communications, outreach and public education costs are expected to be $100,000 over 10 years. For landowner incentives, $1 million will be allotted to the York Natural Planting Partnership and the Backyard Tree Planting Program over 10 years.

Richmond Hill, Ontario

Emerald Ash Borer (EAB) was first detected in the Town of Richmond Hill in March 2011. Town Forestry staff took proactive measures to treat 36 high profile trees with TreeAzin™ to suppress insect damage, while the EAB management plan was under development. The EAB strategic plan will be presented to Council in December 2012. Richmond Hill has approximately 7,867 ash trees on streets and rights of way and approximately 50,000 ash trees in public parks and natural areas. White ash (*Fraxinus americana*) is the third most common species in the Town, comprising approximately 9% of its total tree canopy.

An EAB management plan was approved in October 2011 (Appendix A of SREIS.11.204). The recommended level of management for monitoring, pesticide treatment, ash tree removal, and communications and public awareness is *proactive*, while the recommended level for ash tree replacement is *active*.

The main objectives of the Town of Richmond Hill's communication and public awareness strategy are to educate the residents of Richmond Hill about the impact to their tree canopy. The actions included in the Town's proactive communication and public awareness strategy are outlined in the EAB management plan found on Richmond Hill's website:
http://www.richmondhill.ca/subpage.asp?pageid=emerald_ash_borer

Private ash tree removals require an application to the Town, however residents are exempt from removal fees. Forestry staff encourage 1:1 replacement plantings on private property.

A ten-year budget was presented for the recommended Town of Richmond Hill's EAB management plan. The Town estimated the plan would cost $12.51 million to implement, while the "minimal" level of management would cost $10.28 million. The estimated costs of the monitoring, pesticide treatment and communications portions of the recommended strategy total $3.18 million. Under the "minimal" EAB management plan, an additional $1.2 million has been accounted for in street tree removal and replacement compared to the recommended plan.

Richmond Hill identified streets lined primarily with ash, and is treating 50% of those street trees with DBH greater than 20cm, which are considered in good condition, up to a maximum of 1,600 trees in total. Ash trees along streets, trails and park perimeters were inventoried in 2012, and assessed for condition, extent of canopy loss, structure, and visible symptoms of infestation. Approximately 794 trees were treated in 2012 with TreeAzin™, and an additional 800 are scheduled for injections in 2013, including larger specimen trees identified in parks. 1:1 replacement planting is planned for the year of removal.

Vaughan, Ontario

Emerald Ash Borer (EAB) was first detected in the City of Vaughan in 2008. As of 2011, Vaughan had marked 293 trees for removal, and it was estimated that 14,000 street trees would require removal in the next ten years. The loss of the City's ash would represent a loss of approximately 8% of its urban forest canopy.

City of Vaughan staff is conducting a series of public workshops, which started November 2011, to raise public awareness of the issue. The City's EAB management plan identifies five action priorities, including performing inspections, identifying and monitoring infested trees, removing dead or dying trees, establishing a replacement program, and communicating with the public. Information from the presentations shows that EAB is widespread throughout the City. Removal of dead and dying trees is underway. Wood waste in woodlots will remain *in situ* as part of the natural ecosystem. Ash trees that are removed from parks are replaced (where the budget allows) with non-ash species, and ash species are prohibited from being planted in new parks. Communication with the public is primarily through one-on-one consultations with City staff, or through information seminars. The City's website is regularly updated with EAB information, and additional links for identification are provided as well. Treatment with TreeAzin™ is not being considered due to the costs.

The main objectives of the City of Vaughan's communication appear to focus on identification and removal. Vaughan is exempting private ash trees with a diameter greater than 20 cm (measured 1.2 m above grade) from all fees associated with removal permits.

The City of Vaughan's final draft budget for 2012 allocates $49K to two 10-month contracts related to EAB. For 2012 to 2014, $510K total is allocated to the removal of EAB infested ash trees over this period.

Burlington, Ontario

The City of Burlington has more than 52,000 public street trees, of which approximately 10 % are ash species. Emerald Ash Borer (EAB) was first detected in Burlington in 2010, and 500 ash trees were injected using TreeAzin™ the same year. In 2010, the trees selected for treatment were initially only street trees in 25 monoculture road segments between 30 – 60 cm DBH. In 2011, the treatment criteria were expanded to include street and park trees 20 cm DBH and larger.

Since 2010, the City's EAB management plan has included five general activities: survey for EAB; remove and replace trees as necessary; treat a limited number of trees with TreeAzin™; inventory the City's park trees; and communicate with the community. A management plan (Report number: RPM-03-11), submitted in May 2011 to the City council, provides information on the progress of the EAB management plan with respect to these activities. Surveys employing branch sampling and prism trap techniques indicate that the spread of EAB has not expanded beyond the initial detection area. No trees were removed in 2010, and infested trees will only be removed when external signs of infestation become visible. The treatment area was expanded in 2011, resulting in the treatment of approximately 750 trees, in addition to those treated in 2010. In 2012, 3,500 trees were treated. The City's park & street trees have been inventoried. Communication strategies have been developed, and are in various stages of execution. The main objectives of Burlington's communication campaign were to inform all residents and raise awareness in treatment areas. The strategies and tactics to achieve these objectives are detailed in

the update report of 2011. Generally, the approaches are to use the electronic (website, City Talk) and print media (Burlington Post, mailers) and community information meetings to reach the target audiences. There have been no updates to this management plan to indicate the success of the communication strategies and the electronic media do not currently show that the plans have been executed.

Total program costs are $9.375M over 10 years.

Oakville, Ontario

There are approximately 177,300 ash trees in Oakville threatened by the Emerald Ash Borer (EAB), representing 9.3% of the town's canopy. EAB was first detected in Oakville in 2008, and a successful pilot insecticide injection program using TreeAzin™ was implemented the same year. In 2008, trees selected for treatment were greater than 20 cm DBH in good condition, and these criteria remain in place in 2012.

Since 2010, the Town's EAB management plan has focused on four action areas: treat the ash trees; inventory the Town's ash trees; develop research partnerships; and communicate with the community. Trees treated with TreeAzin™ in 2008 appear to be in relatively good condition as of fall 2012, and the growth and expansion of the EAB population has been modest. The inventory of the City's ash trees has been completed, indicating that the ash population comprises approximately 44,000 woodland and 14,500 street trees. Communications goals have been exceeded through the formation of the Oakville Canopy Club, through the use of media (i.e., social media, conventional media and the City's website) and through constant interaction with and education of residents. Communications includes such high profile advertising as "Treat Your Ash Tree" posted on community buses. Another popular strategy is the interactive map posted on the Town's website where residents can access information about local ash tree treatment.

For 2012, the treatment of healthy canopy trees was the focus of the City of Oakville's EAB management plan. To achieve the goal of 75% canopy preservation of street and park trees, the town needs to treat 5,800 trees (3,300 were treated in 2012 at a cost of approximately $385K). The remaining 8,700 trees have been recommended to be removed over the next six years. Communication and research also remained as priorities of the 2012 EAB management plan, as shown by the budget allocations described below.

The EAB management plan for 2012 may also include a pilot project of managing woodlands with significant ash composition. Oakville has informed residents that woodlots may be closed due to safety risks. It is believed that harvesting ash in some woodlots will generate profit for the town, based on the town's success dealing with Oak Decline in 2002. Forest management plans that comply with "good forestry practices" will be developed and executed by a forestry consultant. Local/regional furniture makers and artists have been identified as potential diversion points for suitable wood waste resulting from these operations.

The tree removal plan includes the most hazardous trees will be removed first, followed by removals systemized by street blocks for efficiency and cost effectiveness. Over the next ten years, 9,554 ash trees along streets and in manicured parks will be removed in addition to 14,450 ashes in wooded areas.

The budget for this fifteen year strategy is projected to be $14.3 million dollars.

City of London

EAB was detected in London in 2006, and spread rapidly throughout the city. In 2011 the Emerald Ash Borer Strategy was developed, guiding decisions to treat or remove ash trees, public communications, wood waste disposal, woodlands, and private property issues.
Ash comprise 10.2% of London's total number of trees and 7.3% of the total canopy cover. 9,554 ash trees will be removed over a 10 year period, with 384 trees assessed for treatment.
Total cost of London's 15 year strategy is estimated at $14.3 million dollars including injection treatments, removals, replanting, monitoring and co-ordination.

Table 1. Comparison of Canopy Structure and Treatment Plans.

City	Year Detected	Ash as % Canopy	# trees treated
York Region	2008	8	200
Richmond Hill	2011	9	800
Vaughan	2008	8	0
Burlington	2010	10	4750
Oakville	2009	9.3	3000
London	2006	7.3	400

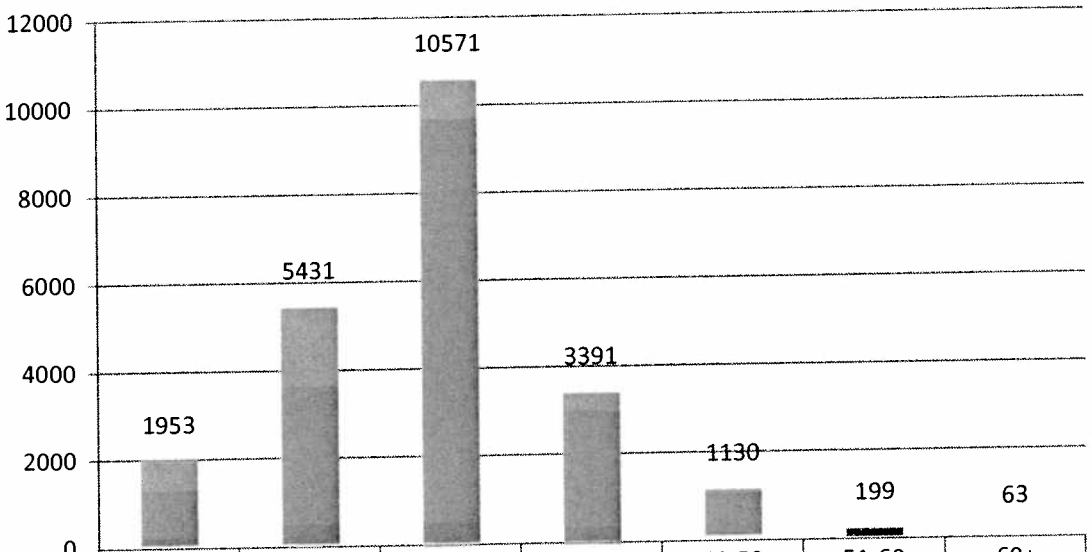
City of Markham's Actions to Date

Assessment of Current Infestation

Figure 14. City Forester Jeff McMann assesses the condition of an ash tree in Riseborough Park, September 2012.

The City of Markham completed an inventory of ash trees along streets and manicured areas of parks throughout late spring and summer of 2012. Survey data was compiled by staff arborists who assessed tree conditions, including canopy condition* and visible EAB infestation symptoms. Staff also assessed trees for good structure, as trees with poor structure have a higher probability of failure. Drought conditions of 2012 severely impacted already stressed trees, to which Markham Forestry staff responded to by re-assessing trees in late summer/fall which showed marked decline over the course of the season.

The 2012 street and public ash tree inventory yielded 16,738 ash trees in total. Trees are shown by size (DBH, or diameter at breast height), and by condition rating, as follows:



	1-10	11-20	21-30	31-40	41-50	51-60	60+
Undefined (0)	0	2	7	4	1	0	0
Good (1)	628	1789	874	392	63	7	0
Some (2)	1104	3146	9206	2638	963	172	56
Significant (3)	164	444	456	339	99	19	6
Dead (4)	57	50	28	18	4	1	1
Total	1953	5431	10571	3391	1130	199	63

Chart 2. Street and Public Ash Tree Inventory.

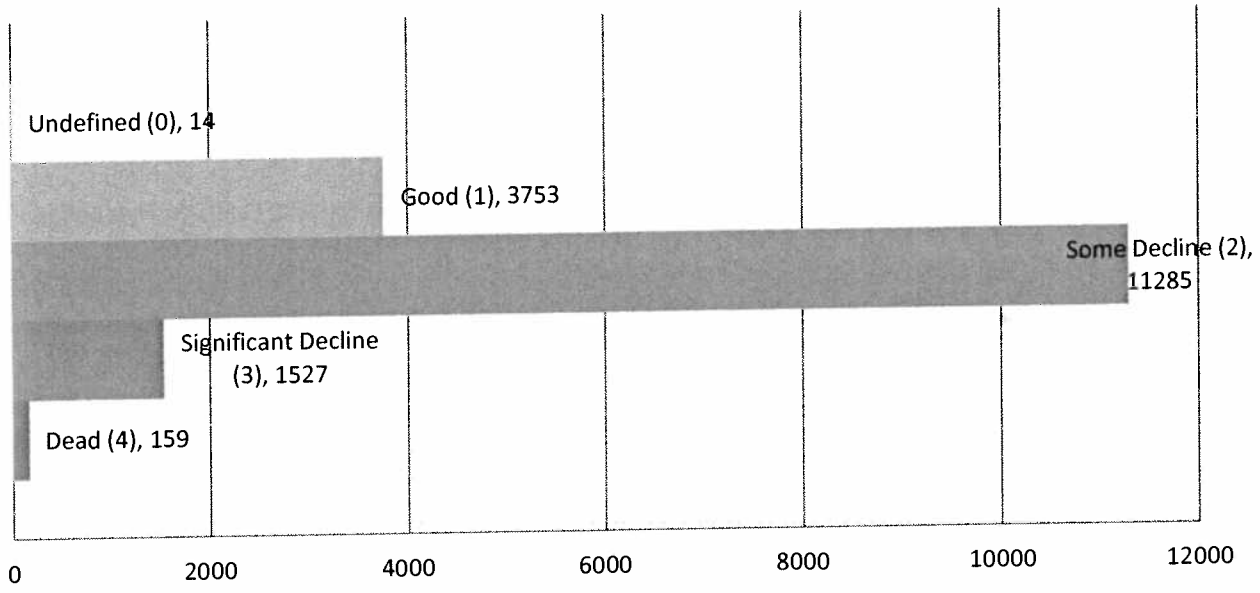


Chart 3. Total Number of Trees by Condition.

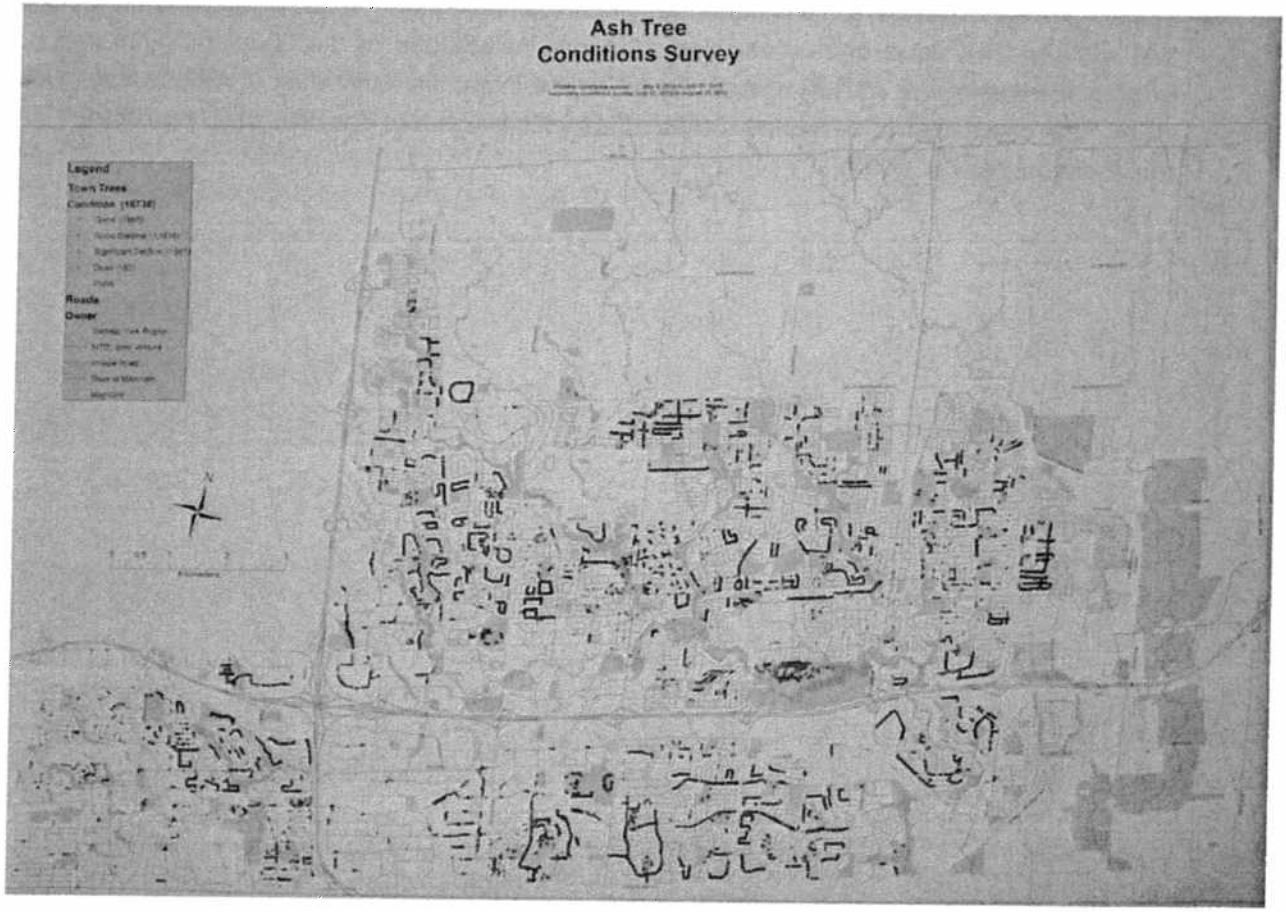


Figure 15. Ash Tree Locations.

City of Markham Forestry staff have also initiated an Ash Tree Injection Pilot Project in 2012, treating approximately half of the 35 trees in Ashton Meadows Park with TreeAzin™. Supervisor of Forestry, Jeff McMann, also actively collaborates with colleagues including the York Region Technical Working Group, spanning all municipalities in York region. Other stakeholders such as the Canadian Food Inspection Agency, Toronto and Region Conservation Authority, Ministry of Natural Resources are also represented in this group.

Markham's 2012 Urban Forest Study

The City of Markham conducted an Urban Forest Study in 2012 to better account for the ash tree population on both public and private lands.

This study provides the following highlights:

- Approximately 3,155,000 trees make up Markham's urban forest (includes both public and private trees).
- Ashes represent 9% of Markham's live tree population, and are evenly distributed across all land uses (residential, commercial, industrial, etc.).
- Ash trees also account for 9% of total leaf area for, and *Fraxinus* is the second most abundant tree genus in Markham.

- Markham's ash trees have a combined structural (compensatory) value of approximately **$47 million.** This value calculation uses guidelines established by the Council of Tree and Landscape Appraisers (CTLA) and published by the International Society of Arboriculture (ISA). This calculation of tree value includes factors such as tree species, size, condition, and location (Nowak 2003).

EAB Detection in Markham

In July 2011, the Canadian Food Inspection Agency (CFIA) confirmed the presence of EAB in Markham. While installing EAB traps as part of the joint Markham/York Region Survey program, forestry staff noted epicormic shoots and canopy thinning on a street tree. Close inspection of the tree yielded insects that appeared to be the EAB. Per government protocol, Markham Forestry staff contacted CFIA, who inspected the tree, collected samples, and confirmed positive detection of the insect. CFIA staff noted that the beetle had been present for some time. 42 green prism traps were installed by City of Markham staff as part of the joint Markham/York Region Trapping project in the vicinity south of Highway 7. Staff installations of traps using bucket trucks proved very successful, with no traps falling out of trees. By the end of the season, all 42 traps showed the positive presence of EAB, with counts averaging approximately 30 insects per trap, indicating widespread and serious infestation throughout the City. York Region installed traps north of Highway 7, which indicated positive finds in virtually all traps placed in ash trees. Traps placed by York Region consultants in trees other than ash, as part of random grid placements, yielded inconsistent results.

Branch sampling of selected areas was performed over the winter months by Forestry staff, resulting in further confirmation of both the widespread extent and high degree of infestation throughout Markham.

Figure 16. Green prism EAB trap.

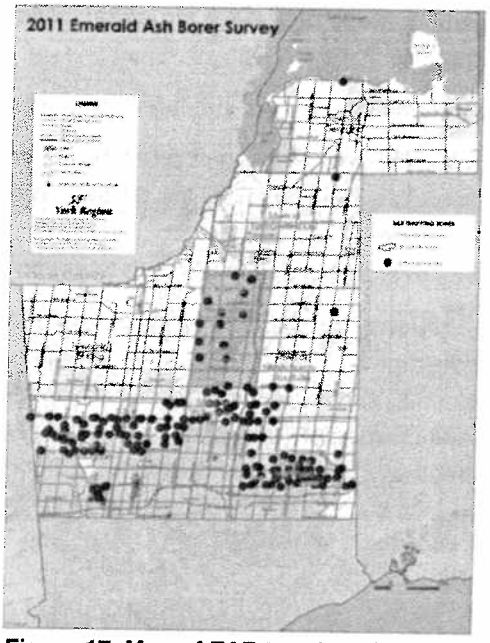


Figure 17. Map of EAB trap locations.

Protection Options and Costs

A case can be made for attempting to protect as many ash trees as possible; however, a reasonable list of criteria is required for selecting trees to protect. The criteria should include at least the following considerations:

Cost – Protecting ash trees with chemical injections requires a program multiple years duration to be effective. Repeat injections are required throughout the remaining serviceable life of a tree. This report is assuming that trees will require an average of 15 years of protection (7 additional treatments beyond the 2013 treatments) at an average cost of $7.00 per centimeter of diameter.

Condition Class – The best treatment candidates vary by condition rating and size class. Large diameter trees that are in good condition make the best candidates. Studies have shown that these trees typically provide the most benefits to society (McPherson, 2003). Trees that are not in fair condition or better likely have compromised vascular systems that will inhibit the flow of injected materials and greatly reduce its efficacy. Published materials from BioForest (the product manufacturer recommends that trees should have less than 30% canopy loss to be injected. As leaves in the living canopy transpire, they give off moisture and create a "pull" effect in the rest of the tree that provides better distribution of the TreeAzin™ chemical through the tree. Reduced canopy size reduces the ability of the injected material to be distributed evenly throughout the tree, hence less favourable results with smaller trees.

Structure - Trees that are dead or in poor condition should not be considered candidates for protection. Many of these may have structural issues or are in significant decline, thus posing high risk to people or property.

Diameter Class – As indicated, large-diameter trees provide greater benefits than smaller trees.

While a publicly managed urban forest should maintain a wide range of diameters to ensure an ample supply of young trees for the future, the cost to chemically treat these young trees through their serviceable life would be prohibitive. Smaller diameter trees may not be able to support multiple injection sites over several years, due to wounding of the tree trunk.

Location – Public trees along streets and in manicured areas of parks are considered a high priority for protection by chemical injection utilizing municipal funds. They are the most visible, provide the greatest benefits, and have the highest potential for creating high levels of risk to public safety if not treated. Ash trees in woodland areas of parks and managed woodlands of other public lands are too numerous to treat effectively, and little data exists about their location and population numbers, There may be a few woodland ash trees in critical locations that will be selected for protection.

The 2012 Urban Forest Study illustrates the size distribution of Markham's urban forest, as follows:

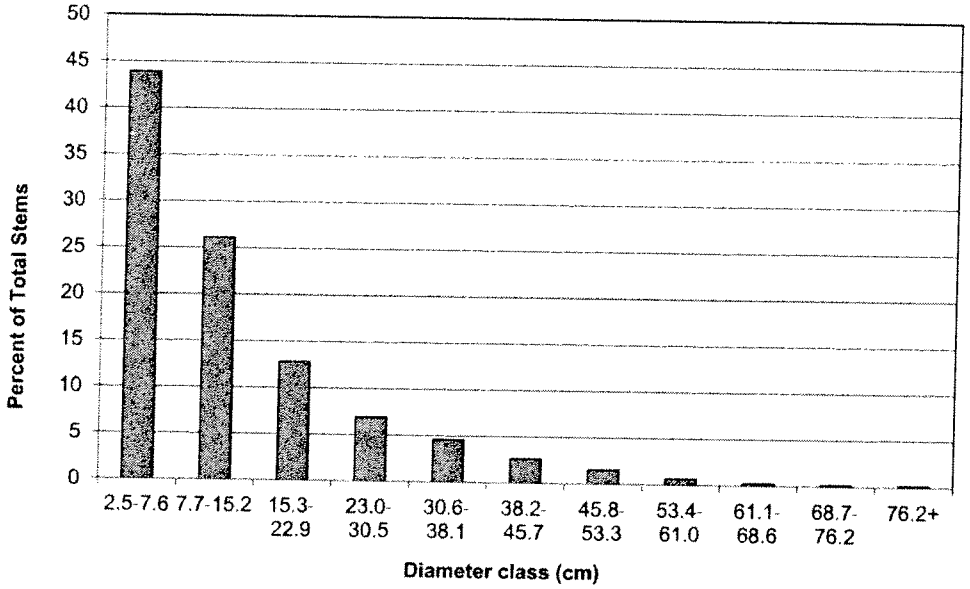
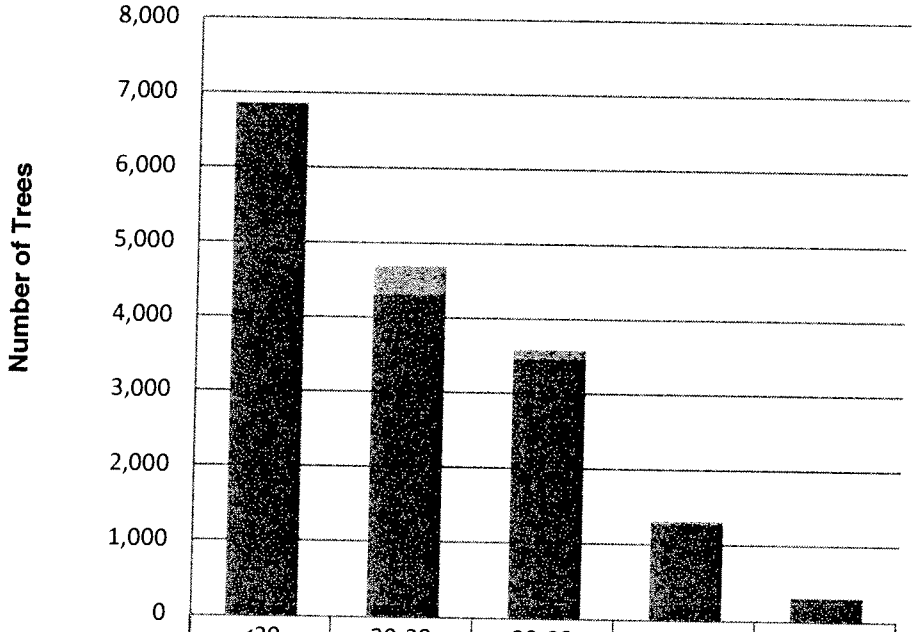


Chart 4. Chart depicting diameter class distribution of trees in Markham.
Source: Markham Urban Forest study.



	<20	20-29	30-39	40-49	>50
Proposed for Treatment	0	380	114	32	4
Proposed for Removal	6,854	4,310	3,466	1,276	302
Total	6,854	4,690	3,580	1,308	306

Chart 5. Treatment candidates by number of trees.

The estimated structural value of all trees in Markham is approximately $1.3 billion, representing an estimate of tree replacement costs and/or compensation to tree owners for tree loss. There is a positive relationship between the structural value of an urban forest and the number and size of healthy trees.

The decision to select candidate trees from the larger and healthier ash trees is based on a combination of scientific research as well as an awareness of the need for budget optimization. It is well documented that larger and healthier trees, with full canopies, provide tremendous benefits that include a reduction in energy needs, a reduction in storm water infrastructure needs, higher real estate values, cleaner air, and more attractive communities (McPherson, 2003). Models such as Urban Forest Study and i-Tree Streets have documented the case for large, healthy trees in urban settings (Nowak, 2003). Protecting these trees for the remaining years of their serviceable life makes economic sense. The case for investing large sums of municipal funds becomes more difficult to make as tree diameter and health are diminished.

The matrix provided in Chart 15 provides information about the number of candidate trees for protection in each diameter x condition class. While the 2012 inventory data indicates that there are 16,738 ash trees in total, City staff have determined high-priority candidates to be the trees assessed as "good –343 trees" or "some decline" – 187 trees, totaling 530 trees. Trees greater than 20 cm are recommended for treatment, as they will provide the most environmental benefits to Markham, preserve the highest amount of canopy cover, and are the most cost-effective trees to treat.

The 530 ash trees to be protected account for of all ash trees on streets and manicured areas of Markham's city parks. This percentage is relatively consistent with other communities that have selected ash tree protection as part of their plan to deal with EAB.

The selection of prime candidates and chemical treatments are consistent with the Coalition for Urban Ash Tree Conservation's—an organization that is composed of 21 private companies, non-profits, and agencies that are promoting the protection of ash where economically feasible—Emerald Ash Borer Management Statement: *"We the undersigned strongly endorse ash tree conservation as a fundamental component of integrated programs to manage emerald ash borer (EAB) in residential and municipal landscapes. Cost-effective, environmentally sound EAB treatment protocols are now available that can preserve ash trees through peak EAB outbreaks with healthy canopy intact. Used in association with tree inventories and strategic removal/replacement of unhealthy ash, tree conservation will help retain maximum integrity and value of urban forests. This integrated approach to urban EAB management is supported by university scientists with expertise in EAB management, commercial arborists, municipal foresters, public works officials, and non-government organizations (NGO's)."*

Trees Proposed for Chemical Treatment

All ash trees in Markham were assessed in August 2012 by City staff for chemical treatment consideration according to the following criteria:

- Greater than 20cm DBH
- Located on streets and manicured areas of parks
- Visual assessment of good health with less than 25% canopy loss
- Good structure without significant defects that would compromise structural integrity of tree
- Location suitable for mature size (e.g. not under overhead utilities, or interfering with stop signs)

The minimum size of trees to be treated is often a point of much consideration for municipalities. While treating all sizes of trees would be an ideal situation, economics often dictates hard choices be made.

Decisions regarding appropriate size trees to treat should consider the following:

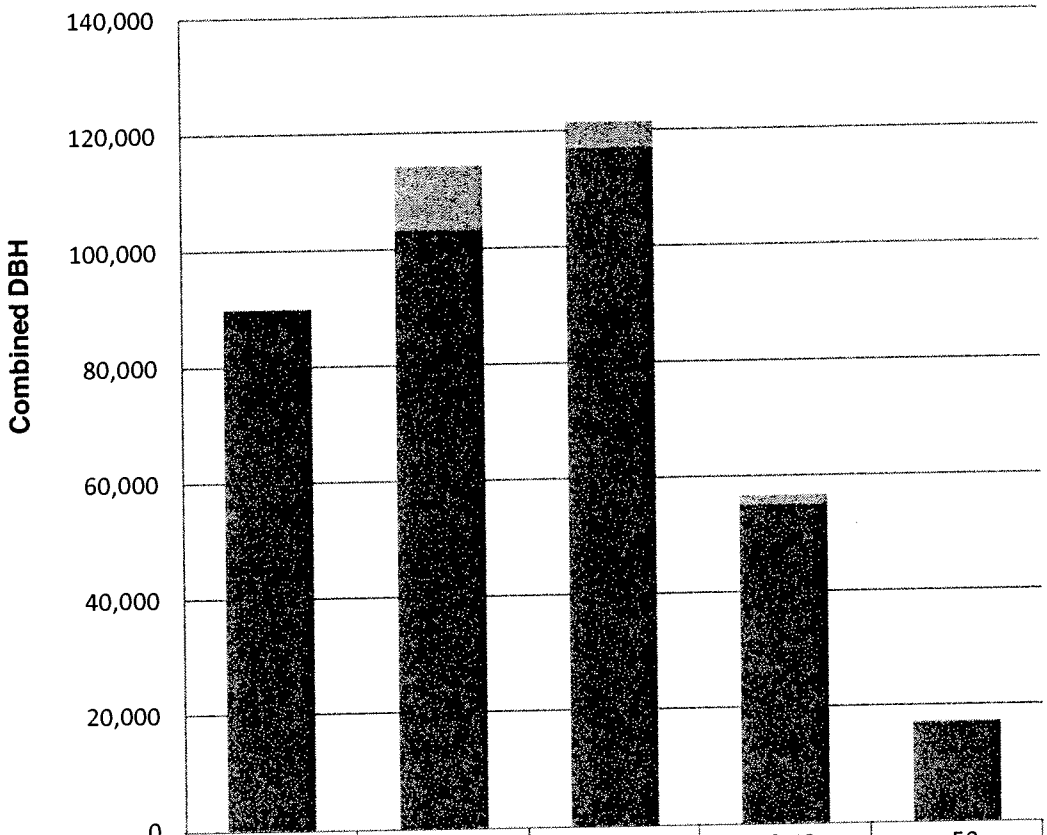
- Economics: the cost to treat trees over a 10-15 year period vs. the cost to establish replacement trees. An additional consideration is the tendency for smaller trees to absorb chemical treatments very slowly in comparison to larger trees, generally attributed to smaller canopies which draw the chemicals up more slowly. Given that, treatment costs may be significantly higher for municipalities that choose to inject smaller trees, as contracted labour times will be higher.
- Benefits: the benefits generated by smaller trees are considerably less than benefits generated by more mature trees, hence selecting larger trees to treat provides best returns from an environmental perspective.

Ash Tree Treatment Candidates–September, 2012

The August 2012 tree inventory determined that 530 trees greater than 20 cm DBH to be good candidates for tree injections based on good/fair canopy condition and good structure. Of these trees, 343 trees are considered in *good* condition, and an additional 187 are considered as showing some *decline*.

Table 2. Removal and Treatment Candidates.

	# Trees	Total DBH	# Trees Treated	DBH to be Treated	# Trees to be Removed	DBH to be Removed
<20	6,854	89,940	0	0	6,854	89,940
20-29	4,690	114,298	380	11,020	4,310	103,278
30-39	3,580	121,429	114	4,446	3,466	116,983
40-49	1,308	56,609	32	1,568	1,276	55,041
>50	306	17,253	4	236	302	17,017
Total	**16,738**	**399,529**	**530**	**17,270**	**16,208**	**382,259**



	<20	20-29	30-39	40-49	>50
Proposed for Treatment	0	11,020	4,446	1,568	236
Proposed for Removal	89,940	103,278	116,983	55,041	17,017
Total DBH	89,940	114,298	121,429	56,609	17,253

Chart 6. Treatment candidates by combined DBH.

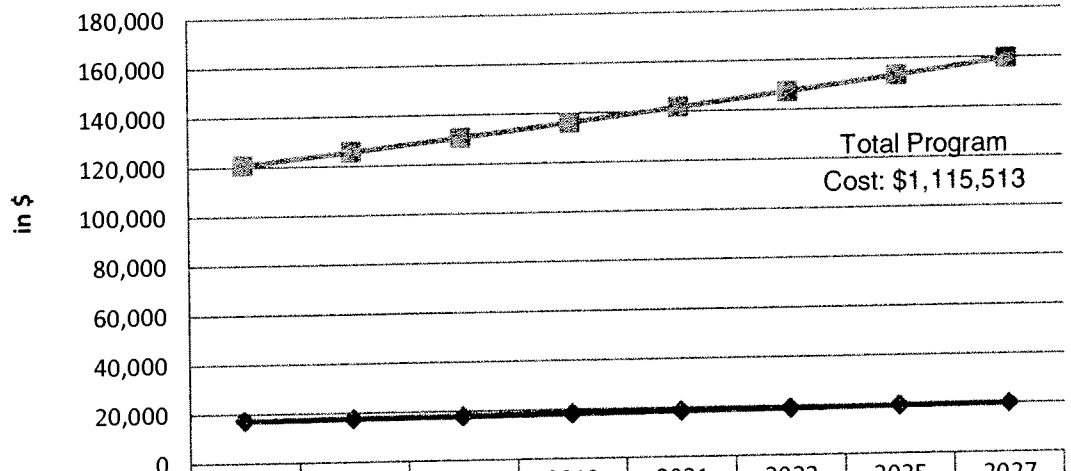
Long Term Treatment Costs

The cost to chemically treat ash trees with TreeAzin™ is based primarily on tree diameter. Larger diameter trees have larger vascular systems and require more chemicals to facilitate an even distribution of effective amounts of chemicals. A rate of $7.00 per centimeter in tree diameter is a current estimated price for municipal injections in the Greater Toronto Area of TreeAzin™ treatments.

During 2012, half of the trees in Ashton Meadows Park were injected as part of a pilot project with an estimated total diameter treatment of centimeters.. It is anticipated that the treated trees will continue to grow and add approximately 2% diameter growth during each two-year injection cycle year.

TreeAzin™ is recommended for application every two years during the serviceable life of the tree, or until the threat of EAB has passed. Chart 7 provides an estimate of the total cost to treat ash trees for the next 15 years. Total cost for injections over the 15-year period is estimated to be $1,115,513 with an annual cost of $74,367 (Injections occur every other year, so costs will occur every other year in the approximate amounts shown in Chart 7.)

The 15-year treatment period is based on research from The Ohio State University and Michigan State University that suggests there will not be sufficient host (ash) trees after that time frame to support a damaging population of EAB. While the studies are not yet published, they indicate that ash trees on public and private streets, parks, and woodlands will be essentially reduced to levels that would not support EAB. While this relies on untested models of population dynamics it is generally accepted that this length of treatment period is adequate. In order to reflect current acceptable practices and the introduction of new treatment options for the Canadian market, it is recommended that Markham's EAB strategy should be revisited again in three years, and updated with modifications that will provide the most efficient strategy available.



	2013 ($7.00/ cm)	2015 ($7.14/ cm)	2017 ($7.28/ cm)	2019 ($7.43/ cm)	2021 ($7.58/ cm)	2023 ($7.73/ cm)	2025 ($7.88/ cm)	2027 ($8.04/ cm)
Total Diameter* (cm)	17,270	17,615	17,967	18,327	18,694	19,068	19,449	19,838
Total Cost to Inject	$120,890	$125,771	$130,800	$136,170	$141,700	$147,426	$153,258	$159,498

Chart 7. Cost to chemically treat trees for 15 years.

*Total diameter is increased by 2% each two-year injection cycle to account for growth of treated ash trees and injection cost is increased at 2% per two-year cycle.

Utilization of Urban Wood Residue

Many communities have programs in place that utilize urban wood residues as a commodity that can be sold or utilized in-house.

Currently Markham does not mulch street or park trees, or those along trails. Some mulch will be used by City staff for this purpose. Mulch will also be offered to residents free of charge on "Mulch giveaway" days, but the amount taken away is expected to be relatively small.

Logs removed will not be left at the curb for residents to remove, due to liability issues plus the responsibility of City staff to do their part to prevent EAB infested logs from moving out of quarantine area established by CFIA. In some municipalities, opportunities exist for using the ash wood that is large enough to be milled in a small, portable sawmill operation. City of Markham Forestry staff has already been proactive in contacting two sawmill operators, however both businesses were not interested in ash wood. The State of Illinois has an *"Illinois EAB Wood Utilization Team"* whose goal is "To encourage the harvesting and use of wood from urban and community trees felled in Illinois". It is comprised of 14 Illinois state and federal government officials and industry leaders and supports a network of over 100 urban foresters, municipalities, landowners, wood processors, green builders, economic development organizations, and consumers. Additional information can be obtained at http://illinoisurbanwood.org.

Wood not suitable for lumber can be ground into landscape mulch using tub grinders that create a variety of mulch textures or material that can be added to other organics to create compost. The use of urban wood residue is a sustainable practice and is recognized by many organizations that promote wide use of natural resources. It is recommended that the City explore opportunities with the Canada Green Building Council to promote the use of urban wood residue as part of their initiatives that include LEED® approved building processes. As part of the LEED® certification process, builders must demonstrate how their products or services are LEED® compliant. It is then up to a project team to use these products, materials, or services on a project in pursuit of certification.

Wood Waste Utilization

Many municipalities believe that wood chips resulting from EAB removals and chipping operations will be readily taken away by citizens and commercial services. Certainly cities with relatively low numbers of ash trees, and an effective public communications program will see wood chip piles diminish, particularly in late spring landscaping season. It is estimated that 10% of Markham's wood chips will be used by private citizens, commercial businesses, and City Forestry staff. However, cities such as Markham with large numbers of ash trees which will necessitate year round removals during a period of a few years, require a comprehensive wood waste disposal strategy.

It is important to understand that large wood piles pose potential dangers, such as spontaneous combustion. The Office of the Fire Marshall, Ontario states in its Technical Guideline OFM-TG-03-1998, Storage of Wood Chips:

"*The outdoor storage of wood chips requires certain fire protection measures in order to prevent a potentially serious fire hazard. Wood chip piles have the potential to heat internally and spontaneously combust if not managed correctly. The 1998 Ice Storm in Eastern Ontario produced a large amount of*

debris from damaged and downed trees. Wood chippers have been used to reduce the debris into more manageable wood chip piles. However, wood chip piles pose a potential fire hazard if not managed correctly.

Internal fires are much more common than surface fires and are difficult to detect and extinguish. Such fires are capable of burning for extended periods before any obvious indications of a fire are observed. Spontaneous heating is caused when heat produced by the microbial decay of wood is not readily dissipated. Pile temperatures can reach a temperature of 66°C after two weeks. In some piles, the temperatures continue to rise due a number of factors. These factors include the pile height, a low surface-area-to-volume ratio, the age of the wood chips (older and more compacted), low air flow, and the presence of impurities such as bark, decayed wood, and sawdust. Fires frequently occur while attempts are made to separate heated from non-heated chips. When heated chips are exposed to sufficient air, combustion may occur.
Blown wood chips or pneumatically conveyed wood chip piles are more vulnerable to spontaneous combustion since the fines are separated and stratified in such a manner that hampers heat dissipation."

The full Technical Guidelines are included in Appendix A, and should be read for important information concerning wood pile size limitations, duration, and fire extinguishing provisions.

The June 1, 2011 fire which started in a massive pile of wood chips at an environmental services business in Stoney Creek was attributed to spontaneous combustion. The City of Markham is advised to follow Office of the Fire Marshall guidelines for safe storage of wood chips.

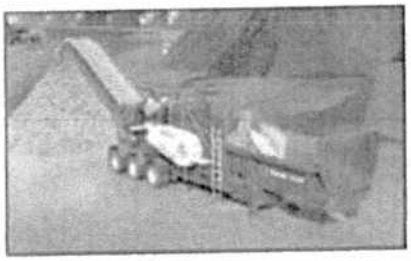
Wood Waste to Landfill

Wood waste is quite costly to dispose of, at an approximate cost of $80 per tonne. One tonne equates to approximately 1.5 cu metres of wood chips.

The option of sending the wood waste from trees removed due to EAB has been calculated by City of Markham Forestry staff as:

Recycling Wood Waste to Compost

An environmental services contractor confirms wood waste can be ground 5/8" (EAB required ¾" to 1"). Using a Peterson Pacific 6700B, chipping smaller logs and limbs at the rate of single grind processing about 40 to 45 MT per hour. The cost to mobilize the tub grinder to Markham, and demobilize it after cessation of work is $1,000. The rate for rental of the grinder is $675 per hour, including the operator who feeds the machine. The City would be required to bring the wood waste to the designated site, for the contractor to load.



Peterson Pacific Corp.

Figure 18. Wood tub grinder.

Discussions have also been initiated between the City and a leading environmental services company, to explore potential wood waste utilization for local composting operations. The City would be

required to deliver waste wood debris to the local yard at Bloomington & Leslie near Hwy 404. Cost to the City is currently estimated by the environmental services company as $60 /Metric tonne (MT). It is important to note that at this time, the huge volumes of wood waste anticipated from ash removals throughout the Greater Toronto Area are posing planning challenges for environmental services firms. Regional composting facilities may need additional sites, or amendments to Certificates of Approval (COA's) to handle increased volumes. The City would be wise to consider alternate disposal options, pending firm commitment from environmental services companies to accept all wood waste, to ensure disposal options will be available given increased supply of regional wood waste, and market pressures.

Recycling Wood Waste to Biofuel

City of Markham Forestry staff initiated a meeting in 2011 with Markham District Energy to discuss opportunities to use wood waste as a fuel source for the co-generation plant. At that time, Markham District Energy declined interest in the waste wood products, as their co-generation plant fuel source is natural gas.

One of the most innovative alternatives to traditional waste disposal or composting, is using the wood waste as a source for biofuel manufacturing. Davey Resource Group has initiated discussions with a leading Canadian biofuel manufacturer to explore utilization of wood waste for a regional biofuel facility. Early discussions are promising for exploration of the utilization of high volumes of wood waste, with potential for lower fees to the City of Markham. A further meeting is scheduled for late November to continue exploration of potential partnership opportunities.

Utilization of Wood for Eco Products

Eco Wood Products Ltd., a Concord manufacturer of recycled wood products including decorative mulches, playground surfacing and animal bedding, has been approached for potential utilization of waste wood. Further dialogue has been initiated by City of Markham Forestry staff, with a mid-November meeting pending.

Replacement Trees: Options and Costs

Identify Trees to Replant and Replanting Costs

Markham has 16,208 ash trees that are scheduled for removal along streets and in manicured areas of City parks. Replacement of these trees is a critical component in a community's response to dealing with a catastrophic tree loss. Replacing large numbers of trees lost to an invasive pest will re-establish the lost component of the urban forest and begin to produce immediate benefits that will increase over time.

While a tree replacement ratio of 1:1 would replace one tree for each tree lost, it will result in an overall loss in tree canopy as the survival rates of newly planted trees is rarely 100%. Additionally, the immediate loss in canopy is impossible to replace when only planting one small-diameter tree to replace a large-diameter tree. Although another option is to consider planting trees at 2:1 rate, City staff are concerned about the current budget pressures of the EAB program, hence are considering the scenario of only 1:1 planting at this time.

The i-Tree Forecast model provides an estimate of the level of annual tree planting required to meet canopy cover targets within the next 50 years. The model simulates the growth of Markham's urban forest based on existing conditions as quantified by the i-Tree Eco analysis, completed as part of the Urban Forest Study. Simulations are based on existing urban forest characteristics, including species growth rates and current tree health. The results are summarized into number of trees planted annually in order to maintain existing canopy cover. In addition, the anticipated impact of the emerald ash borer beetle has also been included in these scenarios by assuming 100% mortality of all ash species over the next ten years, described in the table below as "total ash kill".

Table 3. Estimated tree planting required to maintain existing canopy cover.
Source: Markham Urban Forest Study.

Annual Mortality Rate	Annual Tree Planting to Maintain 18% Cover	
	No Ash Kill	Total Ash Kill
2%	0	8,000
3%	40,000	45,000
4%	90,000	95,000
5%	140,000	145,000
6%	191,000	196,000

With an annual mortality rate of 4%, approximately 90,000 trees will need to be planted to maintain the existing canopy cover (Table 5). Although these numbers appear high, they are reflective of the devastation EAB will create for Markham's urban forest.

The amount of canopy loss alone greatly reduces the overall benefits to the community that were revealed in Markham's 2012 Urban Forest Study analysis. That report indicates that ash trees in Markham are valued at $47 million. It is critical to continue to diversity Markham's urban forest to prevent future devastating pest impacts. The 2012 Urban Forest Study illustrates the vulnerability of Markham's urban forest to major pest threats

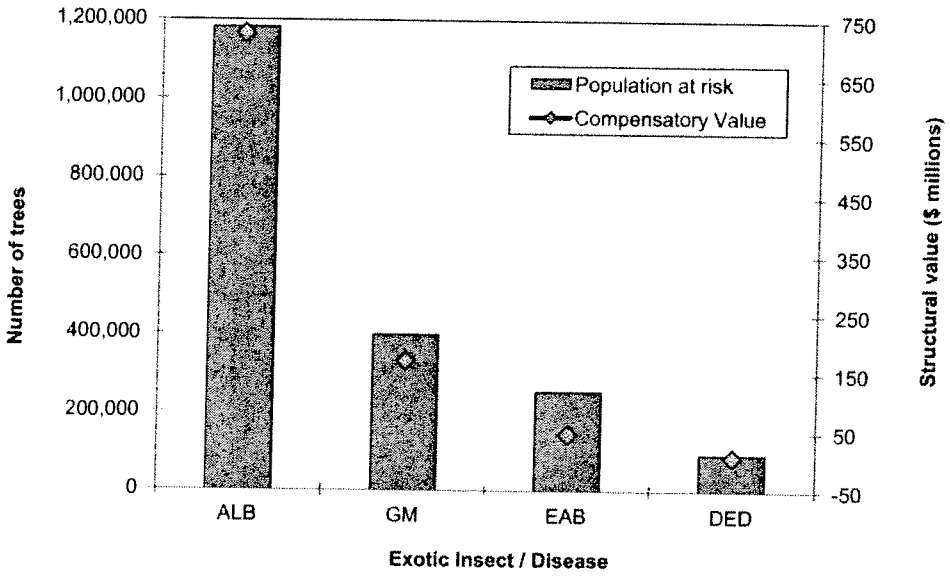


Chart 8. Number of trees susceptible to Asian long-horned beetle (ALB), gypsy moth (GM), emerald ash borer (EAB), and Dutch elm disease (DED), and potential loss in associated structural value of host trees.
Source: Markham Urban Forest Study.

Planting stock is currently 60mm caliper, as specified by City of Markham standard specifications. It is recommended that the City decrease tree standard size to 50mm to reduce nursery costs by approximately 25%, as well as to keep planting costs lower. The general public will see virtually no difference in this size of tree when planted, and tree establishment may in fact, be faster. Commonly available species in excellent condition should be used, with emphasis, but not sole reliance on native plant material. Many excellent cultivars have been bred to adapt to difficult urban conditions, for which some native trees may be unsuitable. Planting costs are assumed to increase by 5% each year. City of Markham currently tenders out their nursery stock purchasing, and has had very good success obtaining quality nursery stock at good prices. Costs used for calculations also include additional maintenance expenses such as watering, mulching, and young tree pruning until the new tree is established. Replanting should occur in the same year as removals, or the subsequent growing season. Planting costs are shown for Years 2013 through 2019, the same 7 years that tree removals are planned. Should annual reassessment of ash trees determine the need for expedited removals, the program should be re-evaluated considering an accelerated schedule.

The tree planting numbers recommended here will only replace the trees lost that are removed from public streets and manicured areas of public parks. They do not reflect the replacement of trees lost from private lands or woodlands, or wooded areas of public parks. Regardless of the replacement ratio that is selected, careful consideration must be given to proper species selection. Always ensure that species selected are tolerant of the site conditions and local climate, i.e. "The Right Tree for the Right Place". It is

imperative that City Planning staff follow the recommended species list provided in Appendix J, which has been updated from the Markham Trees for Tomorrow document. The recommended species list includes several species that will grow well in the urban conditions of Markham, as well as increase the diversity of Markham's urban forest – a critical goal to build long-term environmental health.

It is recommended that the City of Markham explore the impact that EAB will have on woodlands and natural areas of the City, by undertaking an inventory of woodland composition in 2013. The impact of EAB on woodlands is significant, as not only environmental benefits such as air quality will be impacted, but the demise of ash trees will open woodlands to problematic invasive species such as buckthorn.

It is recommended that the City of Markham plant trees that keep the occurrence of each species below 10% of the overall public tree population, to prevent additional catastrophic losses in the future. Experts suggest that a single species occur at less than 10% of the total population, while representatives from a genus should occur at a rate less than 20% of the population.

30-20-10 Rule: A rule-of-thumb, proposed by Santamour (1990), to guide the establishment of the urban forest. The rule states that no tree family exceeds 30%, no tree genus exceeds 20%, and no tree species exceeds 10% of the total urban forest inventory. The objective of this guideline is to promote urban forest diversity and resilience to pests, pathogens and other stressors.

The City should anticipate the selected species as a mature tree and evaluate its fit with its environment. For example, mature trees that drop a great deal of litter might not be the first choice for a street planting. Species such as willow (*Salix* spp.) have weak wood and generally drop many small branches during growing season, while female trees of other species, like ginkgo (*Ginkgo biloba*), produce large and messy fruit. Male trees of the same species, though, do not produce fruit are good candidates for planting. A few species, including black locust (*Robinia pseudoacacia*), honeylocust (*Gleditsia triacanthos*), and hawthorn (*Crataegus* spp.), can have sizeable thorns and should be avoided.

Not all of the removed ash trees should be replanted in the same location. Select locations to avoid overhead wires, nearby underground utilities, and other obstructions such as street lights, street signs and street corners. Replacing park trees should occur as part of an overall park tree planting master plan, with strict adherence to the recommended tree species list. Parks Planning staff play a key role in helping minimize long-term maintenance costs by careful selection of optimal and diverse species, and should consult with City Forestry staff on a frequent basis. An overall park tree planting master plan should be incorporated into the long-term vision for future park improvements, reducing the likelihood of removals.

Table 4. Cost to Replant New Trees

Table 5. Cost to Replant New Trees

Planting Year	Unit Cost per 50 mm tree*	Number of Trees to Plant (1:1)	Cost to Plant Trees (1:1)
2013	$350	2,315	$810,250
2014	$368	2,315	$851,920
2015	$386	2,315	$893,590
2016	$405	2,315	$937,575
2017	$425	2,315	$983,875
2018	$447	2,315	$1,034,805
2019	$469	2,315	$1,085,735
Total		**16,205**	**$6,597,750**

*Assumes a 5% increase in planting cost each year from spring 2012 quotes due to increased demands for nursery stock. Also includes maintenance expenses for young tree training (years 2 and 7), watering 5 times per season, mulching, soil, and seeding as required.

Markham's urban forest is facing uncertain threats from both climate change and invasive species. In order to manage for uncertainty and increase the adaptive capacity of the urban landscape, ecological resilience and adaptive management practices should be incorporated.

The full impact of climate change on Markham's urban forest is uncertain. Given the likelihood of increased summer temperature and drought as experienced in 2012, under future climate change scenarios, the selection of hardy native species that are heat and drought tolerant is recommended. A general trend towards north-ward migration of tree species is also being observed and projected for the future.

Native tree and shrub species under stress from climate change may also become more susceptible to introduced pests or may be out-competed by hardy generalist invasive plants. Controlling emerging invasive species is therefore more critical under future climate change scenarios

It is now likely that all ash trees in Markham (9% of the urban forest) will be eliminated by the EAB infestation that is moving across southern Ontario. There is a need to collect and store high quality seeds from native ash species before this component of the tree population is lost. Preserving seed from a wide range of healthy ash specimens in the local population will prevent the possible loss of native ash species and facilitate reintroduction once adequate environmental control measures for EAB are developed or trees resistant to the insect are bred

The City is advised to work with TRCA, the Ministry of Natural Resources (MNR) and the National Tree Seed Centre of Natural Resources Canada (NRCan) to implement a seed collection program for native ash species; the Town should also participate in other EAB research opportunities as they arise.

Priority Planting Index

Markham's Urban Forest Study developed a Priority Planting Index to provide guidance for tree planting

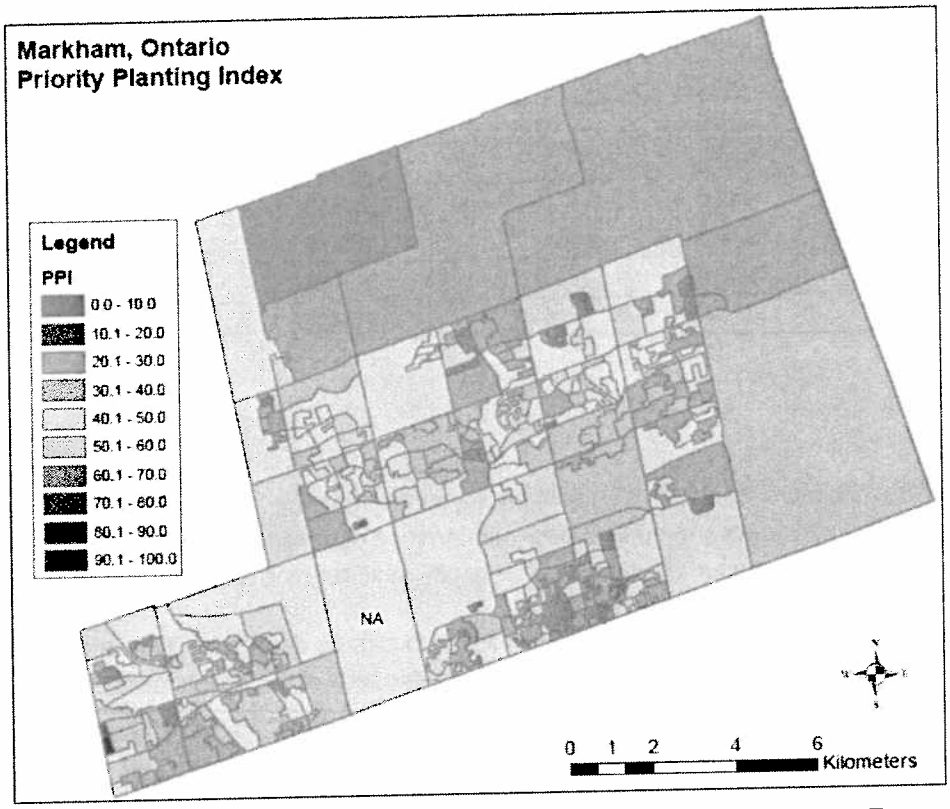


Chart 9. Priority Planting Index summarized by small geographic unit in the Town of Markham. Unit marked with "NA" was not included due to a lack of census data.

and establishment. Each unit of the map in Chart 9 has been assigned a value between 0 (lowest priority) and 100 (highest priority). Units with a higher human population density and a lower canopy green space and tree canopy per capita have received a higher index value.

The commercial and industrial areas adjacent to Highway 404 may have a low degree of tree cover, but they also have a low population density, and so for that reason, the Urban Forest Study considered them a lower priority. The residential areas located in the centre of the municipality, however, support a higher population density but with a limited tree canopy. Because they are not currently receiving an equitable distribution of the ecosystem services provided by the urban forest, they are given greater priority (shown in orange and red).

Tree Planting and Establishment

All removed ash trees should be replaced with species that are appropriate to the planting site and increase overall species and genus diversity of public trees. WDNR recommends that no single genus should comprise more than 10% of the total population. Also, no single species should account for more than 5% of the total population. Appendix J provides a list of recommended species that will help when selecting replacement trees.

There are 16,208 ash trees along streets and in parks that are scheduled for removal. Replacing these trees is a crucial component of a response to catastrophic tree loss, and will produce immediate benefits that will increase over time.

While a tree replacement ratio of 1:1 would initially replace every tree lost, it would likely result in an overall loss in tree canopy as the survival rate for newly planted trees is rarely 100%. Moreover, planting one small diameter, juvenile tree for each large diameter, mature tree will not go far in offsetting the immediate loss in canopy. A better option would be a rate of 2:1, which, considering that not all planted trees survive to an age where they are capable of produce significant canopy, would ensure that City's long term leaf cover is not compromised.

Two factors decide the success of a continuing tree planting program: the money spent on planting and maintaining the new trees, and the tree's health post-planting. A minimal initial investment and minor maintenance costs can, with a small amount of planning, provide healthy trees with longer life expectancies.

Proper tree planting is critical for providing newly planted trees the best chance of survival: improperly placed support wires, inadequately dug holes, etc. can stress young trees and even contribute to their death. A systematic maintenance program, designed specifically for newly planted trees, must be initiated to ensure longevity. Young tree training, involving pruning of the young tree to promote good structure, should be undertaken within 2 years of establishment, including the removal of tree stakes, and again at 6-7 years after planting. Young tree training costs are estimates at $30 per visit, and include top up of mulch at the same time.

Watering is critical to young tree survival. York Region has initiated the use of tree watering bags, which allow slow release of water to the root system. Watering bags are filled from water trucks staffed by seasonal employees. Consideration should be given to adding one additional watering truck to supply increased demands of watering trees. Also, a program to encourage residents to embrace stewardship of their street trees should be developed, to encourage watering of boulevard trees in front of homes and businesses.

Figure 19. Watering apparatus for newly planted trees.

Tree species diversity

Ensuring diversity in new plantings should be a primary consideration. Monocultures are strongly associated with negative outcomes; if a single species is planted heavily and then proves susceptible to disease or pests, large areas can lose a substantial portion of their tree canopy at once.

The following photo captures the monoculture planting in Beaupre Park, which was installed after EAB risk was well known throughout Ontario. It is essential that Planning Department plans landscapes collaboratively with Forestry Department to prevent future landscapes which are at risk for pests or diseases.

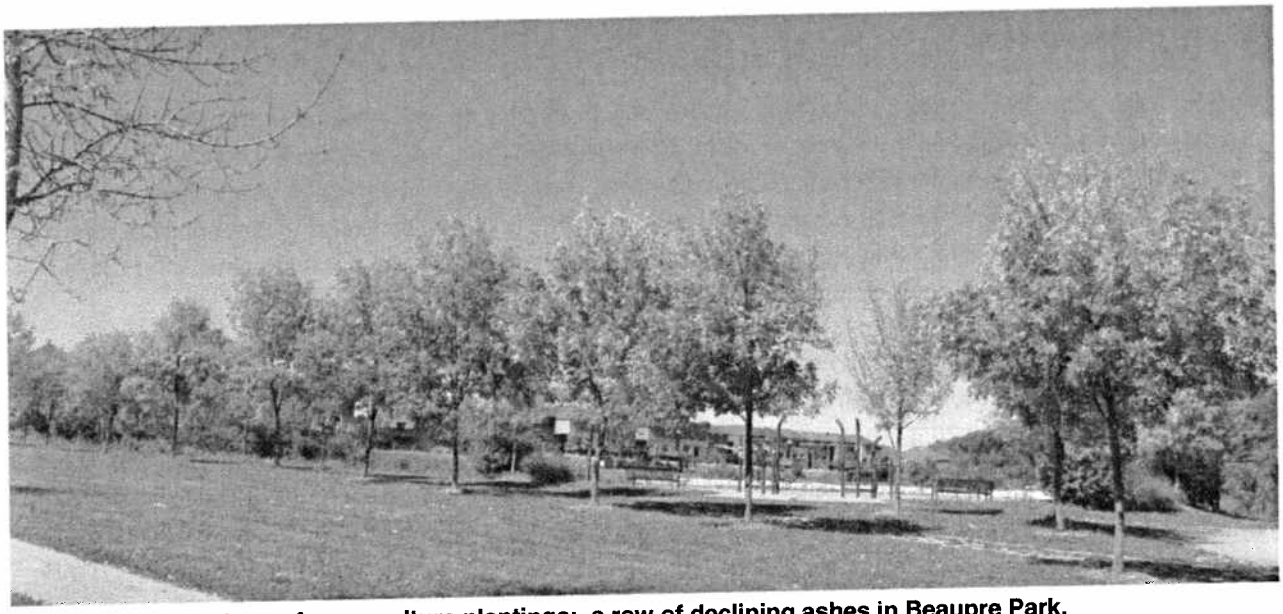


Figure 20. Implications of monoculture plantings: a row of declining ashes in Beaupre Park.

Appendix J provides a comprehensive list of recommended species for Markham's urban forest.

Colour

Planning for seasonal colour should also be considered. Flowering varieties are especially attractive, and deciduous trees with bright fall colours can add interest to their surrounding landscapes.

Above all, the City should place the importance on choosing durable and low maintenance trees. These attributes are largely dependent, however, on a species' own characteristics as well as those of its planting site: think "right tree, right location." A tree with a reputation for hardiness planted in an unsuitable site will not live up to expectations—if it lives. Trees that are planted in their favoured conditions are more resistant to pathogens and pests, and are consequently much more likely to thrive and necessitate less care overall.

Tree Purchasing

It is critical to use detailed specifications in the tender process. A qualified arborist should assess and approve all nursery stock upon receipt, and any specimen that fails to meet the criteria for quality and health should be rejected and replaced.

Tree planting

The most critical step in successfully installing a new tree is preparing the planting site. In general, the hole should be far wider than it is deep: three times as wide as the root ball's diameter, and slightly less deep than its height. Adding soil amendments is not recommended in most situations, as these amendments can lead to serious differences between the structure and texture of the soil inside the planting hole and those of the soil surrounding it. These differences can contribute to water being wicked away from or accumulating in the planting holes.

Tree staking hardware should only be installed when necessary to prevent trees from leaning in windy areas or to prevent damage from pedestrians and/or vandals. Stakes should be secured to trees with loose, flexible material, and all staking material should be removed within one or two growing seasons.

Tree mulching

A 5-10 cm layer of mulch should be applied to the soil's surface around each newly planted tree, in an area three times the diameter of the root ball. It should never be heaped up around the root collar (mulch 'volcanoes'), but instead pulled away from it. Mulch that buries the root collar provides excellent shelter for insects, fungi and small mammals that could damage the tree. Proper mulching suppresses competition from grass and weeds, while also creating a turf maintenance free zone, keeping lawn mowers and string trimmers safely away from the tree's trunk. Mulch also helps the soil surface, where most of the tree's feeder roots will establish, retain moisture.

Private Ash Trees

Although the issue of private ash trees is not part of this report, Davey Resource Group recommends some overall guiding principles for dealing with private ash trees. The City is encouraged to start communicating to property owners to prepare for the loss of all ash trees. Removal costs will be much higher after the death of the trees, as dead, brittle trees are more hazardous and will require additional equipment to remove. Also, as the local market will be flooded with requests for removal works, costs are expected to rise and there may also be an increase in unqualified tree workers performing this dangerous work. Property owners should only hire tree care professionals who are insured and government or ISA certified professionals.

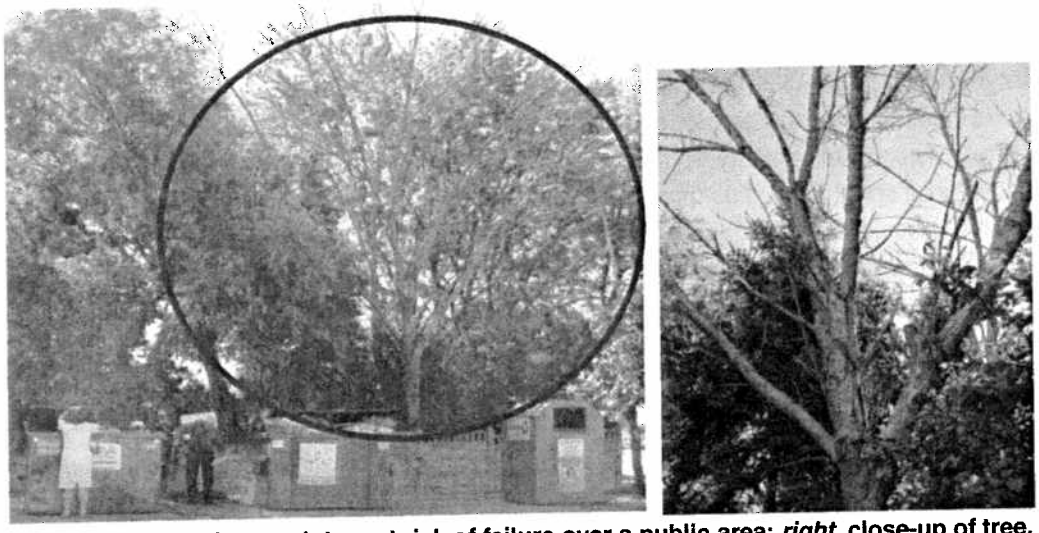


Figure 21. *Left*, private ash tree at risk of failure over a public area; *right*, close-up of tree.

Public Outreach and Education

- Educate local tree advocacy groups of the EAB biology and provide instructions for local monitoring programs
- Consider providing the local library and other public information locations in the community with EAB information and local procedures.
- Keep informed by visiting the following internet sites:
  - http://na.fs.fed.us/fhp/eab/
  - http://www.emeraldashborer.info

Additional Management Considerations

It is important to consider the often-overlooked costs of managing such a large scale community issue which will generate public concern and questions. The following tasks will be needed to be completed in-house by City staff to support the Forestry department:

- Update ash inventory on a regular basis, preferably spring and again early autumn, as part of a continuous monitoring of ash on streets, in manicured areas of parks, public woodlots and greenways, and other public sites. In particular, monitoring of ash trees along trails and along park boundaries will be needed to reduce the chance of high-risk trees creating damage or injuring adjacent residents.
- Update EAB strategy at least every two years to reflect significant changes in strategy success, cost revisions, product availability, etc. The update will be a complete review of which strategies are most effective, inclusion of new research developments, and will provide the potential for considerable cost savings over time.
- Organize and hold "town hall" meetings at the neighborhood and city-wide level to keep public and media apprised of the overall EAB project status.
- Explore community involvement and incentive programs for citizens to plant replacement trees (*e.g.* reduced cost trees). Expand Arbor Week initiatives as part of the EAB replacement trees program.
- Continue to network with other municipalities and industry experts, and attend regional strategy sessions held by government departments (Canadian Forest Service and CFIA), as well as York Region.
- Update EAB program goals and assist with preparing annual program budgets. Prepare program updates and adjustments every two years, as the impact on Markham's urban forest will be dramatic and rapid.
- Lobby provincial and federal government institutions for continued research and assistance with funding EAB strategies at the community level. Currently, municipalities carry the funding burden for planning, treatments, removals, and re-planting associated with EAB. Continued lobbying will assist with getting the message to provincial and federal agencies that EAB is a regional, provincial, and federal problem that will create billions of dollars in cost to communities. A unified approach, directed in part by provincial and federal policies and funding, will greatly assist in the development of a sustainable program. The City of Oakville has prepared lobbying letters available to view at http://www.oakville.ca/eabnews.htm.
- Continue to monitoring EAB population levels as the City's EAB strategy occurs over the next 15 years. This monitoring program can be a cooperative effort between the City and York Region, and include CFIA researchers that have interest in EAB population dynamics. It is anticipated the monitoring will include trapping and branch sampling to gauge EAB levels of infestation.
- Continue to update the city-wide GIS based tree inventory of trees on public property Develop a
- process for inventory and management of natural stands that include an ash component. Consider establishment of continuous forest inventory plots (or permanent inventory plots) for these stands.

The tremendous workload challenges faced by municipal staff in the midst of an EAB infestation must be recognized. Additional staff is needed to manage the increase in workload, as well as public inquiries. It

is recommended that two additional staff members be added: an EAB Lead Hand position, and an Administrative support person. The EAB Lead Hand will be required to handle the tasks of contractor scheduling, management and supervision; ongoing inspection and reassessment of trees; updating inventory; contract administration; sourcing of nursery stock, and preparation of planting plans. Estimated budget for this position (including 50% benefits) is $78K. The administrative support person will handle tasks including preparation of work orders; invoices; public, staff and Councillor inquiries, and assist with community involvement programs. A budget cost of $56K (including benefits) may be used.

Periodic consulting assistance will be necessary to continue to undertake woodland inventories and update the management plan every couple years. A cost of $30K every 3 years has been incorporated into the budget to cover these activities.

Preferred Approach

A complete EAB strategy includes several action items which must be undertaken cohesively to be successful. Some of the action items are direct events, while others are closely aligned supportive or related actions. The previous sections of this report have identified several potential action items and related steps that are now condensed here and presented as a preferred approach to an EAB strategy.

While there are many options for a municipality to consider, this section provides a digest of action items and their associated projected costs.

Action Item 1–Assessment (streets and manicured areas of park lands)

1.1 Assess the current presence and condition of the ash tree resource in Markham. (Completed)

1.2 Assess the level of EAB infestation. (Completed)

Action Item 2–Treatment (streets and manicured areas of park lands)

2.1 Test pilot conducted, treating half the park trees with TreeAzin™ in summer 2012.

2.2 Chemically treat trees every two years through the year 2027. Total cost is $1,115,513.

Action Item 3–Tree Removal (streets and manicured areas of park lands)

3.1 A total of **16,208 ash trees are identified for removal** along streets and in manicured areas of parks over period of 7 years (2013-2019). Total cost **is $5,061,806.**

3.2 Develop markets for ash wood created from removals. Cost is unknown at this time, though there is a potential for income from re-use of ash wood residue. Discussions ongoing.

Action Item 4– Replacement Tree Planting (streets and manicured areas of park lands)

4.1 Replacement of ash trees lost to EAB is a critical component of the EAB strategy. Select species that will maintain, or increase, species diversity. Replanting needs to occur in order to reduce canopy cover losses.

4.2 Plant a total of 16,208 trees (50mm recommended) between 2013-2019 (same years as removals) at a total cost of **$6,597,750** to replace trees removed . Average of 2,315 trees planted each year).

Action Item 5 – Additional Staffing

5.1 Hire EAB Lead Hand to handle increased operational workload at a cost of **$78K**.

5.2 Hire Administrative support staff member to handle inquiries and admin, at a cost of $56K.

Action Item 6 - Develop Public Communications Plan

6.1 Develop comprehensive public communications strategy to inform community

Action Item 7 – Develop Private Ash Tree Strategy

7.1 – Consider private ash tree policy/bylaw to encourage timely removals of high risk trees

Action Item 8 – Inventory Woodlands & Develop Management Strategy

8.1 Conduct inventory of woodlands to determine ash composition

8.2 Develop management strategy for natural areas ash management and reforestation

Review of Cost Estimates

Table 6 provides a spreadsheet of the EAB strategy costs per year by cost category and the total estimated costs of the 15-year project. Although removals, planting and program costs are heavily front-loaded, injections will be expected to continue until the threat of EAB has passes, at this time considered to be 15 years.

Table 5. Total EAB Strategy Costs

Table 6. Total EAB Strategy Costs

Year	Treatment Costs	Removal Costs	Planting Costs	Program Costs	Total Costs
2013	$120,890	$621,698	$810,250	$164,000	$1,716,838
2014	$0	$652,773	$851,920	$138,000	$1,642,693
2015	$125,771	$685,412	$893,590	$172,000	$1,876,773
2016	$0	$719,682	$937,575	$146,000	$1,803,257
2017	$130,800	$755,669	$983,875	$150,000	$2,020,344
2018	$0	$793,450	$1,034,805	$185,000	$2,013,255
2019	$136,170	$833,122	$1,085,735	$160,000	$2,215,027
2020	$0			$165,000	$165,000
2021	$141,700			$170,000	$311,700
2022	$0			$175,000	$175,000
2023	$147,426			$181,000	$328,426
2024	$0			$185,000	$185,000
2025	$153,258			$191,000	$344,258
2026	$0			$197,000	$197,000
2027	$159,498			$207,000	$366,498
Total	**$1,115,513**	**$5,061,806**	**$6,597,750**	**$2,586,000**	**$15,361,069**

While a "do nothing" option exists for dealing with EAB, the costs would be very high. There would still be costs associated with the removal of trees that become infested (potentially over 9,000 ash trees), and if the removals are delayed, there will be large increase in the amount of risk to the public associated with dead and dying ash with very brittle wood. Additionally, the "do nothing" option would mean the loss of all calculated benefits that the ash population provides which is calculated at $130 million dollars utilizing Markham's 2012 Urban Forest Study.

A cost effective system for tree removals would be to schedule mass removals on a block by block basis. More labour efficient, this will reduce costs and also make the task of notifying residents easier. Front-loading removals—removing more trees in earlier years—would also reduce costs by avoiding future price increases.

Summary

The Emerald Ash Borer Strategy developed by the City of Markham presents a realistic and comprehensive program to manage the loss of over sixteen thousand trees across the City. Timely removals are critical to promote public safety, and replanting is necessary to mitigate the dramatic losses to the urban forest canopy. It is also essential to update the Emerald Ash Borer at an interval of every three years, as rapid developments in the management of EAB is changing rapidly, including the introduction of new treatments. This strategy supports tree canopy conservation with treatment of larger trees that provide environmental benefits to the citizens of Markham. Future planning should ensure continued consultation with City Forestry staff and diversification of the urban forest to prevent similar devastating losses to the green infrastructure so important to the community of Markham.

Cited Materials

Careless, P.D. "Known Prey Diversity of *Cerceris fumipennis*." Working with *Cerceris fumipennis*. http://www.cerceris.info/pdf/prey_diversity_c_fumipennis.pdf (accessed October 2012).

City of Chicago. Bureau of Forestry. *Emerald Ash Borer Biological Control Program in Illinois*, by John Lough. Chicago, June 2011. http://www.agr.state.il.us/eab/PDFs_for_web/ News/2011/Illinois _Parasitoid_summary_June_2011.pdf (accessed October 2012).

Kerr, Pat. "Emerald Ash Borer Part III – The Science Makes Progress." *Ontario Arborist* (November-December 2010). http://www.isaontario.com/content/emerald-ash-borer-part-iii-science-makes-progress (accessed October 2012).

McPherson, E. Gregory. "A Benefit-Cost Analysis of Ten Street Tree Species." *Journal of Arboriculture* 29, no. 1 (January 2003): 1-8.

Natural Resources Canada. *Frontline Forestry Research Applications: Emerald Ash Borer.* Technical Note No. 110. Sault Ste. Marie, 2010. http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/31501.pdf (accessed October 2012).

Nowak, David J., Daniel E. Crane, Jack C. Stevens, and Robert E. Hoehn. *The Urban Forest Effects (UFORE) Model: Field Data Collection Manual.* Syracuse, NY: USDA Forest Service, Northeastern Research Station, 2003.

Santamour, F.S. "Trees for Urban Planting: Diversity, Uniformity and Common Sense." *Proceedings of the 7th Conference of METRIA: Metropolitan Tree Improvement Alliance* 7(1990):57-65.

United States Department of Agriculture. Animal and Plant Health Inspection Service. *Biological Control of the Emerald Ash Borer (*Agrilus planipennis*)*. Plan, 2010. http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/eab-biocontrol.pdf (accessed October 2012).

United States Department of Agriculture Forest Service. National Research Station. "Biological Control of the Emerald Ash Borer." http://nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/biological_control/ (accessed October 2012).

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Figure 4. *Clockwise from top*, David Cappaert, Michigan State University; Jeff McMann, Supervisor of Forestry, City of Markham; David Cappaert, Michigan State University; D.B. Lyons, Natural

Resources Canada, Canadian Forest Service, Laurentian Forestry Centre; Ivan Lister, Urban Forestry Manager, City of London; Canadian Food Inspection Agency.

Figure 5. *Clockwise from left*, Benjamin Cummings; Jeff McMann, Supervisor of Forestry, City of Markham; Troy Kimoto, CFIA.

Figure 6. *a*, Barb Rabicki, Davey Resource Group; *b*, Canadian Food Inspection Agency; *c*, Barb Rabicki, DRG; *d*, Edward Czerwinski, Ontario Ministry of Natural Resources; *e*, Department of Agriculture, State of Maine; *f*, Jerry Dowding, Canadian Food Inspection Agency.

Figure 7. CFIA.

Figure 8. BioForest Technologies.

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