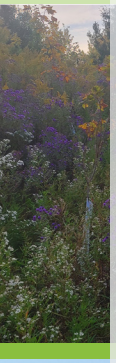
CITY OF MARKHAM

INVASIVE PLANT SPECIES MANAGEMENT PLAN

Natural Heritage Management Study | May 2024





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1 Introduction

The City of Markham (the City) retained CBCL Limited (CBCL) in July of 2022 to undertake a natural heritage management study to support stewardship and enhancement of City-owned natural areas in the Greenway System. The City of Markham's 2014 Official Plan designates approximately 7,000 ha of lands as the City's Greenway System and establishes policies to maintain and enhance this interconnected network of natural areas. More than half of the Greenway System is owned and managed by public agencies: approximately 1,000 ha is owned by the City and another 3,200 ha by Parks Canada (i.e., Rouge National Urban Park).

During field work carried out by CBCL in 2022, invasive plant species were the most frequently observed type of management concern in City-owned natural areas. Invasive species are a major threat to ecosystems and introductions of invasive species to Ontario are predicted to become more frequent in an increasingly globalized world (Nienhuis and Wilson 2018). Invasive species have a variety of impacts on ecosystems and are one of the leading threats to biodiversity worldwide (McNeely et al. 2001). Invasive plant species may compete with native species for water, light, nutrients, and physical space (Duenas et al. 2018; Reaser et al. 2020). In the worst cases, invasive species can cause extirpation of native species and completely dominate habitats where they occur.

This report provides an Invasive Plant Species Management Plan (IPSMP) with information on key invasive plants in Markham, past and ongoing management efforts, and direction on the prioritization and implementation of invasive species management projects in City-owned natural areas. The scope of the IPSMP is limited to plants and does not include other invasive pests such as insects. The IPSMP is presented in the following sections:

- **Existing Conditions Summary:** Invasive plant species identified in City-owned natural areas. Key invasive plant species that occur in the City are described along with their impacts and treatment options.
- **Summary of Past and Ongoing Management Efforts:** Summary of past and ongoing invasive species management activities in the City.
- **Invasive Plant Management Tools, Approaches and Opportunities:** Tools and approaches for managing invasive plant species, with a focus on key invasive species.
- **Prioritization Framework:** A standard framework and approach for identifying high-priority invasive species management projects.
- **Invasive Plant Species Monitoring:** Recommendations for approaches and methodologies for monitoring invasive plant species.

2 Existing Conditions Summary

2.1 Impacts of Invasive Plants

In 2022, invasive plants were the most frequently observed type of management concern in City-owned natural areas.

Invasive species pose the second greatest threat to biodiversity after habitat loss (Erlich, 1998; Wilson, 1992). Invasive plant species can displace native species in a community, negatively impacting ecosystem function and services, and are a growing threat to human health and the economy. Many invasive plants have the ability to spread rapidly and aggressively, leading to a decline in ecological health and recreational enjoyment. The following are some of the significant impacts on natural ecosystems in urbanized environments:

- **Biodiversity loss, habitat degradation, and disruption of ecological and hydrological processes**—Invasive plants can outcompete native plants for resources such as water, light, and nutrients, leading to a decline in native plant populations. As native plants decline, the habitat structure and composition of ecosystems are altered. The degradation of ecosystems can impact native animals by reducing nesting sites and foraging opportunities, or disrupt natural ecological and hydrological processes such as seed dispersal, pollination, water quality, and nutrient cycling.
- **Human health, safety, and recreational enjoyment**—Some invasive plant species pose risks to human health causing severe skin irritations or injuries, impacting the enjoyment of outdoor activities. Certain invasive plant species can limit visibility in rights-of-way increasing the risk of vehicle accidents or they can intensify fire risk by increasing fuel loads or altering fire regimes. Other invasive plants can reduce the aesthetic value or accessibility of recreational land and waterbodies.
- **Economic impacts**—Invasive plant species can have significant economic consequences including the costs of control and management, such as surveys, eradication programs, and public awareness campaigns. In addition, costs can be incurred due to damaged infrastructure, reduction in property values, and negative effects on agriculture and landscaping industries.

2.2 Locations and Abundance of Invasive Plants

Invasive plant species are common in Markham's natural areas. At least 41 invasive plant species are considered to pose a risk to natural areas in Markham; these include species

that have been documented in Markham's natural areas and those that are known to occur in adjacent municipalities and are spreading into Markham (see Table 1[1])[2]. Some of the most common invasive plant species found in the Markham Greenway System in 2022 include Common Buckthorn (*Rhamnus cathartica*), invasive willows (*Salix* spp.), cool season grasses, Dog-strangling Vine (*Vincetoxicum rossicum*), and invasive honeysuckles (*Lonicera* spp.).[3]

The 2022 survey revealed that approximately 300 ha of City-owned natural areas are dominated by alien or invasive plant species[4]. This represents nearly one third of City-owned portions surveyed by CBCL. It was observed that the prevalence of invasive species did not appear to differ significantly between community classes; forests, wetlands, open country/early successional, and other community classes all exhibited roughly equal prevalence of invasive species in terms of the number of polygons dominated by invasives. However, there are differences in which species predominate. The most prevalent invasive species in woodlands are Common Buckthorn, Black Locust, and invasive honeysuckles. The most prevalent invasive species in open country and early successional communities are Dog-strangling Vine, Common Buckthorn, and Autumn Olive. The most prevalent invasive species in wetlands are invasive willows, Phragmites, and Hybrid Cattail.

Table 1: Invasive Plant Species Considered a Risk to City-owned Natural Areas

Common Name	Scientific Name
Autumn Olive	*Elaeagnus umbellata*
Black Alder	*Alnus glutinosa*
Black Locust	*Robinia pseudoacacia*
Common Buckthorn	*Rhamnus cathartica*

[1] Data on invasive species in the City has been informed by detailed field assessments completed on City-owned parts of the Greenway System. This included field investigations by CBCL on approximately 250 ha of the Greenway System in 2022, and investigations completed by others for the City's Natural Heritage Inventory and Assessment Study (NHIAS) in 2020 (North-South Environmental Inc. and Dougan and Associates Inc. 2021).

[2] Manitoba Maple (*Acer negundo*) and Reed Canary Grass (*Phalaris arundinacea*) are not treated as invasive species in this handbook. Although it is generally understood that Manitoba Maple is not historically native to the Markham area, it is native to Ontario and its status as an invasive species outside its historical range is the subject of debate. There is evidence that a non-native form of Reed Canary Grass has become invasive in North America, but there is no reliable way to distinguish native from non-native populations in the absence of genetic testing.

[3] Invasive willows include a combination of White Willow (*S. alba*), Crack Willow (*S. euxina*), and the hybrid *S.* x *fragilis*, which are often found together. Cool season grasses include a mix of non-native species that frequently occur together, most commonly Meadow Bluegrass (*Poa pratensis*), Smooth Brome (*Bromus inermis*), Timothy (*Phleum pratense*), Orchard Grass (*Dactylis glomerata*), Quackgrass (*Elymus repens*), and Creeping Bentgrass (*Agrostis stolonifera*). Invasive honeysuckles include a combination of Tartarian Honeysuckle (*L. tatarica*), Pretty Honeysuckle (*L.* x *bella*), and Morrow's Honeysuckle (*L. morrowi*).

[4] Some of the alien plant species documented in 2022 are not necessarily invasive (i.e., they do not take over native habitats) or they provide wildlife habitat functions (e.g., non-native cattails provide similar structure and habitat to the native species).

Common Name	Scientific Name
Common Privet	*Ligustrum vulgare*
Creeping Bentgrass	*Agrostis stolonifera*
Crown Vetch	*Securigera varia*
Dame's Rocket	*Hesperis matronalis*
Dog-strangling Vine	*Vincetoxicum rossicum*
Domestic Apple	*Malus pumila*
English Elm	*Ulmus glabra*
English Ivy	*Hedera helix*
European Barberry	*Berberis vulgaris*
Phragmites/European Reed	*Phragmites australis* subsp. *Australis*
European Spindle Tree	*Euonymus europaeus*
Garlic Mustard	*Alliaria petiolata*
Glossy Buckthorn	*Frangula alnus*
Guelder Rose	*Viburnum opulus* var. *opulus*
Himalayan Balsam	*Impatiens glandulifera*
Invasive Honeysuckles	*Lonicera* x *bella*, *L. morrowii*, *L. tatarica*
Invasive Willows	*Salix alba*, *S. euxina*, *S.* x *fragilis*, *S.* x *sepulchralis*
Japanese Barberry	*Berberis thunbergii*
Japanese Knotweed	*Reynoutria japonica*
Javanese Water Dropwort	*Oenanthe javanica*
Lesser Periwinkle	*Vinca minor*
Norway Maple	*Acer platanoides*
Orange Daylily	*Hemerocallis fulva*
Oriental Bittersweet	*Celastrus orbiculatus*
Purple Loosestrife	*Lythrum salicaria*
Redtop Bentgrass	*Agrostis gigantea*
Russian Olive	*Elaeagnus angustifolia*
Scots Pine	*Pinus sylvestris*
Siberian Elm	*Ulmus pumila*
Smooth Brome	*Bromus inermis*
Upright Hedge Parsley	*Torilis japonicus*
White Madder	*Galium album*
White Mulberry	*Morus alba*
White Poplar	*Populus alba*
Wild Parsnip	*Pastinaca sativa*
Wood Avens	*Geum urbanum*
Woodland Bluegrass	*Poa nemoralis*

2.3 Gaps in Invasive Plant Species Data

The list of invasive plant species in Table 1 is not inclusive of all species present in City-owned parts of the Greenway System and the distribution and abundance of invasive plant species in the City in general is not well documented. Although invasive species data was collected during the 2020 NHIAS, data collection and mapping was not consistent with the 2022 surveys, which had a greater emphasis on documenting the distribution and abundance of invasive plant species. In future efforts, a standardized approach to invasive species surveys can be used to develop a more comprehensive baseline inventory of City-owned parts of the Greenway System. Standardizing data collection protocols and formats can improve data quality and comparability. All existing information and data collected through future monitoring efforts can be entered into a database used to map invasive species presence and identify high priority areas to facilitate management decisions. See Section 6 for more information on Invasive Plant Species Monitoring considerations.

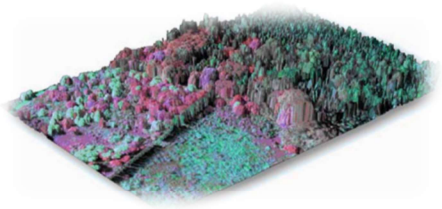
DATA COLLECTION

Data collection for invasive plant species are similar to other plant species. Protocols vary based on the objective, but the following information should be collected for an invasive species inventory:

- Location
- Date
- Species
- Abundance
- Dominance
- Area Occupied
- Condition/Health
- Co-occurring species

To enable more effective and targeted management measures to control and prevent the spread of current and potential invasive plant species in the Greenway System, data on invasive plant species present in the Greenway System and surrounding areas should be gathered and mapped in a central GIS database. Strategies to consider when addressing gaps in invasive species presence, distribution and movement include the following:

- Encouragement and use of community science data—Engage the public to report invasive species sightings through iNaturalist or Early Detection and Distribution Mapping System (EDDMapS) for Ontario. The data collected through these platforms can be incorporated into the City's database of invasive species.
- Collaboration with local experts—Work with local experts, naturalists, conservation organizations, and land managers who have knowledge of specific areas and can provide valuable insights on invasive species occurrences.
- Use of remote sensing and satellite imagery—Use remote sensing technologies, satellite imagery, and other geospatial data to help identify potential invasive species hotspots and areas that require further ground verification. This data can also help identify areas with a high likelihood of invasion and prioritize data collection efforts accordingly.
- Fostering partnerships—Collaborate with academic



Example of remote sensing using LiDAR and hyperspectral data to detect invasive specie (shown in red and pink colours). Source: Huang and Asner (2009).

institutions, research organizations, governmental agencies, and neighbouring jurisdictions such as land managers, York Region, TRCA, and Parks Canada to share existing data and promote collaborative data collection efforts. Pooling resources and knowledge can help fill data gaps more effectively.

Invasive species distribution information and mapping should be periodically revisited and updated to reflect new data and changing conditions. Regularly communicating the findings with relevant stakeholders can facilitate informed decision-making for management measures.

2.4 Priority Species

To effectively allocate City resources, it is advised to concentrate efforts on identifying and managing specific priority invasive plant species present on City-owned lands, particularly within the Markham Greenway System. In addition to economic factors, the prioritization of invasive plant species accounts for risks to natural ecosystems and ecological features, social considerations, and concerns related to human health and safety. While the eradication of priority species is not a feasible goal, the list of priority species can help the City to begin identifying and assessing lands that require attention. By designating these "priority invasive plant species" and focusing long-term and sustained efforts on their control, successful management can be achieved, avoiding repeated reintroduction and waste of resources.

Priority species are emphasized due to their widespread presence, abundance, impact on regional natural heritage values, and potential risks to public health and safety. Table 2 provides a preliminary list of priority invasive species for management in City-owned parts of the Greenway System. The list was developed with considerations of species of importance in consultation with City staff. The invasive species identified as Tier 1 are those that the City already manages to varying degrees and are considered by staff to be the highest priority for continued and increased management. Other invasive species in Table **2** are not currently being managed, but could be considered as additional resources become available.

REMOTE SENSING

Remote sensing uses several techniques, including drones and satellites, to create images of an area. It is increasingly being used to map the distribution of invasive species.

A combination of LiDAR (light detection and ranging) and hyperspectral imagery was used to map two understory invasive plant species—English Ivy and Himalayan Blackberry—in Surrey, British Columbia. Details can be found here: https://open.library.ubc.ca/media/stream/pdf/24/1.0305687/4

Table 2. Priority Invasive Species for Management within City-owned Natural Areas.

Priority Tier	Common Name	
Tier 1	Common Buckthorn; Glossy Buckthorn	Dog-strangling Vine
	Phragmites / European Reed	Giant Hogweed
	Wild parsnip	
Tier 2	Autumn Olive	Lesser Periwinkle
	Black Alder	Lily-of-the-valley
	Garlic Mustard	Norway Maple
	Goutweed	Oriental Bittersweet
	Himalayan Balsam	Russian Olive
	Invasive Honeysuckles	Tree-of-heaven
	Japanese Knotweed	White Mulberry

It is noted that both Poison Ivy and Cow Parsnip are native plants but are considered a priority for management alongside the invasive species on this list due to the harmful effects to humans.

During field surveys in 2022, CBCL observed several invasive plant species occurring in locations within the City's Greenway System that were identified as suitable candidate sites for invasive species management pilot projects. The life histories, ecological impacts, and treatment options for the species present at these possible invasive species management locations are described in more detail below.

2.4.1 Common Buckthorn

Most prevalent in woodlands and early successional communities in the Markham Greenway System, Common Buckthorn is a deciduous shrub or small tree that can form dense thickets that rapidly outcompete native vegetation. Common Buckthorn reproduces through both seed and vegetative propagation and is able to disperse widely as the berries are consumed and dispersed by birds.

By forming dense thickets that shade out and suppress native plant species, Common Buckthorn reduces biodiversity and alters native plant communities by supressing understory plant growth, changing soil nutrient composition, and interrupting successional processes. Buckthorn thickets provide poor habitat for native wildlife and negatively affect the availability of food and nesting sites for birds. Buckthorn can also have negative impacts on recreational values where it is established.

Common Buckthorn

A typical treatment option for Common Buckthorn is through mechanical control measures. Mechanical management is achieved by pulling or cutting the shrubs (with efforts focused on removing female plants). It is recommended to pull plants in the fall when they are readily identifiable and when disturbance to the dormant native vegetation is minimized, but care must be taken to contain branches containing berries. Resprouting can be a problem after mechanical treatments and control measures are often combined with controlled burns and chemical control. Chemical control may be an effective option for treating larger infestations, especially those that threaten forestry or agriculture. Repeated burning may be effective where feasible and natural fire barriers around a buckthorn stand is present. Flooding and re-establishment of water levels is another method that may help to control buckthorn. Federal, provincial, or conservation authority permits or approvals may be required to use this control method.

Common Buckthorn

Restoration of water levels in conjunction with wetland enhancement can be used to manage invasive plants.

Regular follow-up monitoring is suggested to identify and address any new growth or seedlings. New sprouts and seedlings should be promptly removed to prevent further spread and re-infestation. Mowing can be used to reduce vigor of smaller stems and kill seedlings. A typical timeline for treatment of buckthorn is two to six years or more; however, a recent study found that treatment of buckthorn may be needed for only one to two years (Schuster, et. al, 2023). Re-planting with native vegetation following treatment is recommended once buckthorn is eradicated or under control.

2.4.2 Dog-strangling Vine

A common invasive plant of early successional communities in the City, Dog-strangling Vine is a perennial, herbaceous vine that forms extensive stands with the ability to exclude all other species from a site. It is especially problematic for wildlife (particularly grassland birds) due to its habitat-altering capability and reduced capacity to provide food resources for native insects, including the Monarch butterfly (*Danaus plexippus*). Dog-strangling Vine can also severely inhibit recreational activities where it is established, due to the difficulty of travel though the dense tangled mats that it forms.

Dog-strangling Vine

Dog-strangling Vine flower

Infestations of Dog-Strangling Vine can be managed by digging out the plants, ensuring that all root fragments are removed to prevent re-sprouting. This method is most effective when applied before seed production. Other mechanical methods of control include clipping, and tarping when eradication may not be possible. Seed pod removal can be used in the case of a late season discovery to reduce seed dispersal when other control methods are not an option.

Chemical control of Dog-Strangling Vine using herbicides are typically applied during the plant's active growth phase by licensed exterminators. Re-application of herbicides is needed for several years to target seedling growth.

In Ontario, there has been notable progress in the biological control of this weed by introducing *Hypena opulenta*, a leaf-feeding caterpillar (Anderson, 2012). This type of control is best suited to large sites with a high density of plant cover; however, the most effective approach often involves integrated strategies that combine control methods.

Prioritization of efforts should be made where the population of plants is small or newly detected and eradication is possible. Site restoration is needed during and after control activities to reduce the risk of re-invasion.

Dog-strangling Vine seed pod

2.4.3 Phragmites/European Reed

A common invasive plant species of wetlands, Phragmites/European Reed is a tall, perennial grass species that is widespread in Ontario. It has a fibrous root system and can spread through underground rhizomes outcompeting native plants and forming dense monocultures. Phragmites typically grows in dense stands that can reach heights of more than 5 metres, blocking shoreline views and access. Major highways and secondary roads are commonly a vector of spread of this species. A native species of Phragmites is also found in Ontario and does not have the same negative impacts on habitat and biodiversity. Native Phragmites should be distinguished from invasive Phragmites before considering management actions. Native Phragmites grow in sparser stands mixed with other plants, in contrast to the near-monoculture stands of invasive Phragmites. Morphologically, native Phragmites can be distinguished from invasive Phragmites by the ligule width, stem colour, leaf retention and smaller, sparser seedheads.

Phragmites in a wetland

Monotypic stands of Phragmites can significantly alter wetland habitats and have several negative ecological impacts such as reduced biodiversity (including significant impacts to species at risk) and altered hydrology and nutrient cycling. In addition, Phragmites can create human health or safety hazards such as increased fire hazard due to dead stems and reduced visibility along roadways (Nichols, 2020).

Managing Phragmites infestations requires a combination of control methods, and the choice of treatment depends on the extent of the invasion and the specific site conditions. Treatment options typically include mechanical and chemical control methods. Cutting stems can help reduce their density and prevent seed production. This method is best employed repeatedly during the growing season and performed for several years to weaken the plant. However, TRCA does not recommend cutting as a treatment option for Phragmites as it can invigorate growth and increase density. Herbicides can be used to target stands during their active growth phase. Herbicides are typically applied by licensed professionals and should follow environmental regulations to minimize non-target impacts. Other control techniques include mulching and prescribed burning and, where possible on wet sites, flooding can be an effective management tool.

Phragmites/European Reed

Re-vegetation with native plant species, including grasses and forbs, is being used to resist the invasion of Phragmites in Ontario (Nichols, 2020). Research has identified competitive native plants, and initiatives are successfully converting landscapes, such as highway verges, into tall prairie grasslands, effectively inhibiting the plant's spread. Re-vegetation not only prevents its return but also protects soil and complements restoration efforts.

2.4.4 Wild Parsnip

Wild Parsnip is a biennial to perennial herbaceous plant native to Europe and Asia but introduced and now widely distributed in North America. The plant can grow up to 1.5 metres tall, with compound leaves and umbrella-like clusters of yellow flowers. Wild Parsnip can establish in a variety of habitats, including roadsides, fields, disturbed areas, and along waterways.

Wild Parsnip in bloom

Wild Parsnip can have significant ecological impacts, both on native plant communities and wildlife. Its aggressive growth habit allows it to outcompete native vegetation, leading to reduced biodiversity in affected areas. The dense stands of Wild Parsnip can alter habitat structure and reduce available resources for native plants and animals. Furthermore, the plant's sap contains compounds that cause phytophotodermatitis in humans upon contact with the skin, leading to painful burns and blisters when exposed to sunlight. This can affect outdoor activities and pose risks to people working or recreating in infested areas.

Wild Parsnip leaves

Control and management of Wild Parsnip can be achieved through various methods including hand-pulling, cutting, or mowing the plant before it goes to seed to help prevent further spread, and herbicide application. It is essential to wear protective clothing and gloves to avoid skin contact when performing management targeting Wild Parsnip.

Wild Parsnip Size

3 Summary of Past and Ongoing Management Efforts

Currently, the City actively manages several invasive species that pose a risk to humans. Over the last ten years, the TRCA has been retained by the City to control Giant Hogweed infestations within parkland in Markham and affected private properties. TRCA has been providing the oversight, coordination and application of chemical herbicides at sites identified by the City. The treatment involves foliar application and stem injection of glyphosate, combined with manual removal where appropriate. The control program consists of an initial treatment in early June followed up by a repeat treatment approximately four weeks after. Over the last two years the City has also worked collaboratively with York Region to control Wild Parsnip along a few Regional Road rights of way and the adjacent City-owned lands. Mechanical control of Cow Parsnip has been undertaken for the past five to seven years around the Toogood Pond area. Poison Ivy has been managed through a combination of signage and chemical treatment. While Cow Parsnip and Poison Ivy are both native species, control has occurred where they are in proximity to active recreational facilities.

Management of other invasive species has generally been opportunistic and dependent on staff resources. The City provides technical advice and/or tools to facilitate efforts by several community groups to control or eradicate invasive plant species in natural areas, such as buckthorn at Grandview Woodlot or Phragmites at Pomona Mills Park. While these efforts have been cost-effective, the area of management represents less than 0.5% of the City's natural areas.

A biological control program for Dog-strangling Vine was initiated in German Mills and Milne Dam Parks in 2019. This program consisted of releasing the moth, *Hypena opulenta* (Hypena), which feeds exclusively on Dog-strangling Vine, in two release sites in each park. The release of Hypena larvae and pupae was followed up by a visual survey for signs of feeding damage and a monitoring program to detect the overwintering and establishment of the moth. City staff actively participated in the program through the installation and servicing of light traps used for monitoring and conducting visual surveys and data collection. It is expected that this program will be a long-term effort as it may take years to build the population to a level that will produce results. The release of Hypena is not expected to eradicate Dog-strangling Vine alone and is considered as part of a broader management program.

The City has also collaborated with York Region to control Phragmites along Major Mackenzie between Stonebridge Drive and Percy Reesor Street as a part of a broader restoration project. At the same time, the City has also retained the TRCA to manage

Phragmites at Milne Dam Conservation Park and Swan Lake Park to support the ongoing restoration initiatives at both sites.

4 Invasive Plant Management Tools and Approaches

Successful management of invasive plant species should include four key elements:

- **Prevention** of new introductions and spread of existing invasive plants
- **Removal or Control** of occurrences of invasive plants
- **Restoration** of management sites following removal of invasive plants
- **Monitoring** of management sites and for new occurrences of invasive plants

4.1 Preventing the Introduction and Spread of Invasive Plant Species

Prevention is one of the most effective ways to manage invasive species. It is a top priority in the Ontario Invasive Species Strategic Plan (Ministry of Natural Resources, 2012). Invasive plant species can spread through a variety of vectors, including both natural dispersal and other means. Specifically, prevention measures aim to 1) prevent the introduction of invasive species not yet present at a location; and 2) prevent the further spread of invasive species already established at a location.

A key step in preventing new introductions and reducing the spread of established invasive plant species is to conduct a thorough inventory of invasive plant species within an area. A baseline inventory is needed to assess the abundance and map the distribution of invasive plant species (see Section 6 for more detail on invasive species monitoring including baseline inventory and mapping).

Once the status of invasive plant species is determined, steps can be taken to prevent the entry and establishment of new invasive species and efforts can be made to identify and eradicate new infestations. Strategies to prevent new introductions and limit the spread of established invasives include strategic monitoring, the use of current best management practices, use of non-invasive species for new plantings, and the development of public awareness and education programs to promote early detection and management of invasive plant species.

The Ontario Invasive Plant Council (OIPC) produces and maintains up-to-date best management practices for priority invasive plant species across Ontario. The use of these best management practices in addition to the adoption of clean equipment protocols should be encouraged for all City projects to control invasive species (see section 4.4 for more information on integration of invasive species management into existing procedures).

The success of the prevention measures requires collaboration and coordination amongst all stakeholders including government and non-government organizations, private landowners, industry, municipal governments, conservation authorities, indigenous communities, and members of the general public. Knowledge transfer and awareness building amongst partners involved in invasive species management and keeping up to date on emerging invasive plant species are needed for a comprehensive invasive species prevention approach.

4.2 Removal, Control, and Restoration

A strategic and targeted management approach of established priority invasive species should be undertaken (in conjunction with other agencies and partners where possible) to control projects that include removal and containment. An integrated, ecosystem-based approach using a combination of methods can result in the greatest success in invasive plant control (for instance, using chemical treatments on large populations followed by mechanical/manual control to target remaining populations). The choice of method(s) depends on factors like available resources, site constraints, effectiveness, public acceptance, time of year, and specific plant characteristics. Accurate species identification and understanding of the surrounding ecosystem are crucial for informed decision-making. Timing of control measures is important and species specific to consider stage of vegetation and seed production. A commitment to manage sites for multiple years will likely be required in order to treat resprouting from cut stems or plant parts remaining in the soil, and germination of seeds in the recently disturbed soil. Seeds such as Garlic Mustard can remain viable in the soil for seven years (OIPC, 2017).

The four main removal/control methods for invasive plants are mechanical[5], chemical, biological, and controlled burns.

[5] Hand-pulling is sometimes categorized as manual control separately from mechanical control. Although different in scale, both involve physically removing or covering invasive plants and are therefore discussed together in this Invasive Species Management Plan.

Mechanical/Manual Control

Hand-pulling

Mechanical and manual control involves physically removing invasive plants through techniques such as hand-pulling, digging, mowing, cutting, or physically covering with mulch or tarping. Another method for controlling woody plants is girdling, which is done by removing a ring of bark around the tree to disrupt the flow of nutrients and water between the roots and the rest of the plant.

Mechanical control methods allow for a targeted removal of invasive plants, minimizing damage to surrounding native vegetation and are typically low risk in terms of environmental impacts and human health. Generally, mechanical control methods require minimal equipment and can often be performed by hand or with basic tools with minimal training. Some drawbacks to using mechanical control methods are the labour and time required, especially for larger infestations. It is also difficult to remove all roots of plants with extensive root systems and resprouting of woody plants is likely. Often mechanical control efforts are coupled with follow up chemical treatment.

Mechanical control through mowing/cutting

Chemical Control

Chemical control involves the use of herbicides or other chemicals to kill or suppress invasive plants. Herbicides are applied directly to the plants or their surroundings to target and control their growth.

Herbicide spray application

Biological Control

Biological control involves the use of natural enemies, such as insects, pathogens, or herbivores, to control invasive plant populations. These natural enemies are introduced to target and suppress invasive plants without causing harm to native species. Biological control methods generally require approval from the federal government. An example of biological control is the use of two European loosestrife-eating beetles that were approved for release in Canada in 1992 and have proven to be successful in control of purple loosestrife populations, reducing them by up to 90% (MNRF, 2012).

Loosestrife beetle

Controlled burn

Controlled Burns

Management of invasive plants through controlled burns utilizes controlled fires strategically to eliminate or reduce the abundance of invasive plants while promoting the growth of desirable native vegetation. This method is uncommon in and around urban areas.

The use of current best management practices specific for each priority invasive plant species is to be considered during control activities, including weighing the possible costs, site constraints and ecological benefits. Best management practices tailored to each invasive species are available on the OIPC website; however, a summary of appropriate control methods for each of the priority invasive plant species identified in Table 2 is provided in Table 3.

Restoration

Ecological restoration is an important step following invasive species removal, as it helps prevent the recolonization of disturbed areas by aggressive non-native and invasive species. The restoration process involves assisting the recovery of degraded ecosystems, which may happen with little intervention after treatment through natural colonization and succession or may require selective seeding/planting or other methods to reduce soil erosion (landscape cloth or heavy mulching). By increasing the diversity and abundance of native plant species through restoration plantings and ongoing maintenance, the goal is to out-compete non-native and invasive species, enhance ecological integrity, and improve the ecological function of natural areas. This approach aims to reduce the impact of invasive plants and enhance the overall health of the ecosystem.

NON-INVASIVES FOR NEW PLANTINGS

TRCA's Seed Mix Guideline recommends seed mixes for restoration plantings and erosion control based on site conditions and requirements. The guideline is available online: https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2022/02/01124117/Seed-Mix-Guidelines-Update_January-19-2022.pdf

Table 3. Control methods for priority invasive plant species in City-owned natural areas (excluding noxious weeds).

Common Name	Mechanical					Chemical	Biological	Controlled Burns
	Hand Pulling/ Digging	Mowing/ Cutting	Physical Covering		Girdling	Spray or Spot Application	Insects, Fungi, Plant Diseases	
			Mulching	Tarping				
Autumn Olive	X	X			X	X		
Black Alder/European Alder	X	X				X		
Common Buckthorn	X	X				X		X
Dog-strangling Vine		X		X		X	X?	
Phragmites/ European Reed		X		X		X		
Garlic Mustard	X	X	X	X		X		
Glossy Buckthorn	X	X				X		X
Goutweed	X	X	X	X		X		
Himalayan Balsam	X					X		
Invasive Honeysuckles	X	X				X		X
Japanese Knotweed		X		X		X		
Lesser Periwinkle	X			X		X		
Lily-of-the-valley				X		X		
Norway Maple	X	X			X	X		
Oriental Bittersweet	X	X				X		X
Russian Olive	X	X			X	X		
Tree-of-heaven						X		
White Mulberry	X	X			X	X		

Special Considerations for Noxious Plant Management

Giant Hogweed and Wild Parsnip contain phototoxic chemicals in their sap, causing severe rashes. Both species require careful management. Mechanical control methods for Giant Hogweed should be done in early spring before seed production. Mowing and tilling are impractical due to size, while digging is challenging due to the extensive root system. Wild Parsnip can be controlled by mowing, pulling, tarping, or herbicide application, although tilling is ineffective. Chemical control is recommended for both species. Mulching after application prevents seedling growth. Poison Ivy also has toxic sap and can be managed through mechanical means such as hand-pulling or cutting, wearing protective clothing. Chemical control with herbicides specific to Poison Ivy can also be effective. Poison Ivy is a native plant and should be controlled only when there is a safety risk to the public.

4.3 Treatment Costs

Ontario municipalities and conservation authorities incurred costs related to invasive species control and management amounting to over $50 million between 2021 and 2022 (OAGO, 2023). The cost per unit area (e.g., per hectare) for controlling invasive species is difficult to estimate as it can vary depending on several factors, including the type of invasive species, the extent of the infestation, the terrain and accessibility of the site, the chosen control method, and labour and material costs. High-level estimation of the costs for some of the most common treatments are given below. The cost estimation is intended to provide a general overview and should be used only as a rough guideline[6]. In practice, an invasive species management program will typically employ a variety of control methods. Actual costs will depend on the specific circumstances of each invasive species control program and the level of expertise and equipment required. For more accurate cost estimates for invasive species management efforts, it is essential to assess the site and engage with local experts.

- **Mechanical Control (e.g., hand-pulling, cutting, mowing):** The cost for mechanical control can range from $2,500 to $37,000 per hectare or more, depending on the density and size of the invasive species population. This method can be more labor-intensive and may require repeated treatments.
- **Chemical Control (e.g., herbicide application):** The cost for chemical control can vary widely based on the specific herbicide used, the concentration required, and the application method. Generally, chemical control can range from $1,200 to $18,000 per hectare or more. It is crucial to consider the costs of herbicide purchase, equipment, labor, and any required permits.

[6] The cost estimates were from obtained from the Mississauga Invasive Species Management Plan & Implementation Strategy, which provides a high-level costing scheme for invasive plant treatments based on 2016 market values and the TRCA planting budgets in 2022. These estimates would likely be applicable to most urban areas in southern Ontario. A standard inflationary increase of 2.85% per year (Bank of Canada) has been added to update these estimates for 2023.

- **Biological Control:** The costs for biological control are often difficult to estimate, as it depends on research, development, and implementation efforts. Estimates typically consider costs associated with monitoring and assessment. Cost estimates for a *Hypena* release and monitoring program to control Dog-Strangling Vine would be around $16,000 per year. [7]

When determining cost estimates for invasive species management projects it is important to consider the costs for restoration and re-vegetation efforts. These projects can vary based on the scale and complexity of the restoration effort, ranging from $1,200 to $77,000 per hectare or more, considering the cost of native plant materials (herbaceous vs woody vegetation), site preparation, and ongoing maintenance.

4.4 Integration into Existing Procedures

Integrating invasive plant management into existing municipal practices and procedures, presents several opportunities for more effective and sustainable control measures. A first step is integrating the identification and documentation of invasive species into land use planning, construction activities, road and other city vegetation maintenance work. Early detection and diligent documentation of invasive species is integral to a comprehensive approach to invasive species management. Early detection of invasive species occurrences is key to the cost-effective and efficient removal of invasive species using best practices. The TRCA routinely assesses site-specific vegetation data within their regulated areas and collaboration between the City and TRCA presents opportunities for proactive and comprehensive management of invasive species in the City's Greenway System. Additional opportunities to integrate invasive plant management into existing municipal practices and procedures are described below.

Incorporate Invasive Plant Management Practices into Land Use Planning

Land use planning should consider loss of forest cover and forest fragmentation which can contribute to the spread of invasive plants. During the development phase when vegetation cover is removed, proper disposal following species-specific BMPs should be followed if invasive species are present, or before any construction work takes place. Each site should be assessed for presence and abundance of invasive/noxious weeds and pre-work control steps taken to reduce the spread and post-project monitoring for any regrowth. Disturbed areas should be revegetated quickly with native plants to prevent colonization of invasive species. Specific BMPs for reducing risk of invasive plant establishment for new plantings or construction activities should be adopted including an approved list of native seed mixtures and procedure for implementation (i.e., a construction specification for seeding and cover protocol).

[7] This estimate is based on a quote for a project completed at two parks in the City of Markham in 2021.

Adopt Native Species Planting Program

The City can help prevent the introduction of invasive species by discouraging the use of invasive species in planning applications and in City capital projects. During the review process, the City should continue to ensure that only native or non-invasive plant species are used in new site plans or subdivisions. Within and adjacent to natural areas, the City should require the use of native species to support ecological processes.

Norway Maple, a priority invasive due its ability to shade out and outcompete natives in natural areas, was commonly used as a street tree in Markham due to its ability to tolerate stress, attractive appearance, and fast growth. As these trees die and are replaced, the City should continue to phase out the use of Norway Maples to help reduce the overall proportion of Norway Maples in the City's urban forest.

Adopt Clean Equipment Protocols and Proper Disposal of Contaminated Materials

Adoption of clean equipment protocols will help prevent the introduction and further spread of invasive plant species during routine City procedures. Inspecting and cleaning of equipment, including vehicles, large equipment (e.g., mowers) and any hand tools should be conducted regularly. All equipment including boots and clothing of personnel should be inspected and cleaned of all dirt and vegetative plant material at designated areas and any dirt and plant material be disposed of at a designated disposal site.

Best Management Practices for Preventing Invasive Species Spread During Road and Highway Maintenance

By incorporating BMPs to prevent the spread of invasive plants during road and highway maintenance practices, the economic and ecological impacts of invasive plants along transportation corridors can be minimized. These BMPs can be developed to include procedures for regular site assessments to identify potential risks, provide training and education to personnel about invasive species, equipment and vehicles cleaning protocols, use of weed-free mulch and soil for construction projects and re-vegetate disturbed areas with native species. Additionally, highway and road maintenance management personnel can collaborate with neighboring jurisdictions to coordinate invasive species management efforts and share best practices.

Education and Outreach

Education and outreach can increase the success in preventing the introduction and spread of invasive species. Education materials and outreach can increase the awareness of all stakeholders, including members of the public, of the risks posed by invasive species. Education and outreach initiatives such as identification resources, signage, and training programs can promote prevention practices and encourage reporting of sightings.

The illegal dumping of waste frequently facilitates the spread of invasive plants. Educating and promoting proper disposal techniques, specifically targeting residents and landscape contractors for yard waste, can be effective in reducing this problem.

5 Prioritization Framework

An internal working group should be established to help guide the implementation of invasive species management actions. An effective working group can be composed of a multidisciplinary team with experts from relevant fields, such as biology, ecology, environmental science, and policy with representatives from different departments or organizations involved in invasive species management.

The role of a working group is to identify a range of management options based on the prioritization framework. This will include evaluation and ranking of the options based on their effectiveness, feasibility, and cost, with consideration of the short-term and long-term impacts of each option. The working group would also gather input from external stakeholders, such as scientists, local communities, and relevant authorities as necessary.

To determine priorities and recommendations for efficient resource allocation, the working group should complete the following steps:

- Establish Clear Goals, Objectives, and Timelines
- Review Budget and Resourcing Constraints
- Evaluate Natural Areas/Sites
- Evaluate Risk to Public Safety

These steps are further discussed in the sections below. To allow for adaptive and effective management of invasive species, it is advisable to revisit this prioritization framework regularly (on an annual basis or whenever additional resources are available) or based on new information or research findings.

5.1 Establish Goals, Objectives, and Timelines

Clearly defined objectives and goals provide structure to ensure a successful long-term invasive species management plan. A series of management priorities with realistic timelines for achievement will provide an organized approach to manage priority invasive species. Generally, the goal of an invasive species management plan is to establish a systematic approach for effectively managing invasive plant species in an economically

efficient way while increasing native biodiversity and ecological integrity within the City's natural areas.

For each invasive species management project, the geographic scope and specific target species for management should be clearly defined. Each invasive species management project should be evaluated on a site-specific basis. Measurable targets (such as a specific percentage reduction in cover of an invasive species) will allow for efficient monitoring and assessment of the objectives. Tracking the progress of each target will aid in the efficient use of resources and allow for adaptation of management decisions.

5.2 Review Budget and Resourcing Constraints

Knowing budget limitations is essential in prioritizing invasive species management projects. Planning will have to take into account the full implementation process including the potential for treatment over multiple seasons or years, monitoring, and follow-up. A review of existing budgets and staff resources for current and future activities and expenditures, will determine the scope and scale of invasive species management activities. If the need for additional resources is identified, potential funding from external sources, grants, or partnerships can be considered.

During an invasive species management project, the budget for all project activities should be tracked accurately so that the knowledge gained can be used to inform future budgeting of invasive species management activities.

5.3 Evaluate Natural Areas/Sites

Criteria to prioritize which natural areas or sites within natural areas will be targeted each year are needed to guide management actions. Priority sites will be identified where management actions will have the most beneficial ecological and cost-effective outcomes. Site prioritization should first consider the priority invasive species identified in Table 2 when choosing which sites to allocate resources to invasive species management projects, with focus on the removal of newly established priority invasive plants and/or the protection of rare species, rare community types, or other significant natural features.

Development of a table or decision matrix to identify priority sites will help guide the decision-making process. Examples of criteria used to evaluate natural areas or sites for invasive species management projects may include the following:

- Ecological impact—Assessment of the potential harm caused by the invasive species on native biodiversity including the risk to significant ecological features (e.g., occurrences in wetlands, waterbodies) or rare species/vegetation communities.

- Economic impact—Evaluation of the economic losses associated with the invasive species and consideration of areas which have work planned to maximize staffing and equipment efficiencies.
- Feasibility—Consider the feasibility of management options, including technical feasibility, likelihood of success, availability of resources, and accessibility of work locations.
- Public concern—Take into account public awareness and perception, as well as any community groups potentially willing to take on long-term stewardship.

A conceptual prioritization scoring framework for management sites and actions in City-owned natural areas is provided below. This prioritization framework is conceptual; a more detailed tool or modified tool with different factors, and weights applied to those factors, may be preferable. The matrix should be considered a working matrix to be reviewed and revised as needed to account for changes to available resources and management activities.

Conceptual Prioritization Framework for Invasive Species Management in City-owned Natural Areas

Factor	Circle One			Score
Ecological Impact	Low impact (1)	Moderate impact (2)	Significant impact (3)	
Economic Impact – cost to infrastructure, jobs etc.	Low impact (1)	Moderate impact (2)	Significant impact (3)	
Economic Impact – cost to manage and monitor	High cost (1)	Moderate cost (2)	Low cost (3)	
Feasibility – Resource Availability	No resources available (1)	Some resources available (2)	All resources available (3)	
Feasibility – Likelihood of Success	Low probability (1)	Moderate probability (2)	High probability (3)	
Feasibility – Accessibility of Sites	Not accessible (1)	Accessible, but not directly adjacent to path/road (2)	Easily accessible (3)	
Public Concern	Low concern / no community support for stewardship (1)	Moderate concern / some community support for stewardship (2)	Significant concern / significant community support for stewardship (3)	
TOTAL SCORE >14 = High Priority; 8 to 14 = Medium Priority; <8 = Low Priority				

6 Invasive Plant Species Monitoring

6.1 Baseline Inventory and Mapping

An invasive plant inventory provides the foundation for management decisions for the invasive species management plan. The purpose of the baseline inventory is to identify, record and map specific priority invasive plant species especially within high priority areas of the City. This could include locations frequently used by residents or high-quality vegetation communities. An invasive plant species inventory provides a benchmark to focus future management activities and serve as a baseline to monitor the spread and effectiveness of eradication techniques to control priority invasive plants.

Baseline inventories are crucial to determine which invasive species are present and where they are located. Inventories are also essential in revealing vectors or pathways of introduction and identifying the presence of rare species and rare community types to prioritize management.

A standardized approach to surveys is best for consistent data collection which can be compared over time. For a successful baseline inventory and monitoring program a consistent intensity of inventory and monitoring program should be decided. Specifically, areas where monitoring will be completed including boundaries, mapping, and data collection requirements (including written procedures and data collection templates to allow for consistency over time) should be determined. An annual monitoring regime will enable adaptation in a management plan as populations shift, new species arrive, and new locations are prioritized.

Before conducting field surveys, it is important to prepare a mapping and field plan. Existing and collected information can be input into a GIS database for species mapping and identification of high concentration areas. Mapping exercises can supplement data collection with readily available data through online sources such as EDDMapS (Early Detection and Distribution Mapping System) Ontario (http://www.eddmaps.org/ontario), iNaturalist or through contact with TRCA, community groups and neighbouring partners.

Mapping species distribution provides insights into size, spread direction, rate, and relevant information for management and control strategies. Mapping serves as a valuable tool to identify priority areas and detect newly reported invasive species early on. Targeting areas where invasive species initially establish, such as trails and adjacent lands, allows for efficient monitoring. Monitoring should align with the flowering time of priority invasive species, and frequent monitoring is recommended to detect changes and respond promptly. Until such time that a baseline inventory along with regular updates can be

achieved, the City should continue to rely on readily available sources of information including online databases, knowledge from staff, and information received by residents.

6.2 Early Detection, Rapid Response (EDRR)

EDRR is a proactive strategy for managing invasive plants which aims to prevent new arrivals from establishing and spreading by detecting them early and responding quickly. Early detection followed by a coordinated rapid response increases the likelihood of control or eradication. This approach is a cost-effective way of controlling invasive species as it is initiated when environmental, social, and economic costs are lowest.

An EDRR plan includes six main steps:

- Early detection—Observation, preliminary identification, and reporting of invasive plants suspected to be newly introduced to a given area.
- Identification—Confirming the identification of the observed plants.
- Alert Screening—Determining if the species is new to the area, assesses its ability to be eradicated, and check if the species is prohibited at the provincial or federal level.
- Risk Assessment—Evaluating the likelihood of the species entering, establishing, and spreading, as well as the economic, environmental, and social impacts. Assigning a risk rating (high, medium, or low) to guide the EDRR process.
- Rapid Response—Creating and implementing a response plan, including acquiring permits and access to the affected land for treatment.
- Monitoring and Reassessment—Assessing the response's effectiveness and whether the EDRR objectives were achieved. Continuously reassessing the plan as new monitoring data becomes available.

To facilitate EDRR, a web-based mapping system for documenting invasive species distribution can be utilized and promoted widely through public outreach. The EDDMapS Ontario website streamlines the early detection process by using a common reporting tool and allows invasive species distribution information to be held in a central database. iNaturalist website or app can also be used to record invasive species and EDDMapS web account will download all verified reports by species for use.

6.3 Post-Treatment Monitoring

A post-treatment monitoring protocol should be established for each invasive species control project to increase the effectiveness of control measures and to detect and address any regrowth or new invasive species infestations. Post-treatment monitoring protocols may vary depending on the specific invasive species, treatment methods, and ecological context. Species-specific BMPs should be used to develop site-specific monitoring plans for each location where control methods were implemented. Monitoring will include an evaluation of the need for follow-up treatments and documentation of changes in vegetation composition and native species recovery.

Monitoring frequency will be dependent on the control species BMPs, site conditions, and treatment methods, but may be initially more frequent to capture any immediate regrowth and to assess the success of the control measures. At minimum, post-treatment monitoring should occur within one to two years of management activity.

Seed bank assessments to evaluate the persistence of invasive species seeds in the ground may be employed as part of a monitoring plan to help identify areas of future outbreaks while also guiding management strategies. Stratified random sampling of soil using soil core samplers will be the most efficient method of assessing seed banks in post-treated sites. In larger treatment areas remote sensing technologies may be used to monitor changes in vegetation cover or detect new infestations.

The information gathered during post-treatment monitoring should be used to adapt management strategies, refine treatment approaches, and inform decision-making processes over the lifespan of an invasive species management project.

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