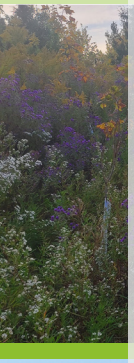
CITY OF MARKHAM
NATURAL AREA MANAGEMENT GUIDEBOOK

Natural Heritage Management Study | May 2024








Acknowledgements

The City of Markham acknowledges the traditional territories of Indigenous peoples and their commitment to stewardship of the land. We acknowledge the communities in circle. The North, West, South and Eastern directions, and Haudenosaunee, Huron-Wendat, Anishnabeg, Seneca, Chippewa, and the current treaty holders Mississaugas of the Credit peoples. We share the responsibility with the caretakers of this land to ensure the dish is never empty and to restore relationships that are based on peace, friendship, and trust. We are committed to reconciliation, partnership and enhanced understanding.

The City of Markham would also like to acknowledge the many valued contributions from staff, consultants, and other agencies that have informed and contributed to the content of this document. This version of the document was prepared on behalf of the City by CBCL Limited and key contributors include York Region, Toronto and Region Conservation Authority, Parks Canada, and City staff.

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1 Introduction

1.1 Plan Background and Purpose

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. Markham's natural areas support a high diversity of plants and wildlife, including over 500 species of vascular plants, 77 species of birds, 12 species of mammals, seven species of amphibians and four species of reptiles. Between 1993 and 2020, natural cover in the City increased from 13.6% to 14.9%, with woodland expansion representing the largest proportion of this increase. During the same time period, the City's population nearly doubled, and more than 3,000 ha of greenfield land was converted to urban land uses.

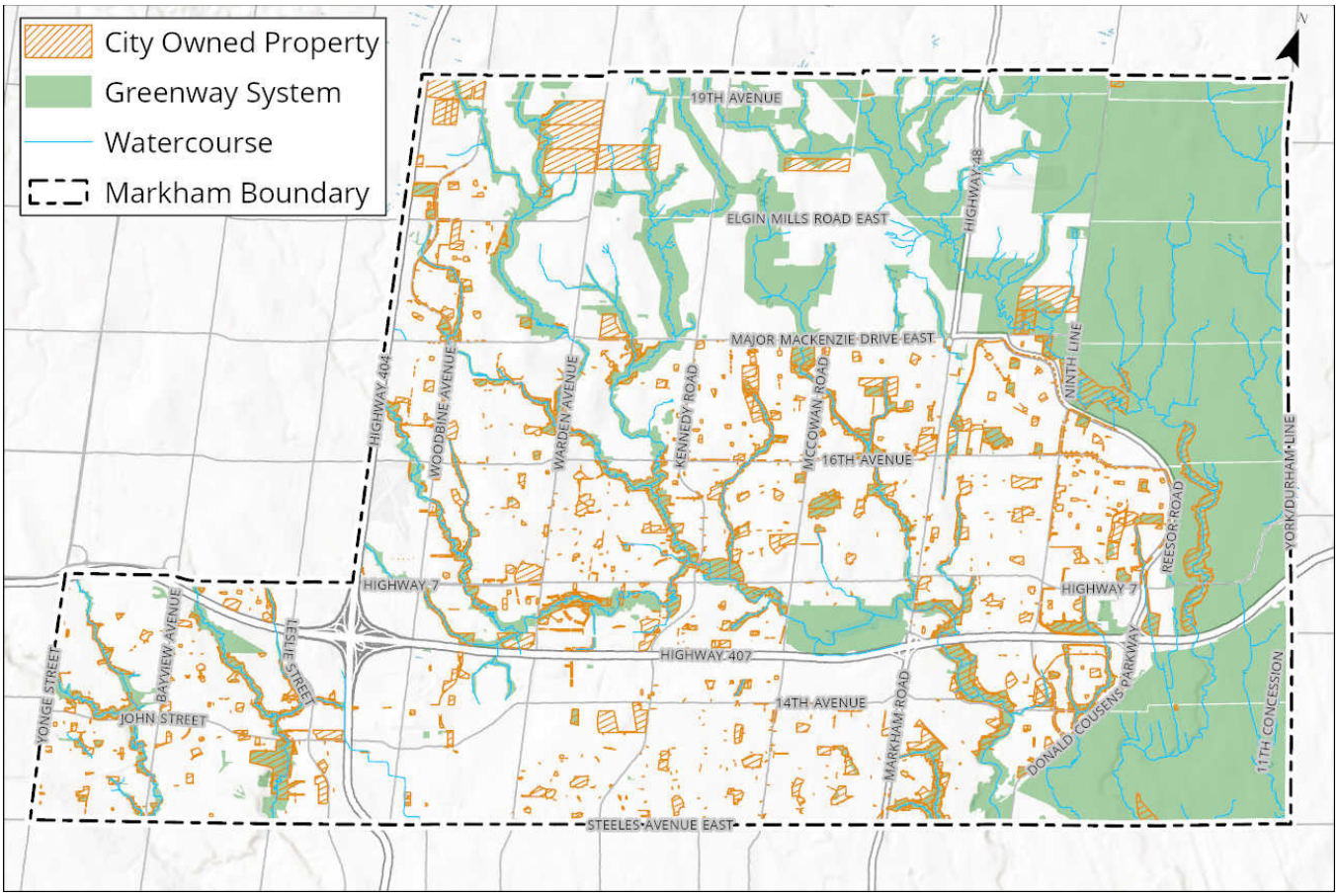
GOAL OF THE NATURAL AREA GUIDELINES:
To provide a framework for protecting and enhancing existing natural heritage and hydrologic features and supporting biodiversity in the Greenway System within Markham.

To support stewardship and enhancement of City-owned natural areas in the Greenway System, the City has prepared this Natural Area Management Guidebook (NAMG), which includes a risk assessment for City-owned natural areas and guidelines for natural area management. This NAMG provides guidance and direction for managing and conserving natural areas such as woodlands, wetlands, grasslands, and wildlife habitat.

1.2 Greenway System

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). The Greenway System contains a system of natural heritage and hydrologic features, including valleylands, woodlands, associated vegetation protection zones, protected agricultural lands, and Natural Heritage Network Enhancement Lands. The objective of the Greenway System is to maintain and enhance areas of significant ecological value to improve biodiversity and ecological function. Markham's Greenway System, shown in Figure 1, forms part of the Region's System.

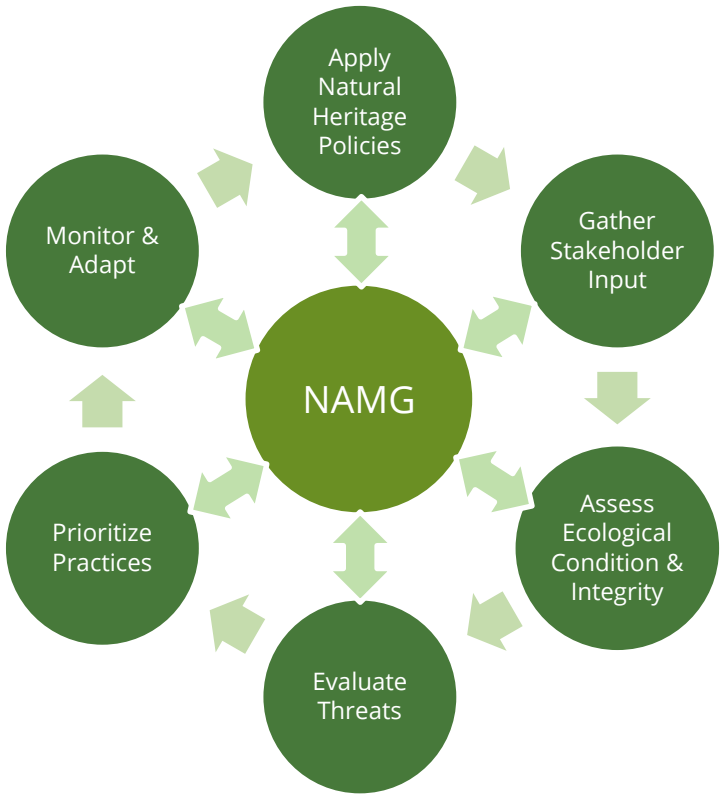
Figure 1 City of Markam Greenway System



1.3 Guidebook Overview

A natural area management guideline serves as a valuable tool for city land managers, policymakers, and stakeholders involved in protecting and preserving the ecological integrity of natural areas for current and future generations. Natural area management is a living process, represented in Figure 2 as a cycle of interconnected steps. Plans for implementation, including associated management practices, must be adaptive to system changes, external and emergent stressors, and responsive to new knowledge gained through monitoring and follow-up. The NAMG is intended to be a "living" document, based on current knowledge and natural heritage policies, providing best practices for natural area management, and evolving through monitoring and adaptive management to integrate new information and resources.

Figure 2 Natural Area Management Process



The NAMG is presented in eight sections, including this introduction.

- The natural heritage policy context provides an overview of relevant laws, regulations, and policies governing natural area management in the City of Markham.
- The ecological characteristics of Markham's natural areas are described, with an assessment of overall condition and ecological integrity.
- The risk assessment section discusses some of the primary threats and stressors to Markham's natural areas as well as providing high-level recommendations for threat mitigation and monitoring. This ecological characteristics and risk assessment are primarily informed by field assessments of City-owned natural areas completed in 2020 and 2022 (North-South Environmental Inc. and Dougan and Associates Inc. 2021; CBCL 2022).
- The management practices section provides a collection of best practices for the management of City-owned natural areas. The application of these best practices, along with site constraints, are to be considered when developing specific procedures.
- A strategy for implementation of the NAMG is presented, with a tool to prioritize the implementation of recommended practices, guidance on integrating into City practices, recommendations on a monitoring approach and regular reporting, and guidance on adaptive management.
- References for literature cited in this document are provided in the final section.

2 Natural Heritage Policy Context

The City's approach to natural area management will continue to conform with and be directed by municipal, provincial, and federal policies and regulations. The following sections briefly describe the policies that provide direction to, or influence, natural area management in Markham.

2.1 City of Markham

The 2014 Official Plan sets out the City's land use policies for development and growth up to 2031. Chapter 2 of the Official Plan outlines the City's commitment to prioritize natural heritage protection in the Greenway System and Chapter 3 details specific policies for identifying, protecting, and enhancing the Greenway System.

A Greenway System of linked natural heritage and hydrologic features, identified through a comprehensive Environmental Policy Review, establishes limits and priorities for protection of Markham's significant environmental features.

Policy 2.2.1 of the Official Plan states the City's goal to "ensure the protection and enhancement of Markham's waterways, woodlands and wetlands, and promote the enhancement of ecological corridors and the protection of agricultural lands". The strategic objective to "establish an interconnected Greenway System within Markham, protecting and enhancing existing natural heritage and hydrologic features and supporting biodiversity" is the fundamental goal of the natural area management in the City and is reiterated under Management Practices in this document (**Section 5**).

The Greenprint, Markham's Sustainability Plan, provides the vision, priorities, and governance framework for a sustainable community, integrating the City's municipal planning and decision making. The Greenprint lists ecosystem integrity as a sustainability priority with the following objectives:

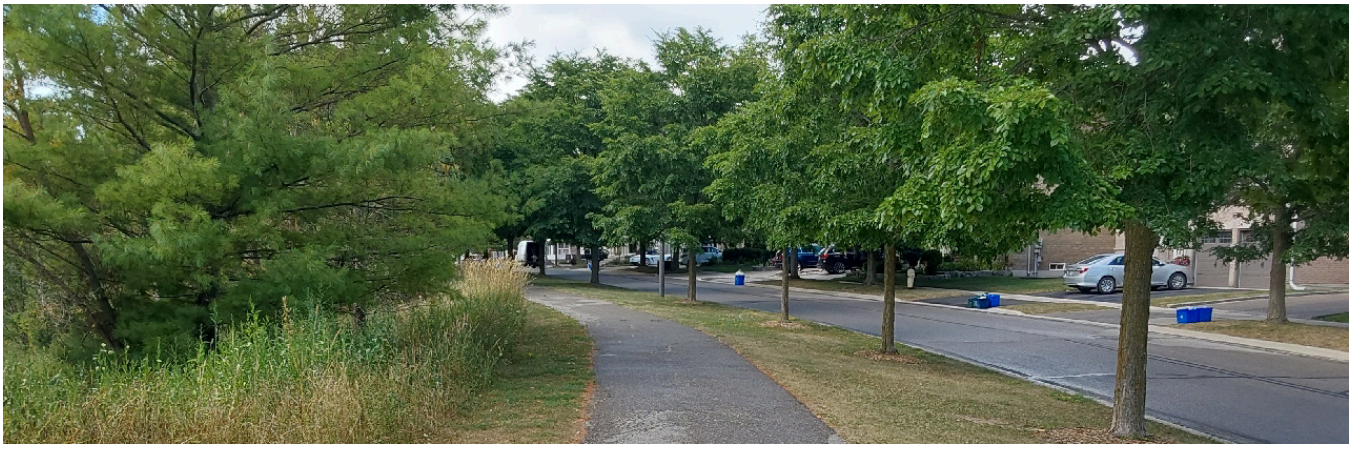
- Increase biodiversity
- Reach 30% tree canopy and vegetation coverage City-wide
- Develop and support wildlife habitat

Some of the initial ecosystem integrity recommendations from the Greenprint include the following:

- *implement landscaping standards for public and private development that include native plants for habitat and are informed by green building rating programs, bird-friendly guidelines, and the Local Food Strategy*
- *acquire lands that enhance or connect wildlife habitat within urban and rural areas and can support habitat enhancement with park planning, maintenance, and management of all new and existing landscaped areas*
- *develop, promote and maintain an Urban Forest Strategy as part of the Trees for Tomorrow tree planting program, contributing to habitat enhancement, climate change mitigation, and other ecological services*
- *preserve natural green spaces and agricultural land by defining a physical urban-rural boundary and can protect and enhance the biodiversity of existing wildlife habitat develop a community emergency management strategy that includes responsibilities for wildlife, livestock, and domestic pets*

The City of Markham's By-laws provide specifics on the rules and procedures for land use and development in Markham. The following By-laws are of particular relevance to the management of natural areas in the City:

- Zoning By-law 177-96 identifies the Greenway as an open space zone and specifies standards that apply to development in or adjacent to the Greenway Zone.
- Standards for the Maintenance and Occupancy of Property in the City of Markham By-law 2017-26 defines the standards for property maintenance including yard maintenance, waste management, drainage, and pest prevention.
- Site Alteration By-law 2011-232 details the requirements to permit site alteration in the City.
- General Management and Regulation of Parks Within the [City] of Markham By-law 167-92 outlines the activities that are prohibited in City-owned parks, including damaging vegetation, vehicle use, pets, fires, and wildlife disturbance.
- Tree Preservation By-law 2023-164 outlines the requirements, and exceptions, to permit tree removal on privately-owned lands in the City.
- Animal Protection and Services By-law 2018-91 specifies restrictions on pets in the City.



2.2 York Region

The 2022 York Region Official Plan sets out the policies for development and growth management in the Region to 2051. A major goal, as stated in Section 1.3 of the Regional Official Plan, is to "protect and enhance the natural environment for current and future generations so that it will sustain life, maintain health and provide a high quality of life". Chapter 3 provides specific policies to identify, protect, restore, and enhance natural systems in the Region, including Markham's Greenway System.

The Greening Strategy (York Region 2022b) outlines the actions the Region is taking to fulfill their commitment to protecting and enhancing the natural environment. Action areas for natural area protection, restoration, and enhancement include the following:

- Forming partnerships to secure land for conservation purpose
- Tree planting programs
- Stream and wetland rehabilitation programs
- Property naturalization
- Promoting pollinator habitat
- Knowledge sharing and transfer

Regional by-laws complement the City of Markham's by-laws on the rules and procedures for land use and development in Markham. The Forest Conservation Bylaw 2013-68 is of particular relevance to the management of natural areas in the Region and prohibits the destruction or damage of trees.

2.3 Toronto and Region Conservation Authority

The entirety of the City of Markham is within the watershed-based jurisdiction of the Toronto and Region Conservation Authority (TRCA), which regulates development in and near shorelines, valleylands, wetlands, watercourses, and floodplains under the *Conservation Authorities Act*. TRCA may issue permits for development, including construction and maintenance of public infrastructure, in these regulated areas if it is demonstrated that the development will not affect aspects such as flooding, erosion, pollution, or conservation of land.

In the municipal planning process under the *Planning Act*, TRCA provides technical expertise and input to the City in accordance with the *Conservation Authorities Act* and O.Reg 686/21: Mandatory Programs and Services, on the risks related to natural hazards and the areas important for managing those hazards. This includes how to prevent or mitigate those risks and how they are affected by climate change.

As a result of recent amendments to the *Conservation Authorities Act*, some technical reviews related to natural heritage conformity that TRCA formerly provided can no longer be provided under a plan review Memorandum of Understanding with the City. TRCA can still provide natural heritage data, mapping, and advice outside the municipal plan review process, for example, as part of watershed planning. The City, York Region, TRCA, and neighbouring municipalities have collaborated on watershed plans for commonly held watersheds.

In 2007, TRCA and the Rouge Park Alliance prepared the Rouge River Watershed Plan, which provides strategies for protecting, restoring, and enhancing the ecological integrity of the natural heritage system in the watershed. Natural area management in Markham will continue to reflect the objectives and principles of natural heritage and natural hazard management and the strategies of the Rouge River Watershed Plan.

TRCA has developed an Integrated Restoration Prioritization framework to identify and prioritize areas for restoration (TRCA undated). TRCA maintains a database of restoration opportunities with areas categorized as “protection”, “low priority”, “medium priority”, and “high priority” for restoration.

2.4 Government of Ontario

The Provincial Policy Statement, 2020 (PPS) issued under the *Planning Act* provides direction on land use planning and development in Ontario municipalities, including the protection of natural heritage features and functions. Section 2.1 of the PPS directs municipalities to identify key natural heritage and hydrologic features and functions, including significant woodlands, valleylands, wildlife habitat, wetlands, and watercourses. Criteria and guidelines for identifying key natural heritage and hydrologic features are detailed in various provincial documents:

- Natural Heritage Reference Manual, 2nd Edition (Ministry of Natural Resources, 2010)
- Significant Wildlife Habitat Criteria Schedules (Ministry of Natural Resources and Forestry, 2015)
- Significant Wildlife Habitat Technical Guide (Ministry of Natural Resources, 2000)

The Regional and local Official Plans are the implementation tools of the PPS in Markham. Key natural heritage and hydrologic features are components of Markham's Greenway System, and identification of significant features in City-owned natural areas will continue to follow the methodology and guidelines outlined in provincial documents.

Further policy direction on growth management and environmental protection in Markham are provided in the following provincial plans:

- Growth Plan for the Greater Golden Horseshoe (Government of Ontario, 2020) issued under the *Places To Grow Act*
- Greenbelt Plan (Government of Ontario, 2017a) issued under the *Greenbelt Act*
- Oak Ridges Moraine Conservation Plan (Government of Ontario, 2017b) issued under the *Oak Ridges Moraine Conservation Act*

The PPS and Growth Plan are both currently under review by the province.

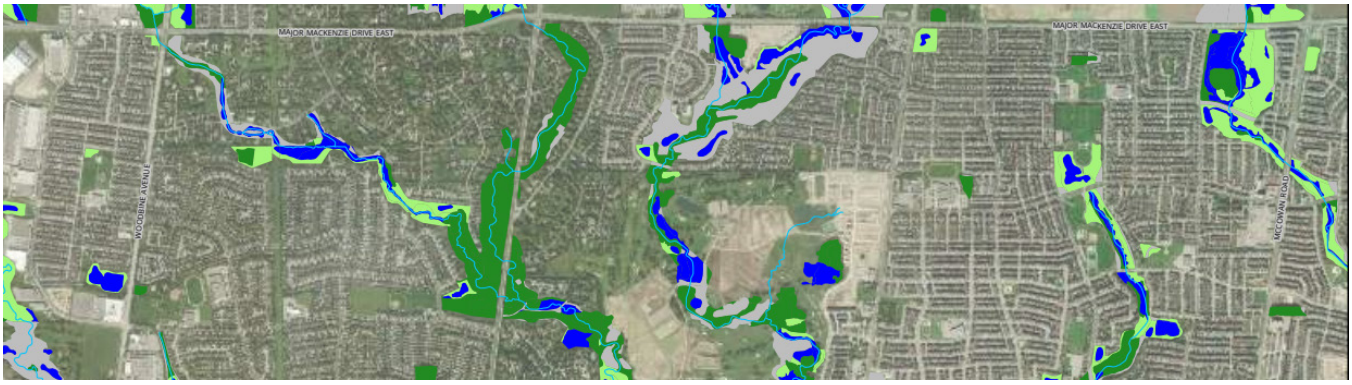
2.5 Government of Canada

A large portion of Markham's Greenway System is in Rouge National Urban Park, which is managed by Parks Canada. The Rouge National Urban Park Management Plan (Parks Canada 2019) details Parks Canada's key strategies and objectives to protect and restore ecological integrity in the park. The proposed Multi-species Action Plan for Rouge National Urban Park of Canada details measures that meet the requirements set out in the *Species at Risk Act* for regularly occurring species that require an action plan. Ongoing collaboration between the City and Parks Canada will promote good management of the entire Greenway System.

The following federal policies may also influence or inform natural area management practices in Markham:

- The Federal Policy on Wetland Conservation (Government of Canada, 1991)
- Fish and Fish Habitat Protection Policy Statement (Fisheries and Oceans Canada, 2019)
- A Canadian Action Plan to Address the Threat of Aquatic Invasive Species (Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group, 2004)
- An Invasive Alien Species Strategy for Canada (Government of Canada, 2004)
- A Healthy Environment and a Healthy Economy. Canada's strengthened climate plan to create jobs and support people, communities and the planet (Environment and Climate Change Canada, 2020)
- Canada's National Adaptation Strategy. Building Resilient Communities and a Strong Economy (Government of Canada, 2022)
- Clean Canada. Protecting the Environment and Growing Our Economy (Environment and Climate Change Canada, 2019)
- Federal Sustainable Development Strategy 2022 to 2026 (Environment and Climate Change Canada, 2022)
- Guidelines to avoid harm to migratory birds (Environment and Climate Change Canada, 2023) protected under the *Migratory Birds Convention Act, 1994*





3 Markham's Natural Areas

The City's 2020 Natural Heritage Inventory and Assessment Study assessed vegetation communities on approximately 750 ha, or three-quarters, of City-owned portions of the Greenway System. Most of the remaining City-owned portions of the Greenway System were assessed by CBCL in 2022. This section provides an update to the vegetation analysis, combining the results of 2022 with the 2020 results supplemented with TRCA data, and should be read in conjunction with the Natural Heritage Inventory and Assessment Study report.

3.1 Vegetation Communities

Table 1 provides metrics on the area and cover of vegetation communities for Markham's Greenway System. These metrics were derived from the combined data from 2022 field work (CBCL), 2020 field work and air photo interpretation (North-South Environmental Inc. and Dougan and Associates Inc. 2021), and vegetation community classification by TRCA and others provided in the City's existing ELC shapefile. Land cover in the Greenway System is illustrated on a series of maps provided in Appendix A.

Table 1: Land Cover in Markham's Greenway System in 2022

Ecoseries	Area Covered (ha)	Proportion (%)
Anthropogenic (including agricultural)	3,844.8	53.0
Open Country and Early Successional	1,119.0	15.5
Woodland	1,457.2	20.2
Wetlands and Waterbodies	810.0	11.2
Other*	2.6	<0.1
Greenway Total	**7,223.6**	**100.0**

*Other includes open beach/bar, shrub beach/bar, open bluff, treed bluff, and open tallgrass prairie

Agricultural and anthropogenic land cover dominate Markham's Greenway System but are predicted to decline in significance over time as they transition to natural communities either through human assistance (i.e., restoration) or natural regeneration. The largest natural land cover class is woodland, which make up just over one fifth of the Greenway System, followed by open country and early successional land cover, wetlands and waterbodies. Other vegetation communities (e.g., tallgrass prairies) make up a very small proportion of the Greenway System.

Two vegetation communities considered to be provincially rare (NHIC 2022) occur in Markham's natural areas: tallgrass prairie and fresh-moist lowland walnut deciduous forest.

Tallgrass Prairies
All of the extant tallgrass prairie communities in Markham were planted within the past 30 years and should not be interpreted as natural remnants of pre-settlement vegetation. Provincially and locally rare plant species found in these communities were introduced and do not represent natural occurrences of those species.

Fresh-Moist Lowland Walnut Deciduous Forest
Black Walnut (*Juglans nigra*) appears to have increased substantially in the City since the original natural heritage study was completed in 1991 (Gore and Storrie Limited 1992). At least 123 polygons are now dominated by Black Walnut, primarily lowland deciduous forest and cultural woodland communities. Despite its increasing prevalence in Markham, lowland Black Walnut forests are still considered to be provincially rare. Markham's Black Walnut forests, while relatively young communities, support a diversity of plants and wildlife.

3.2 Flora and Fauna

A total of 530 vascular plant species were documented in Markham's Greenway System between 2020 and 2022. The majority of these (61.6%) are native to the Markham area and the remainder (38.4%) are considered to be introduced species.[1]

- The highest diversity of native plants was found in the eastern part of the City (excluding Rouge National Urban Park). The Raymerville Woodlot is a particularly diverse site, containing a large number of regionally rare plants as well as significant features such as calcareous seeps and springs.
- The flora of Markham's Greenway System includes three species at risk, ten provincially rare species, and 62 regionally rare species. A number of these have been deliberately planted and or are escapes from cultivation and are not believed to occur naturally in Markham. The three plant species at risk are Black Ash (*Fraxinus nigra*), Butternut (*Juglans cinerea*), and Dense Blazingstar (*Liatris spicata*).

[1] Native status in Markham was determined using the TRCA's flora checklist (2020) and therefore refers to the native status in TRCA's watersheds. This includes species that are native to other parts of Ontario but are considered to be introduced in the Markham area.

- Of the ten provincially rare species that occur in Markham's Greenways, six occur as deliberate plantings and two are escapes from cultivation and have become naturalized and self-sustaining. The two provincially rare species that are known to occur naturally in Markham are Large Toothwort (*Cardamine maxima*) and Butternut, both of which are found in deciduous forest communities.
- A total of 62 regionally rare plant species have been identified in Markham's Greenway System. Nine of these were deliberately planted and are not believed to occur naturally in Markham, although they may have historically occurred. The majority of regionally rare plant species are either obligate or facultative wetland species and occur in swamp and lowland forest communities.

The Natural Heritage Inventory and Assessment Study documented a diversity of wildlife, including 75 species of birds, species of eight amphibians, four species of reptiles, and a variety of mammals and insects.

3.3 Health, Condition, and Integrity of Markham's Natural Areas

Overall, the health and condition of vegetation communities in Markham's Greenway System is variable, with some apparent geographical patterns. In 2022, CBCL observed that natural areas in the southwestern part of the City (e.g., Pomona Mills Park, German Mills Park) exhibited greater proportions of invasive species and more intense disturbance than natural areas elsewhere in the City. This is not unsurprising given that this part of the City has been urbanized for longer, so natural communities have endured environmental change for longer than those located in more recently developed parts of the City. Forests in this southwestern part of the City, for example, contain large amounts of Norway Maple (*Acer platanoides*), Black Locust (*Robinia pseudoacacia*), and other non-native species than forests elsewhere in the City.

Some natural areas continue to exhibit relatively good ecological health given their urban settings. Toogood Park and Raymerville Woodlot are two natural areas that were found to have a high diversity of native species in 2022 despite the surrounding urban pressures. Raymerville Woodlot, in particular, supports a high diversity of regionally rare native species as well as unique and significant features such as calcareous seeps and springs.

4 Threats to Natural Areas

4.1 Environmental Change

4.1.1 Climate Change

In December of 2013, Markham and the surrounding area experienced an unprecedented ice storm which left hundreds of residents without power and severely damaged thousands of trees. Many trees and branches that fell during the 2013 ice storm can still be seen in Markham's natural areas, and the resulting canopy gaps have altered vegetation structure in both positive and negative ways. Ice storms and other extreme weather events are predicted to become increasingly frequent as a result of climate change and this could become a significant factor in the health and integrity of the City's natural areas (Dale *et al*. 2001; Klima and Morgan 2015; Martel *et al*. 2021; York Region 2022).

Climate change is a global threat to the biosphere and local ecosystems (International Panel on Climate Change 2022). Climate change has already been observed in southern Ontario, including Markham, and this region will continue to experience a changing climate for many decades or longer (Fausto *et al*. 2015; Ridgway *et al*. 2018; Bush and Lemmen 2019; York Region 2022). Although the overall climate trend in Markham is predicted to be an increase in the average annual temperature, the effects of climate change on weather systems at shorter time scales are less predictable. Winters are predicted to get warmer, but this may be accompanied by larger swings in temperature, bringing early spring warmth followed by late frosts (Cohen *et al*. 2012; Cohen *et al*. 2013; Francis and Vavrus 2015; York Region 2022). There is still considerable uncertainty over how precipitation patterns will change in this region, but there is evidence that storms are already becoming more intense and will continue to increase in intensity but may decrease in frequency[2] (Waters *et al*. 2010; Martel *et al*. 2021; York Region 2022).

[2] The net outcome being an overall decrease in storm frequency but an increase in the frequency of large storms (e.g., 100-year, 500-year, 1,000-year storms, etc.).

The overall risk of climate change to Markham's natural areas is extensive in scope, but the severity is still largely unknown. Although climate change is a global phenomenon that will affect all of Markham's natural areas, uncertainty about how climate change will manifest at the local scale makes it difficult to predict how natural areas may be affected. Based on a high carbon scenario, some general predictions can be made about the future impacts of climate change (Climate Atlas of Canada 2019). Climate change is likely to exacerbate other risks, such as flooding, erosion and windthrow. Erratic temperature and precipitation patterns may promote the spread of invasive species that have a greater tolerance to weather extremes than native vegetation. Plants and wildlife—including both native and non-native species—have varying degrees of tolerance to extreme temperatures and precipitation. Species reliant on stable hydrology (e.g., aquatic and wetland species) are some of the most vulnerable (Brinker *et al.* 2018), and trees already weakened by pests or disease will be disproportionately affected by wind and ice storms. Climate change may therefore cause changes to vegetation composition and structure and these changes will, in turn, affect the types of wildlife habitats and ecosystem services that natural areas provide. More granular climate change predictions specific to Markham would help inform management of City-owned natural areas.

4.1.2 Urbanization

The population of Markham is expected to grow by at least 200,000 people by 2050, and this increase in population will be accompanied by increases in housing, employment areas, and associated infrastructure, which will necessitate urban growth (City of Markham 2021a, b; York Region 2021a, b). This means that some parts of the Greenway System that are currently surrounded by agriculture or other open space will be surrounded by urban land uses by 2050. Urbanization—the conversion of lands from agriculture or open space to urban land uses—will have short- and long-term impacts on natural areas. It can result in localized temperature increases (i.e., urban heat islands) and alterations to diurnal temperature regimes, which may be exacerbated by global climate change (Chen *et al.* 2017), as well as fragmentation and isolation of natural habitats, which reduces ecological resilience (Alberti and Marzluff 2004). It also results in increased human pressures on natural areas (e.g., recreation, see **Section 4.3.2**).

Habitat connectivity supports metapopulations of plants and wildlife, and loss of ecological connections can thus lead to local species extirpations (Hess 1996). Markham may wish to undertake a more detailed analysis of natural area connectivity, to identify critical habitat

corridors and locations where creation of new corridors may help to maintain the integrity of plant and wildlife populations.

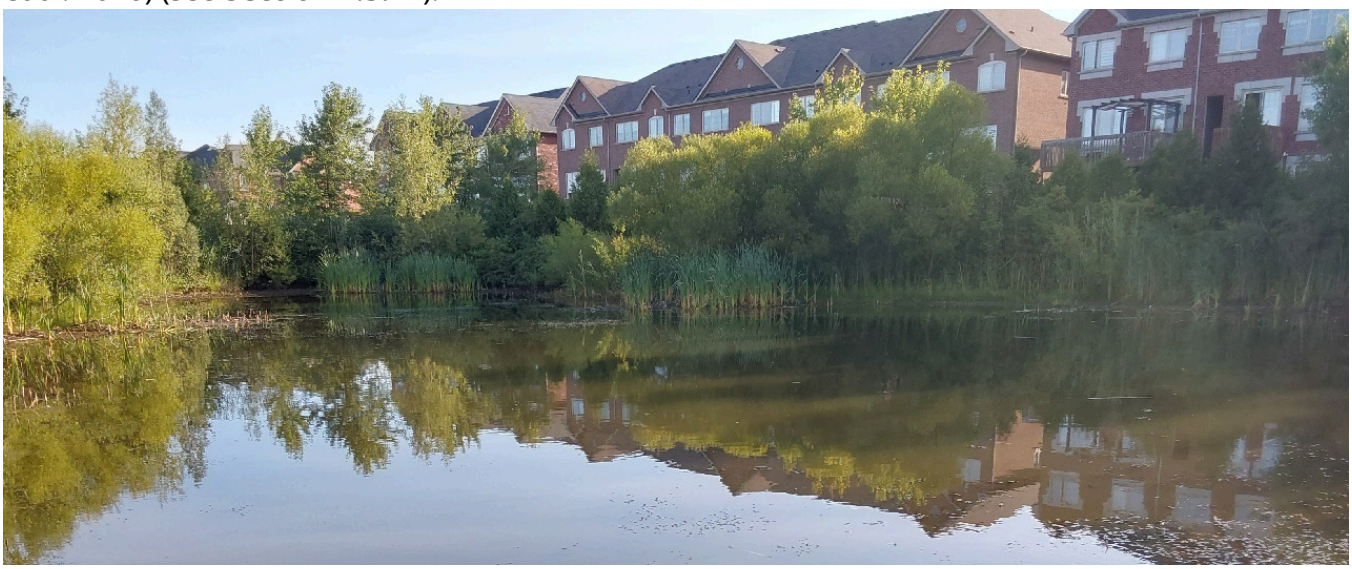
Fragmentation and Isolation

Conversion of agriculture and open space to urban land uses results in decreased landscape permeability, which alters wildlife movement patterns and can genetically isolate plant and wildlife populations (Layman *et al*. 2007; Major *et al*. 2014; Lourenco 2017). A growing body of research has demonstrated that plants and wildlife in fragmented urban landscapes have reduced fitness and reduced resilience to disturbance as a result of movement restrictions and genetic isolation (Major *et al*. 2014; Schutz and Schulz 2015; Evans *et al*. 2017; Lourenco *et al*. 2017; Schneiberg *et al*. 2020). Construction of new infrastructure (e.g., roads and utilities) across habitat corridors can impede wildlife movement and potentially lead to local species extirpation.

Habitat fragmentation and isolation exacerbate the other threats described in this report and are considered by some academics to be the threats of largest scope and severity to urban natural areas (Pardini *et al*. 2010; Haddad *et al*. 2015). Small, isolated natural communities have a lower tolerance for disturbance than large, connected communities because their ability to respond to disturbances is impaired (Alberti and Marzluff 2004; Pardini *et al*. 2010). Very small or narrow communities can experience significant ecological change as a result of relatively minor disturbances (e.g., the loss of a single large tree). Isolated communities are less adaptable because they lack the connections necessary for new species and genotypes to become established in response to changing environmental conditions (Layman *et al*. 2007; Lourenco *et al*. 2017). Thus, disturbances that have minimal impacts—or even regenerative effects—on wilderness and rural natural areas can damage urban natural areas beyond their ability to recover. This highlights the importance of providing connections and corridors between natural habitats on the urban landscape for improving ecological resilience.

Hydrologic Alterations

Urbanization frequently causes local changes in hydrology because of changes in microtopography and the expansion of roads and other impervious surfaces over previously permeable areas. Even with well-designed stormwater management infrastructure, expansive impervious surfaces result in greater volumes of surface runoff reaching watercourses, which is why urban watercourses experience more intense storm flows and more frequent flood events than rural watercourses (Hopkins *et al*. 2015; Feng *et al*. 2021). Urban runoff also tends to contain higher concentrations of pollutants (e.g., chlorides from road salt) than rural watercourses (Muller *et al*. 2020) (see **Section 4.3.11**).



Urban watercourses often experience channel straightening and hardening, although most of Markham's urban watercourses retain natural channel morphology. Dams and other impoundments can interrupt fish migration and cause fragmentation of aquatic ecosystems. Construction of bridges and culverts to convey watercourses under new or expanded roads can also result in knickpoints, which interrupt aquatic communities. The Milne Dam over the Rouge River and the Toogood Pond Dam over Bruce's Creek in Unionville are examples of watercourse impoundments in Markham, but both dams currently have fish ladders which contribute to maintaining aquatic habitat connectivity.

Urbanization can lead to changes in soil moisture regimes through complex feedback mechanisms that can result in urban vegetation communities becoming drier or wetter than pre-urban conditions (Zipper *et al*. 2017). This can be exacerbated by invasions of woody plant species which take up large amounts of soil moisture (LeMaitre 2004).

More detailed assessments of threats associated with urbanization (e.g., residential encroachment, light and noise pollution) are provided in **Section 4.3**.

4.2 Biological Threats

4.2.1 Invasive Species

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 alien species have a variety of impacts on ecosystems and are one of the leading threats to biodiversity worldwide (IUCN 2021). They may feed on native species or compete with native species for water, light, nutrients, and physical space (Duenas *et al*. 2018; Bradley *et al*. 2019; Reaser *et al*. 2020). In the worst cases, invasive species can cause extirpation of native species and completely dominate habitats where they occur.

Invasive species, including at least 47 invasive alien plants, are widespread in Markham's natural areas (see **Table 2**).[3] Based on field work by CBCL in 2022 and field work in 2020 by others for the Natural Heritage Inventory and Assessment Study, 377 polygons with a total area of 313 ha are dominated by invasive plant species. This represents nearly 5% of the total Greenway System and nearly one third of City-owned portions of the Greenway System. Some of the most common species found in the Markham Greenway System include Common Buckthorn (*Rhamnus cathartica*), invasive willows (*Salix* spp.), cool season grasses, Dog-strangling Vine (*Vincetoxicum rossicum*), and invasive honeysuckles (*Lonicera* spp.).[4]

Table 2: Invasive Alien Plant Species in City-owned Natural Areas

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

[3] 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.

[4] 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. morrowii*).

Common Name	Scientific Name
English Elm	*Ulmus glabra*
English Ivy	*Hedera helix*
European Barberry	*Berberis vulgaris*
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 Honeysuckle	*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*

Invasive plant species can come to completely dominate vegetation communities, and this can be seen at several locations in Markham. Dog-strangling Vine is the dominant plant across nearly 10 ha of meadow habitat at German Mills Park, and Norway Maple dominates the canopy, subcanopy, and understorey in some parts of the Pomona Creek Valley. Most open and early successional vegetation communities in Markham's natural areas are dominated by a combination of cool season grasses, Dog-strangling Vine, and Common Buckthorn. Although the canopies of most forests remain dominated by native species, many forest communities in Markham have some amount of Common Buckthorn in the subcanopy or understory. Many deciduous swamps are dominated by invasive willows. Some marshes are dominated by European Reed (*Phragmites australis* subsp. *australis*).

The prevalence of invasive plant species does not appear to differ significantly between community classes; forests, wetlands, open country/early successional, and other community classes all exhibit 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, European Reed, and Hybrid Cattail.

Some of the most prominent invasive vertebrate species in Markham include birds and mammals such as the House Sparrow (*Passer domesticus*), European Starling (*Sturnus vulgaris*), Brown Rat (*Rattus norvegicus*), and House Mouse (*Mus musculus*). Wild Boar (*Sus scrofa*) have been seen in parts of Durham Region adjacent to the City of Markham and should be watched for. Although the full extent of the impacts of House Sparrows and other invasive birds on native ecological communities are not fully known, there is evidence that they displace native birds and can harbour diseases that spread to native birds (MacGregor-Fors *et al*. 2010; Marzal *et al*. 2011; Ramirez-Cruz and Ortega-Alvarez 2021).

Other invasive species that are impacting Markham's natural areas include tree pests—notably Emerald Ash Borer (*Agrilus planipennis*)—earthworms (*Lumbricina* spp.), and invasive aquatic species such as European Carp (*Cyprinus carpio*). Invasive species are the threat of greatest scope and severity to Markham's natural areas, and their impacts both exacerbate and are exacerbated by the impacts of other threats described in this report.

4.2.2 Forest Decline and Death of Trees

Tree death and decline can occur at different scales, from individual trees to groups of trees to entire populations of specific tree species. Death and decline of trees can be the result of native and non-native pathogens, adverse weather events, changes in hydrology, and other biotic and abiotic factors. Disease and death of individual trees is a natural part of local ecological processes, and death of trees that results in canopy gaps can be an important regenerative process in forest ecosystems (Natural Resources Canada 2022). Therefore, disease and death of individual trees is not normally a management concern in natural areas. However, it may be an early warning sign of more severe threats and can exacerbate the impacts of other threats to natural areas. Disease and death of large numbers of trees in a natural area, or of large numbers of a particular species of tree across multiple natural areas, are serious management concerns.

Tree pests and pathogens may be native or non-native and include viruses, bacteria, fungi, wood boring and defoliating insects, and other animals.

Table 3 lists some of the tree pests and pathogens which have been observed in Markham's natural areas. Not all of these pests and pathogens are necessarily management concerns. For example, the Fall Webworm (*Hyphantria cunea*) is native to the Markham area and most deciduous trees are adapted to fall defoliation by this species. However, native pests can

potentially become problematic in small, fragmented vegetation communities that may have less resilience even to native threats, particularly in combination with other stressors.

Table 3: Tree Pests and Pathogens Observed in Markham's Natural Areas

Common Name	Scientific Name	Tree Species Affected
Beech Bark Disease	*Neonectria* spp.	American Beech
Butternut Canker	*Ophiognomonia clavigignenti-juglandacearum*	Butternut
Dutch Elm Disease	*Ophiostoma* spp.	Elm
Emerald Ash Borer	*Agrilus planipennis*	Ash
Fall Webworm	*Hyphantria cunea*	Deciduous trees
Spongy Moth	*Lymantria dispar*	Primarily deciduous trees
Horse-chestnut Leaf Blotch	*Phyllosticta paviae (syn. Guignardia aesculi)*	Horse-chestnut
Scale Insect	*Coccoidea spp.*	Conifers
Willow Leaf Beetle	*Plagiodera versicolora*	Willow
Spruce Spider Mite	*Oligonychus ununguis*	Spruce
Spruce Budworm	*Choristoneura spp.*	Spruce
Spruce Gall Adelgid	*Adelges cooleyi*	Spruce
Needlecast	*Rhizosphaera*	Conifers, notably spruce and pine
Diplodia Tip Blight	*Diplodia pinea*	Conifers, notably spruce and pine
Sawfly Sp.	*Symphyta spp.*	Conifers, notably spruce and larch
White Pine Weevil	*Pissodes strobi*	Pine
Black Knot	*Dibotryon morbosum*	Peach, plum, cherry
Armillaria Root Rot	*Armillaria heimii*	Oak
Fire Blight	*Erwinia amylovora*	Mountain Ash
Nectria Canker	*Neonectria galligena*	Maple
Anthracnose	*Colletotrichum spp.*	Primarily deciduous trees, notably hardwood (maple)
Japanese Beetle	*Popillia japonica*	Primarily deciduous trees, notably linden
Cankerworm	*Alsophila pometaria*	Linden
Elm Bark Beetle	*Hylurgopinus rufipes*	Elm
Apple Scab	*Venturia inaequalis*	Apple
Cedar Apple Rust/Juniper Rust	*Gymnosporangium juniperi-virginianae*	Cedar and juniper
Bronze Birch Borer	*Agrilus anxius*	Birch
Verticillium Wilt	*Verticillium dahliae*	Primarily deciduous trees, notably maples

Hydrological changes can result in large scale death and decline of trees. Drought can affect trees across large areas due to lack of soil moisture, and land use changes can result in localized drying

or flooding which can harm trees. Flooding caused by natural or anthropogenic watercourse modifications can impact trees not adapted to wet environments.

Forest gaps and overall canopy decline can be seen in woodland communities in the Greenway System. Small gaps in forests are usually the result of natural disturbances (e.g., windthrow) and are generally required in order to maintain forest health by promoting tree seed germination and canopy replacement. However, large gaps caused by disease and death of trees can be seen at several locations.

One of the most frequently observed causes of tree death and canopy decline is Emerald Ash Borer, an invasive alien insect that has caused mass mortality of ash trees across eastern North America. In some cases, ash mortality has resulted in changes to the ecological community classification (e.g., communities previously classified as ash forest were determined to now be dominated by other species). Mortality of other types of trees have also been observed, including elm dieback due to Dutch Elm Disease and infestations of American Beech (*Fagus grandifolia*) by scale insects which carry Beech Bark Disease. Extensive mortality of poplars (*Populus* spp.) has been observed, but the cause is unclear and should be examined in more detail.

Localized windthrow was observed in a few polygons but was never significant enough to cause more than small canopy gaps. Windthrow of individual trees is a natural and important disturbance regime in forests. More extensive windthrow may occur during major storms, but this was not observed during 2022 field work.

Other pests and pathogens that have potential to exist and cause negative impacts Markham's natural areas to be aware of are the Asian Long-horned Beetle (*Anoplophora glabripennis*), Mountain Pine Beetle (*Dendroctonus ponderosae*), Spotted Lantern fly (*Lycorma delicatula*), Oak Wilt (*Bretziella fagacearum*), and Hemlock Woolly Adelgid (*Adelges tsugae*). The Asian Long-horned Beetle is an invasive insect that has been successfully eradicated from Ontario twice now (Government of Canada 2021). Though this species is currently eradicated, new populations could invade. These beetles primarily attack maples, but also many other species such as poplars, birches, willows, and elms (Turgeon 2011). Several tree pests and diseases that do not currently occur in Markham have the potential to be detected here in the near future. Monitoring protocols should be implemented with the objective of early detection of these and other novel tree pathogens.

4.2.3 Problematic Native Species

In some cases, native species can become problematic and negatively impact ecosystems in fragmented landscapes. For example, White-tailed Deer *(Odocoileus virginianus)*, can cause changes to the structure and composition of woodlands by over-browsing vegetation (Gill and Beardall 2001). Over-browsing by White-tailed Deer can result in depauperate vegetation and potentially local extirpation of plant species (McGraw and Furedi 2005).

American Beavers (*Castor canadensis*) have the ability to manipulate the hydrology, geomorphology, and ecology of their habitats (Braizer 2020). This is generally not detrimental to ecological integrity and beaver activity is an important component of many aquatic and terrestrial systems (e.g., beaver ponds provide critical wetland habitat for birds and other wildlife). In some cases, beaver activity can negatively impact terrestrial systems by displacing terrestrial species or altering vegetation composition and structure. Flooding due to beaver activity can cause structural damage to buildings, roadways, and may threaten agricultural crops.

Other native rodents have proven to be problematic and negatively impact ecosystems in fragmented landscapes as well. Some of these rodents include native mice and voles. Rodents such as mice have been known to cause significant damage to crops and native plants (EPA 2022). Voles such as the Woodland Vole (*Microtis pinetorum)* can cause significant damage to lawns, native landscapes, and parks as their diet is made up of green plants and seeds (Government of Canada 2013). Voles also use tunnel systems along the surface of the earth, tearing up and manipulating native grasses to create safe travel routes where predators are less likely to detect them. This type of disturbance to grasses causes browning and eventually death to the vegetation in this manipulated area.

Rabbits such as the Eastern Cottontail *(Sylvilagus floridanus)* are also known to strip and eat the bark off the entire diameter of young trees; this causes significant damage called “girdling” or “ring barking”. Once this damage has occurred it prevents water and sap from flowing past the damaged area, in turn eventually causing the tree to die. This type of damage is difficult to repair and most commonly results in loss of the tree (Wimbush and Forrester 1988).

Evidence of deer browse was observed sporadically in Markham’s natural areas in 2022 but was not observed to have had a visible effect on any communities. Beavers occur in Markham’s natural areas, but no examples of beavers negatively affecting natural communities were noted during field work carried out for this study in 2020 and 2022. The threat of problematic native wildlife to Markham’s natural areas is therefore believed to be low in scope and severity.

4.2.4 Outdoor Pets

Domestic cats *(Felis catus)* and dogs (*Canis familiaris)* can have significant ecological impacts when allowed outside and off-leash. Cats hunt and kill birds, rodents, reptiles, amphibians, and other small animals, and it is estimated that free-roaming domestic cats kill up to four billion birds and 22 billion mammals annually (Loss *et al*. 2013). Un-spayed or neutered cats can establish populations of feral cats that can be invasive and can transmit a variety of diseases to other animals (Cornell University College of Veterinary Medicine 2017). Domestic dogs can have negative ecological impacts if allowed off leash. Some ways in which off-leash dogs negatively impact ecosystems include displacement, disturbance, and indirect and direct mortality (e.g., dogs may kill animals or transmit diseases such as distemper and rabies) (Hennings 2016).

Free roaming cats and dogs are themselves at risk of becoming prey for wild predators or catching diseases from other animals. Allowing domestic pets outdoors can result in human-wildlife

conflicts with undesirable ecological outcomes. Cats were rarely observed in Markham's natural areas during field work by CBCL in 2022, but off-leash dogs were frequently observed, and leashed dogs were ubiquitous. The impacts of dogs, whether on or off leash, on wildlife in Markham's natural areas remains a knowledge gap, but death or displacement of wildlife by dogs may be a threat of considerable scope and severity.

4.3 Abiotic Threats

4.3.1 Residential Encroachment

Encroachment of residential properties into publicly owned natural areas is a widespread and pervasive management challenge for planners and land managers (McWilliam *et al*. 2012, 2013, 2015). Examples of encroachment of residential land uses into publicly owned natural areas include dumping, creation of informal trails, expansion of lawns and gardens, and, in extreme cases, earth grading and excavation. Residential encroachment can alter vegetation community structure and depress biodiversity by removing groundcover and understory vegetation and establishing monocultures (i.e., turfgrass). It can also result in introductions of invasive species from lawns and gardens, some common invasive species introduced from gardening include English Ivy (*Hedera helix*), Daylily (*Hemerocallis fulva*), Goutweed (*Aegopodium podagraria*), Japanese Barberry (*Berberis thunbergia*), and Euonymus (*Euonymus europaeus*). Removal or failure to erect a fence between residential properties and natural areas, even without physical expansion of residential land uses, can result in displacement of wildlife due the presence of household pets and increased human activity.

Residential encroachment into City-owned natural areas is notably rare in Markham, but it does occur. During field work by CBCL in 2022, the majority of residential properties adjacent to natural areas were observed to have well-maintained fences or otherwise clearly delineated property boundaries with no signs of encroachment. Encroachment is most prevalent adjacent to older neighbourhoods (i.e., built before approximately 2002), which is possibly a reflection of the City's current standards for setbacks and fences between urban and natural land uses. Residential encroachment in Markham most often consists of removal (or failure to erect) fencing along property boundaries abutting natural areas. Intentional or unintentional expansion of lawns, gardens, and other anthropogenic

land covers into City-owned properties was observed at a few locations. At Toogood Park, for example, non-native plant species were observed to be spreading from gardens intentionally planted outside adjacent property boundaries.

4.3.2 Trails and Recreation

Human recreational use is ubiquitous in Markham's natural areas. Nearly every City-owned natural area contains formal or informal trails, and many natural areas contain other recreational infrastructure such as sports fields and manicured lawns. It is well known that access to natural spaces improves the mental and physical well-being of urban residents (Aerts *et al*. 2018; Twohigg-Bennett and Jones 2018; Grima *et al*. 2020). However, recreational use can affect local ecology in a variety of ways. Heavy recreational use of natural areas can result in exposure of tree roots, soil compaction, and erosion (Hammitt and Cole 1998; Leung and Marion 2000). Severe erosion and root exposure can eventually lead to the death of trees or entire vegetation communities (Liddle 1997).

Most natural areas surveyed by CBCL in 2022 contained both formal and informal trails. Formal trails included access roads (both paved and unpaved), paved multiuse paths, gravel paths, and dirt footpaths. Informal trails consisting of faint to well-defined dirt paths were almost ubiquitous throughout the study area. Informal trails were most frequently observed connecting residential properties to formal trails. Others were constructed by mountain bikers, and some were "desire paths"[5] representing corridors of frequent human movement within natural areas. These informal trails can have a variety of impacts on natural areas: they can accelerate the dispersal of invasive species, cause localized soil compaction, and result in micro-fragmentation of already fragmented ecosystems (Marion and Leung 2011). In some cases, they can result in littering and vandalism.

Informal trails were not generally found to be negatively impacting local ecology, but earth disturbance (e.g., pits and mounds excavated by mountain bikers) and evidence of fires were found along a small number of informal trails. Likewise, despite the high volume of recreational users in

[5] A "desire path" is a type of informal trail that develops spontaneously in response to frequent human movement. Desire paths represent human movement corridors that optimize connectivity and/or enjoyment of public spaces. See: Luckert 2012; Kohlstedt 2016; Bramley 2018.

some natural areas, recreational use was not observed to have resulted in significant ecological impacts. Therefore, while the threats of trails and recreational use to Markham's natural areas are extensive in scope, the severity of these impacts is believed to be low.

4.3.3 Dumping

Illegal dumping is a pervasive problem in natural areas, even in places with robust waste management programs like the City of Markham (Gardinetti 2020). Aside from the aesthetic impacts and potential human health risks from litter and other waste, illegal dumping can have a variety of ecological impacts, depending on the type and volume of material. Yard waste is potentially a major dispersal vector for invasive plant species (Rusterholz *et al*. 2012). Some types of waste can contaminate groundwater or poison wildlife and plants (Gardinetti 2020). Plastic bags and hydrocarbons (e.g., asphalt) can persist for thousands of years without breaking down (Kale *et al*. 2015), so some illegally dumped waste can have long-term impacts to natural areas.

Dumping in Markham's natural areas most frequently consists of yard waste (e.g., grass clippings, potted and bare root plants, branches, leaves, and topsoil), but some instances of illegally dumped construction materials and hazardous waste have been observed. In a few cases, non-native species have been observed to be spreading into natural areas from dumped garden waste (e.g., English Ivy (*Hedera helix*) in Toogood Pond Park).

Deliberate dumping of large quantities of waste is infrequent in Markham's natural areas, but casual littering is ubiquitous and was observed in almost every natural area during field work by CBCL in 2022. When littering is included, the threat of dumping to Markham's natural areas is extensive in scope and may be high in severity.

4.3.4 Harvesting of Plants and Wildlife

A body of research has explored the role of urban foraging in building emotional and spiritual relationships between urban residents and natural communities (McLain *et al*. 2012, 2014; Poe *et al*. 2014). However, the impacts of plant, fungus, and wildlife harvesting in urban natural areas may be significant, especially considering the low tolerance of fragmented urban natural areas to disturbance (Ticktin 2004; Ticktin and Shackleton 2011). Native plant species already stressed by competition with alien species may be at risk of overharvesting or even extirpation. Although urban foraging has not been observed frequently in Markham, and many of the plants harvested are non-native species, harvesting of plants and other organisms should continue to be discouraged.

4.3.5 Noise Pollution

Natural areas in close proximity to major roads and highways experience traffic noise and this is especially severe in natural areas adjacent to Highway 404 and 407. Although the specific impacts of traffic noise on wildlife in Markham's natural areas have not been explored in detail, research from other regions has found strong evidence that traffic noise can displace wildlife from natural areas (McClure *et al*. 2013). The abundance of birds, for example, can be up to one-third lower in

areas subject to traffic noise compared with quiet areas (Parris and Schneider 2008; McClure *et al*. 2013) and traffic noise can affect breeding success of amphibians (Troianowski *et al*. 2017; Castaneda *et al*. 2021). Traffic noise is variable and fluctuates with traffic volumes and road conditions, but even periodic traffic noise can affect wildlife that live near highways.

Natural areas adjacent to highways and arterial roads in Markham experience extensive traffic noise which varies with traffic volumes and road conditions, but no specific impacts of traffic noise on local ecology have been observed. Traffic volumes are expected to increase as Markham continues to grow (City of Markham 2014) and these increases will be most significant along highways and arterial roads, so natural areas located along these corridors can be expected to endure increasing levels of traffic noise. Traffic noise is a widespread threat to natural areas in Markham, although the severity of the potential impacts on natural areas remains a knowledge gap.

4.3.6 Light Pollution

Urban areas generate continuous light pollution which can impact wildlife and wildlife habitat in protected areas (Mu *et al*. 2021). Light pollution has been shown to decrease fitness of insect populations and may disturb or displace other wildlife (Gaston *et al*. 2012; Grubisic *et al*. 2018). Urban light pollution can disrupt bird migration and interrupt physiological processes of other animals as well as alter seasonal metabolic processes in plants (Gaston *et al.* 2012). Many of Markham's natural areas occupy narrow valleylands which have limited buffers between artificial lighting and natural habitats, and a few natural areas contain trails with artificial lighting. Light pollution is a threat of extensive scope to Markham's natural areas but the severity of the impacts on plants and wildlife is unknown. While artificial light can be assumed to have some impacts on urban wildlife, these impacts should be considered with respect to its contributions to user safety.

4.3.7 Erosion and Earth Displacement

Wind, water, ice, and other natural processes that result in erosion are some of the primary drivers of physiography, topography, and stream morphology in natural areas. Natural erosional processes have occurred throughout Earth's history and are important regenerative processes in some ecological communities, such as floodplains (Thornes 1985; Osterkamp *et al*. 2011). However, erosion can be exacerbated by anthropogenic land use change in urban landscapes where it can threaten human infrastructure

and cause irreversible alterations to natural habitats (Borrelli *et al*. 2017). Erosion can also result in sediment inputs into waterbodies that may exceed the tolerances of aquatic ecosystems (Newcombe and Macdonald 1991; Yamashiki *et al*. 2006).

Varying degrees of erosion can be seen along all of the watercourses in Markham's natural areas. Problematic areas of erosion are tracked by the City of Markham and restoration and mitigation works are already ongoing at some of these sites, such as several locations along German Mills Creek. During field work by CBCL in 2022, localized erosion (e.g., gullying) was observed on slopes where stabilizing vegetation was absent (e.g., along informal trails where vegetation had been trampled). Other examples of natural earth displacement observed in Markham's natural areas included large animal burrows, including some extensive animal tunnel systems presumably built by woodchucks (*Marmota monax*). Aside from being safety hazards for human users, animal burrows are not a major management concern in natural areas.

Types of earth displacement of greater concern are those caused by humans, either as part of construction projects or unsanctioned earth displacement by recreational users. Construction projects in the City's natural areas may be required to restore excavated and graded areas to a natural state; however, if not managed effectively, excavation and grading can result in long-term alterations to vegetation structure and may potentially lead to erosion in other areas if drainage patterns are changed. Unsanctioned excavations observed by CBCL in Markham's natural areas were generally smaller in scale (e.g., excavations by mountain bikers to build jumps and other obstacles).

Erosion and earth displacement are threats of extensive scope and potentially high severity in Markham's natural areas. The City will continue to monitor areas of erosion concern.

4.3.8 Fires

Fire has historically played a complex role in driving vegetation patterns on the landscape of southern Ontario. Wildfires are necessary for maintaining grasslands and savannahs and also for promoting regeneration of certain forest trees, such as oaks and pines (Day and Guyette 2000; Dickenson 2005). Prior to European settlement of southern Ontario, Indigenous peoples used fire to maintain open habitats within the surrounding forested landscape (Day and Guyette 2000). Fire suppression since European settlement has promoted the expansion and persistence of vegetation communities that are not fire driven, namely deciduous forests and thickets (Clark *et al*. 1996; Flory *et al*. 2015; Mekonnen *et al*. 2019).

The absence of fire is a key factor in the successional trajectory of Markham's natural areas and is partially responsible for the dense understory and subcanopy vegetation typical of vegetation communities in the Greenway System. Notwithstanding other factors (e.g., climate change, tree pests and pathogens, vegetation clearing and planting, windthrow), the majority of Markham's natural areas can be expected to succeed into mature deciduous forests dominated by fire intolerant species such as maples and Black Walnut. Controlled burns have been used by land

managers in adjacent municipalities to maintain certain habitats (e.g., meadows) and fire could be used as a management tool to maintain these habitats in Markham's Greenway System.

Wildfires have been extremely rare in southern Ontario since European settlement, largely due to active suppression, but partially because temperate deciduous forests are somewhat fire resistant (Clark *et al*. 1996). The question of whether wildfires are a "risk" to natural areas is largely a philosophical one for land managers to consider. Although a wildfire in Markham's urban area could potentially be catastrophic for human property and infrastructure, it may ultimately benefit the natural environment by promoting habitat regeneration and driving landscape heterogeneity. Regardless, the probability of wildfires occurring naturally in Markham's natural areas under current environmental conditions is probably low and the potential for spread would be limited by the highly fragmented nature of the City's natural areas.

Although the probability of large fires remains low, small fires do occur in Markham's natural areas. Evidence of recent campfires was observed by CBCL in 2022 along informal trails in Pomona Mills Park. Other evidence of fires included a tree at German Mills Park presumed to have been struck by lightning.

4.3.9 Floods

Flooding may be short-term and periodic (e.g., occurring after storms or snowmelt) or long-term and isolated (e.g., caused by hydrologic or topographic changes). The periodicity of flooding depends on weather patterns, elevation, and topography. In Markham, the Toronto and Region Conservation Authority is responsible for modeling flood lines for storm events of different intensities (e.g., 50-year, 100-year, and Regional Storm, which reflects their historical probability of occurrence). Parts of natural areas that fall below the flood line can be expected to experience flooding more frequently than those between the 100-year and regional flood lines. Long-term flooding can be caused by beaver dams or anthropogenic watercourse impoundments.

Most vegetation communities on floodplains are adapted to natural flood regimes and some require periodic flooding to maintain biodiversity (Gerard *et al*. 2008), so the impacts of flooding in these communities is not necessarily detrimental. However, even in natural communities that are adapted to periodic immersion, flooding can carry sediment and pollutants that may impact the ecosystem. Because runoff increases with urbanization and because storms are predicted to increase in frequency and intensity due to climate change, Markham's natural areas will likely experience more frequent, intense flooding in the future (Feng *et al*. 2021; York Region 2022). More frequent, intense floods

may exceed the tolerance thresholds of some vegetation communities.

Some of Markham's municipal stormwater management facilities include constructed ponds and wetlands that are designed to attenuate runoff and therefore experience more abrupt and extreme water level fluctuations than their receiving systems. These facilities will play an important role in mitigating the scope and severity of flood impacts to natural areas.

4.3.10 Droughts

Droughts and abnormally dry weather occur periodically as part of natural weather cycles. Evidence from tree rings shows that droughts have occurred periodically in eastern North America for thousands of years (Girardin *et al*. 2006), and ecosystems in this region have a degree of tolerance to droughts (Fahey *et al*. 2013). However, like all other threats to natural areas, the impacts of drought can be exacerbated by habitat fragmentation and isolation, making urban natural areas less tolerant to the effects of drought. It is unclear whether climate change will change the frequency or severity of droughts in our region. Like other climatological threats, the impacts of droughts on natural areas are likely to be extensive in scope, but the potential severity is largely unknown.

4.3.11 Pollution

Pollution can be airborne, aquatic, or terrestrial and occur at different scales (e.g., air pollution affecting large regions vs. site-specific soil contamination). The impacts of pollutants on natural areas can be chronic (i.e., manifesting over long time periods) or acute (i.e., causing immediate harm). Littering and dumping (see **Section 4.3.3**) can also be considered pollution.

The most common airborne pollutants in urban areas are emitted from vehicles and industrial activities. Common airborne pollutants include nitrogen oxides, ozone, hydrogen sulfide and particulate matter. The concentration of these and other airborne pollutants is low in the Markham area relative to many global metropolitan areas, but their concentrations vary with wind and weather patterns and proximity to sources, such as roads and highways (Ontario Ministry of Environment, Conservation and Parks 2022). Airborne pollutants have a variety of impacts on natural areas: the acidity of hydrogen sulfide can damage foliage and ground level ozone can reduce productivity of terrestrial vegetation; nitrogen oxides can cause eutrophication of aquatic ecosystems; and airborne particulate matter can affect wildlife fitness (Gheorghe and Ion 2011; Stevens *et al*. 2020). Airborne particulate matter can precipitate out of the atmosphere and contaminate soils and waterbodies with heavy metals or hazardous chemicals (Gheorghe and Ion 2011).

Pollutants that commonly contaminate soils, surface water, and groundwater include hydrocarbons (e.g., gasoline and motor oil), chlorides from road salt, nitrates and phosphates from fertilizers and industrial chemicals. These types of pollutants can cause injury, death, and long-term reductions in fitness of aquatic and terrestrial organisms (Simonich and Hites 1995; Srivastava *et al*. 2019). Sources of these types of pollutants tend to increase with urbanization because of the expansion of roads, parking lots, and other impervious surfaces. The groundwater impacts of liberal application of de-icing salt to roads and parking lots were identified in the Markham area as early as the late 1990s (Williams *et al*. 1999), and elevated levels of surface water pollutants originating from storm sewers have been detected in this region for just as long (Behera *et al*. 2000).

The former Sabiston Landfill in what is now German Mills Meadow and Natural Habitat is an example of a point source of both air and soil pollution (Penner and Kumar 2012; City of Markham 2020). The natural environment impacts of pollution originating from the landfill are largely unknown and the human health risks are overall low, but it highlights the importance of regular monitoring for mitigating pollution risks.

Pollution of air, water, and soils can potentially occur anywhere in Markham; however, the overall scope and severity of these threats is difficult to assess. Air pollution is probably a threat of large scope but low severity in Markham since concentrations of all measured airborne pollutants have decreased substantially over the past ten years (Ministry of Environment, Conservation and Parks, 2022). Water and soil pollution are more localized but vary in severity depending on the nature of the contaminant and extent of the release (e.g., large pollutant spills could have severe impacts). Natural areas also play an important role in removing and attenuating pollutants from air, water, and soil (Hill 1971; Van de Moortel *et al*. 2010; Muerdter *et al*. 2018). For example, some wetland and aquatic plants remove and sequester certain pollutants from water (Van de Moortel *et al*. 2010), and terrestrial vegetation along highways helps remove atmospheric pollutants from traffic (Wang *et al*. 2019).

4.4 Summary of Risks to Natural Areas

A summary of the risks to natural areas with respect to the threats identified is provided in **Table 4**. Potential impacts to biodiversity, ecological function and services, user safety, and recreation have been assessed.

Table 4: Summary of Risk Assessment for Natural Area Components

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	**Ecological Function and Services**	**User Safety**	**Recreation**
Climate Change	Scope: extensive Severity: unknown Harm or death of organisms intolerant of temperature and precipitation changes.	Scope: extensive Severity: unknown Loss of suitable habitat for specialized wildlife. Longer growing season and higher atmospheric carbon may increase plant productivity (though warmer summer temperatures could decrease productivity). More intense storms may exceed the capacity of natural areas to attenuate runoff.	More intense precipitation may exacerbate erosion and flooding which could be dangerous for park users.	Heat waves and more intense storms may reduce the amount of time residents spend in natural areas. More intense precipitation may damage amenities.
Urbanization	Scope: extensive Severity: high Loss of taxonomic and genetic diversity due to habitat fragmentation and isolation. Introductions of non-native, invasive species.	Scope: extensive Severity: high Local temperature increases due to urban heat island effect. Increased surface runoff can exceed the attenuation capacity of natural features. Increased human population pressure can exacerbate other impacts. Habitat removal and loss of habitat corridors due to infrastructure construction. Habitat isolation due to adjacent land use change.	Local temperature increases and increased runoff may pose environmental threats to human users.	Urbanization brings opportunities for recreational improvements in natural areas.

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	Ecological Function and Services	User Safety	Recreation
Hydrologic Alterations	Scope: widespread Severity: unknown Harm or displacement of aquatic species. Harm or death of vegetation intolerant of increased/decreased soil moisture.	Scope: widespread Severity: unknown Loss of aquatic habitat. Flooding of terrestrial habitats. Changes in moisture regimes of terrestrial habitats.	More frequent or intense flooding can be a threat to human safety.	More frequent or intense flooding can damage recreational amenities.
Invasive Species	Scope: extensive Severity: high Displacement or direct harm to native plants and wildlife.	Scope: extensive Severity: high Changes to vegetation composition and structure. Loss of specialized wildlife habitat. Can increase runoff (e.g., soil compaction by buckthorn) or reduce runoff attenuation capacity (e.g., invasive of wetlands by European Reed).	Some invasive plants can be harmful to humans (e.g., Wild Parsnip, Giant Hogweed). Trees injured or killed by invasive pests pose a safety hazard.	Aesthetic impacts due to tree death or large infestations of invasive plants.
Forest Decline, Disease and Death of Trees	Scope: widespread Severity: high Local or regional tree species extirpation.	Scope: widespread Severity: high Changes to vegetation composition and structure. Loss of wildlife habitat. Alien species invasions.	Dead and dying trees can harm users or damage infrastructure.	Harm to landscape aesthetics. Dead and dying trees can harm users or damage infrastructure.

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	Ecological Function and Services	User Safety	Recreation
Problematic Native Species	Scope: unknown Severity: unknown Harm or extirpation of species preferred by deer. Injury or death of trees from beaver cutting or girdling. Displacement of terrestrial species due to beaver flooding.	Scope: unknown Severity: unknown Changes in vegetation composition and structure due to deer over-browse. Loss of specialized wildlife habitat due to beaver flooding.	Some conflicts between humans and native wildlife can result in injuries.	Aesthetic impacts to vegetation from deer over-browse or beaver cutting and girdling. Beaver flooding can damage recreational amenities.
Outdoor Pets	Scope: widespread Severity: unknown Death, injury, displacement, or disturbance of wildlife.	Scope: widespread Severity: unknown Reduced area or quality of wildlife habitat.	Off-leash dogs can occasionally injure other park users.	Off-leash dogs may deter other residents from using natural areas.
Residential Encroachment	Scope: local Severity: high Damage to or removal of native plant species. Displacement or disturbance of wildlife. Introduction of non-native, invasive species.	Scope: local Severity: high Loss of wildlife habitat. Changes in vegetation composition and structure.	Tree cutting, dumping or earth displacement by adjacent residents may create hazards for natural area users.	Reduces the area of natural space available for the enjoyment of other users.

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	Ecological Function and Services	User Safety	Recreation
Trails and Recreation	Scope: local Severity: unknown Damage to vegetation from trampling. Displacement or disturbance of wildlife.	Scope: local Severity: unknown Soil compaction and micro-fragmentation can reduce wildlife habitat quality. Fires, litter, earth displacement, and some recreational activities (e.g., mountain biking) can damage natural communities.	Informal trails may have hazardous conditions for users.	Abundance of informal trails to adjacent residential properties may reduce sense of place for other park users.
Dumping	Scope: local Severity: high Introduction of non-native, invasive species from yard waste. Hazardous waste can injure or poison wildlife.	Scope: local Severity: high Reduction in wildlife habitat quality. Hazardous waste can result in chronic pollution of soils, surface water, and groundwater.	Biowaste (e.g., needles), household chemicals and construction materials can injure natural area users.	Aesthetic impacts. Extensive dumping could potentially deter residents from visiting a natural area.
Harvesting of Plants and Wildlife	Scope: local Severity: low Overharvesting can reduce populations of native plants, fungi, or wildlife, and can potentially result in species extirpations.	Scope: local Severity: low Overharvesting of plants and wildlife can reduce resilience of already stressed ecosystems.	Misidentification of plants or fungi could result in accidental poisoning.	Overharvesting of plants or fungi can affect enjoyment of other natural area users.
Noise Pollution	Scope: widespread Severity: unknown Disturbance or displacement of wildlife, potentially resulting in abandonment of nests, dens, etc.	Scope: widespread Severity: unknown Reduction of wildlife habitat quality.	Excessive noise can be damaging to human hearing.	Excessive noise affects nature enjoyment and may deter residents from visiting a natural area.

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	Ecological Function and Services	User Safety	Recreation
Light Pollution	Scope: widespread Severity: unknown Disturbance or displacement of wildlife, potentially resulting in abandonment of nests, dens, etc. Changes to plant and wildlife physiological processes.	Scope: widespread Severity: unknown Reduction of wildlife habitat quality.		Excessive light pollution can affect nature enjoyment.
Erosion and Earth Displacement	Scope: local Severity: unknown Damage, injury, or death of terrestrial and aquatic species either directly (e.g., root exposure, burying) or indirectly (e.g., increased turbidity from suspended sediments).	Scope: local Severity: unknown Loss of terrestrial and/or aquatic habitats. Changes to vegetation composition and structure. Changes in the capacity of natural features to attenuate runoff.	Erosion and earth displacement can create falling risks for natural area users.	Erosion and earth displacement can damage recreational amenities.
Fires	Scope: local Severity: low Injury or death of trees and other vegetation. Displacement or disturbance of wildlife.	Scope: local Severity: low Changes to vegetation composition and structure. Loss of terrestrial vegetation can lead to increased surface runoff and erosion.	Fires or remnants of fires can injure natural area users. Trees damaged by fire can pose a safety risk.	Remnants of illicit campfires may reduce sense of place for other park users.

Threat	Risk Assessment: Potential Impacts			
	Biodiversity	Ecological Function and Services	User Safety	Recreation
Floods	Scope: widespread Severity: low Damage to terrestrial vegetation. Injury or death of terrestrial wildlife.	Scope: widespread Severity: low Short-term flooding can result in changes to vegetation composition and structure. Long-term flooding results in loss of terrestrial wildlife habitat. Erosion and structural damage to terrestrial systems.	Risk of drowning or injury to natural area users.	Damage to recreational amenities.
Droughts	Scope: extensive Severity: unknown Injury or death of vegetation with low tolerance to dry conditions.	Scope: extensive Severity: unknown Depressed plant productivity can affect wildlife habitat quality. Parched soils have reduced infiltration capacity which leads to increased surface runoff.	Dead or injured trees can pose a safety risk.	Dead or injured trees can damage recreational amenities if they fall. Aesthetic impacts of dead or dormant vegetation.
Pollution	Scope: extensive Severity: unknown Death or injury of plants. Death, injury, or reduced fitness of wildlife.	Scope: extensive Severity: unknown Pollution of soils or groundwater can result in long-term vegetation community changes and reduced wildlife habitat quality.	Poor air quality can be a health concern for natural area users. Pollution of soils, surface water or groundwater can potentially injure or poison natural area users.	Poor air quality can deter residents from visiting natural areas.

4.5 Mitigation and Monitoring

Threats to Markham's natural areas occur at different scales but are interconnected; the impacts of a particular threat may be either mediated or exacerbated by others. Natural area management, including threat mitigation and monitoring, should therefore be holistic in scope and have consideration for the interconnectivity and cumulative impacts of threats. Holistic natural area management should be proactive, adaptable, and system-focused, and should incorporate the key principles outlined in **Table 5**. These principles will guide the development of the best management practices which are presented in Section 5.

Table 5: Key Principles for Holistic Natural Area Management in the City of Markham

Key Principles
Resilience: Threats to natural areas are cumulative and there is still considerable uncertainty about how certain threats (e.g., climate change) will manifest and interact with other threats at the local scale. A key focus, therefore, should be to promote resilience (i.e., tolerance to environmental change and disturbance) and the establishment of self-sustaining ecosystems to the extent possible. Resilient natural areas have structural stability, high biodiversity, and a wide distribution of ages and life stages of vegetation and wildlife (Sasaki *et al*. 2015; Chambers *et al*. 2019).
Connectivity: Urbanization amplifies threats to natural areas by limiting movement and genetic exchange across fragmented landscapes. Providing connections and corridors among natural areas should continue to be a key focus of land use planning in Markham. Most of Markham's natural areas occur in valleylands and are connected along riverine corridors, but lateral connections among these corridors and between valleylands and tablelands are weak or non-existent. Existing corridors should be protected and opportunities to restore or create new corridors should be identified.
Socio-ecology: Urban natural areas are both affected by and have effects on their surrounding human communities. The City should continue to provide infrastructure and amenities within natural areas that allow for sustainable human use while protecting significant features. Management actions should consider the outcomes for human health, safety, and enjoyment.
Buffers: As Markham continues to grow, areas of open space will continue to be converted to urban land uses. Providing appropriate setbacks between new developments and natural areas, and enforcing edge treatments (e.g., fences) along property lines where they abut natural areas, will reduce the intensity of amplified human pressure on natural habitats. The City should continue to enforce its current policies and approaches pertaining to development setbacks and fencing.

Management actions implemented in isolation and without consideration of the outcomes for other aspects of the socio-ecological system may result in unintended consequences even if they succeed at mitigating a specific impact. For example, removal of an invasive plant species from a specific location could result in loss of wildlife habitat, increased erosion, or reinvasion by other

alien species unless a site restoration plan is also implemented. Similarly, the introduction of non-native plants from more southern regions into natural areas (i.e., assisted migration) may improve species diversity in the short-term, but may not necessarily improve long-term ecosystem resilience as effectively as reintroducing a diversity of species native to the Markham area.[6] For applicable projects in the Greenway System, the City should continue to ensure that appropriately-scoped environmental impact studies are prepared with consideration of the ecological outcomes, and that commitments to mitigation measures are implemented.

To proactively mitigate threats and respond rapidly to emerging threats, a natural area monitoring framework should be implemented. A conceptual framework for monitoring natural areas is provided in **Table 6**. The natural heritage field studies completed in 2020 and 2022 provided baseline data on vegetation characteristics, invasive species, and disturbance throughout the City-owned Greenway System. Additional studies could be undertaken to provide a more robust baseline for these and other aspects of the Greenway System (e.g., landscape connectivity analysis to identify potential connections and corridors; risk mapping using GIS to identify priority sites for monitoring). Natural areas should be assessed periodically for changes to environmental components (e.g., biodiversity, ecological function, user safety) and emergence of threats. Monitoring should be standardized by collecting a series of quantitative and qualitative metrics, but also flexible enough to detect threats before the impacts manifest quantitatively (i.e., emergent threats may not be immediately detectable in ecological metrics). Monitoring should also be able to detect both acute, localized impacts (e.g., dumping, pollutant spills) and long-term, ecosite-scale impacts (e.g., changes in vegetation composition and structure).

Table 6: Conceptual Monitoring Framework for Environmental Components and Threats to Natural Areas in the City of Markham

Component/ Threat	Description	Metrics
Community Classification	Ecological classification of vegetation communities	• Ecoelement code
Biodiversity	Taxonomic and trophic diversity	• Species Richness • Higher taxon richness (e.g., family, order, class) • Floristic Quality Index
Ecological Function	Function of the natural area for wildlife and humans	Presence of: • Waterbodies • Wetlands • Significant Wildlife Habitat • Rare vegetation communities • Specialized species • Rare species • Endangered or Threatened species

[6] Although our region is predicted to experience warmer average annual temperatures and longer growing seasons as a result of climate change, we may also experience increasingly acute temperature swings, which could affect the survival of species adapted to warmer climates (Liu *et al*. 2018; Montwe *et al*. 2018; Richardson *et al*. 2018).

Component/ Threat	Description	Metrics
User Safety	Potential for harm to human users	Presence of: • Dead and dying trees • Harmful invasive species • Risks to infrastructure
Recreation	Recreational value for humans	• Length of managed trails • Trail treatment (e.g., unpaved, paved, gravel) • Feedback from recreational users Presence of: • Heritage features • Signature sites (e.g., lookout points) • Recreational infrastructure
Climate Change	Changes in climate and weather patterns	• Average annual temperature • Length of frost-free period • Growing degree days • Annual precipitation • Severity of storms
Urbanization	Changes to surrounding land cover	• Adjacent land use type • Area of impervious surfaces • Surrounding population • Traffic volumes
Fragmentation and Isolation	Connectivity between natural areas	• Area of natural land cover • Landscape connectivity • Proximity to other natural areas • Area of interior habitat • Number of roads crossing natural areas • Area of habitat restoration • Ratio of isolated to connected natural areas
Hydrologic Alterations	Changes to surface and groundwater	• Stream morphology • Frequency and volume of peak flows • Depth to water table • Soil moisture regime
Invasive Species	Presence and extent of invasive alien species	• Presence of invasive species • Number of invasive species • Area occupied by invasive species
Forest Decline, Disease and Death of Trees	Canopy decline and emergence of gaps	• Number of canopy gaps • Size of canopy gaps • Evidence of tree pests or pathogens
Problematic Native Species	Native species which may adversely impact the ecosystem	• Extent of deer browse • Evidence of beaver activity • Presence of beaver dams
Outdoor Pets	Presence of outdoor pets	• Presence of outdoor pets • Number of outdoor pets

Component/ Threat	Description	Metrics
Residential Encroachment	Extension of adjacent residential land uses into natural areas	• Ratio of fenced: unfenced property boundaries Presence of: • Gates in fences • Informal trails entering the natural area • Planting, mowing or other vegetation alterations on public lands adjacent to residential properties • Earth displacement on public lands adjacent to residential properties
Trails and Recreation	Characteristics of trails and recreational amenities in natural areas	• Length of managed and informal trails • Surface treatment of managed trails • Condition of managed trails • Presence of other recreational amenities • Number and frequency of park users
Dumping	Illicit dumping in natural areas	• Locations of illicit dumping • Extent and severity of dumping • Type of material
Harvesting of Plants and Wildlife	Harvesting of plants, mushrooms, and wildlife by urban residents	• Evidence of plant, mushroom, and animal harvesting • Extent and severity plant, mushroom, and animal harvesting
Noise Pollution	Excessive noise in natural areas	• Extent and severity of noise pollution
Light Pollution	Artificial light in natural areas	• Extent and severity of light pollution
Erosion and Earth Displacement	Erosion and earth displacement in natural areas	• Extent and severity of erosion and earth displacement • Type of earth displacement (human vs. natural) • Threats to human health and property
Fires	Evidence of fires in natural areas	• Evidence of campfires • Evidence of other fires (e.g., lightning strikes)
Floods	Short- or long-term flooding of natural areas	• Evidence of flooding • Frequency of flood events • Length of flood events
Droughts	Droughts or abnormally dry weather affecting natural areas	• Local drought index • Annual accumulated precipitation • Changes in soil moisture regimes
Pollution	Pollution of air, surface water and groundwater affecting natural areas	• Local air quality index • Surface water and groundwater quality Presence of: • Point sources of pollutants • Hazardous materials

5 Management Practices

The fundamental goal of natural area management in Markham shall reflect Policy 2.2.1 of the City's 2014 Official Plan, specifically the strategic objective of Policy 2.2.1.1.

To this end, objectives for managing the City's natural areas are recommended in the following sections. Current management approaches are reviewed and best practices for achieving the objectives and core goal of natural area management are recommended.

5.1 Land Use and Natural Heritage Planning

Objective 1: Protect natural heritage features and functions within the Greenway System.

The watercourses, wetlands, forests, grasslands, and other features of Markham's Greenway System provide habitat for a diversity of plants and wildlife and are some of the most important contributors to community well-being and enjoyment. These features shall be protected from the negative impacts of development and urban land use and shall be expanded where possible.

The Greenway System is concentrated in valleylands of the Rouge River, Don River, and their tributaries, but there is a conspicuous lack of lateral tableland connections among these features. Creating and maintaining habitat corridors to connect the City's valleylands will significantly improve ecological integrity across the City.

5.1.1 Current Approach

Beyond enforcing and adhering to the requirements of municipal, provincial, and federal policies, the City's approach to natural area management has generally been reactive, opportunistic, and driven by resource availability. Development and site alteration within the Greenway System are managed through the development approvals process following the policies in the PPS, provincial plans, Regional Official Plan, and City Official Plan. The City requires the preparation of Environmental Impact Studies to assess natural features and to confirm the limits of development in accordance with applicable land use policies. Conditions of approval are placed on development applications to ensure that natural features are appropriately protected and that negative impacts are minimized and mitigated. This includes the re-naturalization of environmental buffers as well as the installation of galvanized steel fencing along the boundaries between natural areas and urban development.

5.1.2 Recommended Management Practices

Strategy 1.1: Protect and secure natural areas.

Practices:

a) Continue to apply and defend the natural heritage policies in the City's Official Plan to protect the Greenway System. Seek conveyance of Greenway System lands into public ownership for their long-term protection and for the recreational benefit of Markham residents.
b) Continue to participate in natural area protection initiatives of other agencies, such as Rouge National Urban Park management plans.
c) Identify opportunities to create and maintain lateral upland connections among valleylands in accordance with Official Plan policies.

Strategy 1.2: Prevent and attenuate the impacts of urbanization on natural areas.

Practices:

a) Require minimum setbacks for all new developments adjacent to natural areas. Setback distances should be based on the Official Plan and on the topography, land use, and buffers required to protect ecological integrity.
b) Restore and/or maintain the natural condition of buffer zones between natural areas and urban land uses.
c) Continue to install fencing along the boundaries between natural areas and new development.
d) Easement and access routes should be developed to facilitate maintenance access to existing infrastructure in natural areas, and (where necessary) to support any maintenance of natural assets.
e) Increase outreach to landowners adjacent to natural areas about the importance of maintaining buffers and fencing.
f) Remediate issues associated with encroachment, dumping, and other damage to natural areas.

5.2 Ecosystem Management and Restoration

Objective 2: Maintain and restore diverse native vegetation communities that provide wildlife habitat and ecological services.

Vegetation is integral to the City's natural areas. The forests, grasslands, and early successional communities within the Greenway System contain provincially and local rare plants and provide habitat for a diversity of wildlife with different life histories and ecological niches. Increased ecosystem diversity can increase the capacity for ecosystems to recover from disturbances. A diverse vegetation community, including fallen trees and decaying vegetation, provide natural habitat, organic material, increase biodiversity, and contribute to cycling of nutrients.

5.2.1 Current Approach

The City's current and historical approach to vegetation management has been based on a combination of risk and opportunity. Removal and pruning of hazard trees are undertaken where they pose a threat to public safety and is largely based on public complaints or done opportunistically when encountered by parks staff. The City recognizes the importance of underbrush and fallen trees; logs and brush piles are generally left in place except where they interfere with trails and recreational areas or the flow of water in flood-sensitive channels and watercourse reaches.

The general approach to managing meadows, thickets, and other early successional habitats has been to promote their succession, actively or passively, to forest or riparian communities. The City-funded Trees for Tomorrow program supports community-led tree planting and reforestation projects by non-profit partners (e.g., Ontario Streams, Friends of the Rouge Watershed, 10,000 Trees for the Rouge). Through the development approvals process, the City has accepted cash-in-lieu for tree and woodland removals, which is primarily used for reforestation projects led by TRCA under contract to the City. Reforestation sites are determined based on staff knowledge supplemented by TRCA's restoration opportunities mapping. Currently, the highest priority sites for reforestation are primarily along the Rouge River (e.g., Campbell Park, Austin Drive Park, Mildred Temple Park, Milne Dam Conservation Area) and Robinson Creek (e.g., from Major Mackenzie Drive to Roy Rainey Avenue). The City has a target to protect and expand the urban forest and woodland cover to 30% and 10% respectively over the next 20 to 25 years.

The City actively manages grasslands at the German Mills Meadow and Natural Habitat and the Pomona Mills Park Meadow. In particular, the German Mills Meadow and Natural Habitat is a rare example of a grassland habitat in Markham where observations of species-at-risk birds such as Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) have been recorded. These are mowed annually, outside of the nesting period for breeding birds, to suppress woody vegetation. The City supports wildflower plantings at both grassland sites.

The City has occasionally undertaken wetland creation projects, such as the one-hectare Hillmount Valley wetland which was constructed using compensation funds from TRCA. However, no regular funding exists for wetland creation projects. The City has completed the planning for and is advancing the design of the Don Mills Channel flood control facility, a two-hectare naturalized wetland area that expands and restores the floodplain of this Don River tributary, replacing current commercial buildings and their surrounding hard-scaped surfaces.

5.2.2 Recommended Management Practices

Strategy 2.1: Maintain and improve native vegetation composition and structure.

Practices:

a) Leave natural vegetation, including deadwood, leaves, and detritus, in place except where there are clear hazards to public safety or property, or as part of invasive species control or integrated pest management.
b) Use seeds and plants native to the Markham area as much as possible for restoration, enhancement, and horticultural plantings. Refer to TRCA's flora checklist[7] for the native status of species in Markham.
c) Monitor the composition, structure, and health of vegetation communities and respond to indicators of declining vegetation health where appropriate (e.g., disease and death of trees, non-native invasive species).
d) Monitor trees along natural area trails for potential hazards through scheduled maintenance and inspections.
e) Control invasive plant species following the principles of the Invasive Plant Species Management Plan. See also Section 5.5.
f) Control vegetation pests and pathogens following the principles of integrated pest management. See also Section 5.5.
g) Collaborate with adjacent municipalities, other levels of government, and non-government organizations to detect and respond to novel threats to vegetation.
h) Continue to develop an inventory of ecological restoration/naturalization projects in partnership with the TRCA.
i) Implement ecological restoration/naturalization projects on sites identified on TRCA's Restoration Opportunities Mapping.
j) Support and encourage community-led naturalization and ecological enhancement projects.
k) Identify opportunities to create and maintain lateral, upland habitat connections between the City's valleylands.

[7] The current version of TRCA's flora checklist is here: https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2023/05/02125714/2023_Flora_Ranks__Scores.pdf

Strategy 2.2: Maintain and expand urban forest cover.

Practices:

a) Continue to support community-led tree planting and reforestation projects by non- profit partners through the Trees for Tomorrow program.

b) Work with the TRCA to develop typical reforestation plans, species lists, and planting details that are adapted for the climate and geography of Markham and Eco-Region 6E/7E.

c) Develop and support an understory planting program for existing forests and woodlots.

d) Allow cash-in-lieu for tree and woodland removals only where it can be demonstrated that a reforestation project would result in a net benefit to ecological integrity within the Greenway System.

e) Continue to protect trees and woodlands with City and Regional by-laws and ensure that replanting requirements support the health of the urban forest canopy.

Strategy 2.3: Recognize and enhance the ecological value of meadows, thickets, plantations, and early successional communities.

Practices:

a) Monitor and promote the natural succession processes for meadows, thickets, and other early successional ecosystems. Some of these natural areas may require active intervention such as isolated natural areas without sufficient native seed banks or those subject to recreational activity and stresses.

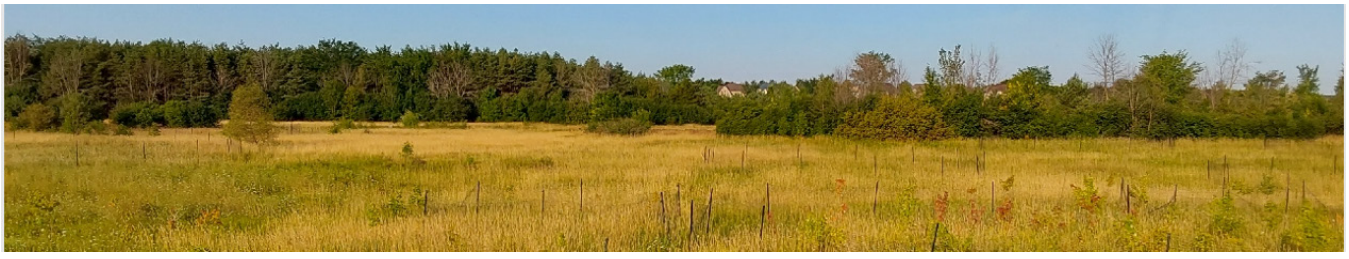
b) Maintain wildlife habitat value of the largest meadows (>10 ha) through mowing, burning, grazing, and/or other methods.

c) Thin plantations to support diversity, regeneration, and growth of native forest ecosystems.

WHAT IS NET BENEFIT TO ECOLOGICAL INTEGRITY?

The guiding legislation for Ontario Parks defines ecological integrity as "a condition in which biotic and abiotic components of ecosystems and the composition and abundance of native species and biological communities are characteristic of their natural regions and rates of change and ecosystem processes are unimpeded".

Net benefit to ecological integrity in the Greenway System can be considered gains in the value of ecological properties attained by ecological restoration minus the value of adverse ecological effects caused by those actions.



Strategy 2.4: Protect, enhance, and expand wetland habitats.

Practices:

- **a)** Continue to avoid utilizing existing wetlands for attenuation of untreated stormwater.
- **b)** Leave an unmown vegetated buffer at least 1.5 m from the edges of all wetlands where an existing riparian buffer does not exist.
- **c)** Implement and support wetland creation projects on sites identified on TRCA's restoration opportunities mapping to strive for a City-wide wetland cover target of 4 to 6%.

WETLAND CREATION

Wetland creation refers to non-infrastructure-related wetlands exclusively. Wetland plunge pools and polishing wetlands are not considered wetland habitats, as they fall under the category of infrastructure.

5.3 Wildlife

Objective 3: Preserve and restore wildlife habitats and respect the freedom of animals to feed, shelter, reproduce, and migrate within the urban landscape.

Markham's natural areas provide important habitat for wildlife. Forests, meadows, and successional communities are breeding habitat for a diversity of migratory birds, including federally and provincially listed species at risk. Wetlands are breeding habitats for amphibians and some are overwintering habitats for turtles. The City's valleylands are important movement corridors for wildlife, connecting the Oak Ridges Moraine to Lake Ontario. These and other wildlife habitat features and functions of the Greenway System shall be protected, enhanced, and restored.

As the City's urbanized area continues to expand and intensify, interactions between humans and wildlife are expected to increase in frequency. The rights of animals to coexist with humans and engage in critical life processes in the urban environment shall be respected. A preventative, rather than reactive, approach to addressing problematic wildlife should be taken. Opportunities to mitigate wildlife road mortality and improve habitat connectivity using wildlife culverts should be explored.

5.3.1 Current Approach

Significant wildlife habitat is generally identified through the development approvals process and is protected under municipal policies. Opportunistic restoration and enhancement of vegetation communities serves to create and maintain wildlife habitat. TRCA has installed some wildlife habitat structures (e.g., bird and bat boxes) in natural areas.

The design of new bridge crossings considers the TRCA's Crossing Guidelines for Valley and Stream Corridors so that terrestrial wildlife passage requirements are incorporated. Wildlife road

mortality is not generally addressed in road construction and maintenance work, although concerns about turtle mortality have been raised at one location in the City.

Native wildlife can occasionally be problematic in the urban context. Deer have been known to over-browse existing natural areas and can damage or destroy restoration plantings. Flooding caused by beavers can damage public infrastructure. Geese and coyotes can occasionally be aggressive towards humans, especially where off leash pets are involved. The City has generally taken a preventative approach to these problems, by protecting restoration plantings, creating and maintaining riparian buffers around waterbodies, and implementing education campaigns about urban coyotes. Where problematic wildlife needs to be removed, the City generally relies on external contractors, such as Ontario Streams (for beaver dam removal).

The City provides fenced off-leash dog parks and requires dogs to be leashed in natural areas. This can help avoid conflicts between dogs and wildlife (e.g., coyotes) and minimize impacts to ground-nesting birds and other small mammals/wildlife. The City has a geese management program at two major water bodies (Swan Lake and Toogood Pond) to haze/chase away geese to prevent and help limit water quality impairment. Goose hazing is also practiced in some public parks and City facilities.

5.3.2 Recommended Management Practices

Strategy 3.1: Identify and monitor wildlife habitat attributes of natural areas.

Practices:

- **a)** Identify significant wildlife habitat in City-owned natural areas using the appropriate Significant Wildlife Habitat Criteria Schedule (Ministry of Natural Resources and Forestry 2015).
- **b)** Monitor structural changes, disturbance, and threats that could alter the wildlife habitat attributes of natural areas.
- **c)** Encourage and support community-led biological surveys and monitoring (e.g., Ontario Breeding Bird Atlas, Marsh Monitoring Program) on City-owned natural areas.

Strategy 3.2: Avoid or minimize harm to wildlife and protect and enhance wildlife habitats.

Practices:

- **a)** Avoid mowing or clearing vegetation during the general nesting period for migratory birds (April 1st to August 31st), except where required as part of emergency maintenance or hazard mitigation.
- **b)** Retain the lower 3 m trunks of hazardous trees removed to protect public safety; leave cut wood in natural areas to function as wildlife habitat. Cut wood should be spread in a safe manner with no standing parts above 1 m tall. Where safe and appropriate, encourage

through proper arboricultural techniques, the development of habitat hollows, cavities and forked top roosts/nesting perches on standing dead snags and/or damaged live tree parts.

c) Add turtle basking structures where these features are limited in aquatic habitat that is suitable for turtles.

d) Add bird/bat boxes in suitable habitat for bats and/or cavity-nesting birds.

Strategy 3.3: Recognize the rights of native wildlife to use natural areas for feeding, sheltering, reproduction, and migration, and to coexist with humans.

Practices*:*

a) Control of nuisance animals shall generally be avoided unless there are clear threats to public safety or infrastructure such as trails or municipal services. For certain animals, the potential impacts and threats to the surrounding ecosystems and natural areas may also need to be evaluated (as may be the case with beavers, geese, and deer).

b) Use natural barriers (e.g., tall grass, shrubs, trees) around ponds and wetlands to discourage use by Canada Geese.

c) Humane trapping and relocation of nuisance animals is preferable to euthanasia.

d) Use of insecticides for control of mosquitoes and other insects should be avoided.

Strategy 3.4: Provide opportunities for safe wildlife movement across the urban landscape.

Practices:

a) Assess the need to install wildlife exclusion fencing when planning new roads, road expansions, and resurfacing projects.

b) Terrestrial and aquatic wildlife movement shall be considered in the size specifications for new/replacement bridges and culverts including the consideration for wildlife culverts.

5.4 Watercourses and Aquatic Habitat

Objective 4: Protect and restore aquatic habitats, water quality, and natural flow regimes of watercourses.

Watercourses are, in many ways, the core features of Markham's Greenway System. The Rouge River, Don River, and their tributaries provide habitat for fish and other aquatic life, including rare species and species at risk, and contribute to downstream water quality in those systems and in the Great Lakes watershed as a whole. The natural forms and habitat features of all watercourses, including headwater drainage features, shall be protected, and opportunities to restore the natural geometry of channelized watercourses should be explored. Whereas watercourses and fish habitat are regulated at the federal and provincial levels, the City shall work with DFO, MNRF, MECP, and TRCA to ensure the protection of these features.

5.4.1 Current Approach

Aquatic habitat is protected under federal and provincial legislation and development and site alteration around watercourses are regulated by TRCA. DFO and MNRF are responsible for protection and regulation of fish and fish habitat. MECP is responsible for protection and regulation of water quality and quantity, as well as species at risk and their habitat. TRCA is responsible for protecting property from natural hazards associated with watercourses and protection of watercourses from erosion and destruction. The City and the TRCA also assess headwater drainage features for ecological and hydrologic functions. Headwater drainage features are protected or managed according to technical guidelines prepared by the TRCA. There is no annual funding for watercourse restoration and enhancement projects, and these are generally completed opportunistically as part of other infrastructure projects (e.g., erosion mitigation works led by Environmental Services and Engineering departments; Robinson Creek habitat enhancement as part of regional sewer construction). Ontario Streams has led several small habitat enhancement and restoration projects for Redside Dace (*Clinostomus elongatus*).

The City is currently implementing a stormwater management facilities retrofit project to improve stormwater management, and a salt management plan to reduce the environmental effects of excessive salt use on roads and parking lots. A water quality improvement program that aims to improve the overall health of Swan Lake is also currently being implemented by the City.

The City has developed a City-wide plan to identify erosion restoration opportunities along City-owned and privately-owned watercourses. Initiated in 2007 and updated on a regular basis, the City-Wide Erosion Master Plan prioritizes restoration opportunities needed to protect public safety, infrastructure, and the environment. Past projects have included migration barrier removal and restoration of natural vegetation, applying natural channel design principles. This long-term program is funded through the City's lifecycle program with contributions from municipal taxes and development charges. Works at individual sites or entire restoration reaches are implemented by the Development Services Commission (Engineering Department) while emergency repairs are identified and managed through the Community Services Commission (Environmental Services Department).

5.4.2 Recommended Management Practices

Strategy 4.1: Maintain and improve surface water quantity and quality.

Practices*:*

- **a)** Leave an unmown buffer of riparian vegetation at least 1.5 m from the bank of all watercourses where an existing riparian buffer does not exist.
- **b)** Avoid using fertilizers and pesticides to maintain landscaping in City parks.
- **c)** Collaborate with other municipal departments and government agencies (e.g., York Region) to minimize pollution from road salting.
- **d)** Collaborate with other municipal departments and government agencies (e.g., York Region) to minimize pollution from maintenance, construction, landscaping, stormwater management, etc.
- **e)** Continue to improve the management of stormwater in the City through implementation of stormwater retrofits.
- **f)** Continue to implement the City-Wide Erosion Master Study according to Council policy (2016).

Strategy 4.2: Restore natural geometry and geomorphology of urban watercourses.

Practices*:*

- **a)** Avoid watercourse channel hardening unless erosion poses a clear threat to infrastructure, public safety, or water quality.
- **b)** Collaborate with departments within Markham and York Region to strategically plan infrastructure development outside of erosion hazards and avoid watercourse crossings.
- **c)** Prepare a long-term strategy for the removal of dams, weirs, and other artificial watercourse impoundments in consultation with TRCA.
- **d)** Continue to explore opportunities for natural channel restoration of urban watercourses; support non-profit and community-led fish habitat creation and riparian restoration projects.

5.5 Invasive Species

Objective 5: Prevent the introduction and spread of invasive species and mitigate the impacts of established invasive species in the Greenway System.

Invasive species are a global threat to biodiversity and ecological integrity and Markham's natural areas are no exception. Invasive plants, pests, pathogens, and other organisms are widespread in the City's natural areas, and new hazardous invasive species are likely to be found in the future as the City continues to grow. It is recognized that eradication of invasive species across the Greenway System is not feasible; however, a focused approach can help mitigate the impacts of invasive species on the most sensitive habitats and prevent the spread of novel invasive species in

the City. Invasive species management shall primarily be directed by the Invasive Plant Species Management Plan.

5.5.1 Current Approach

Invasive species management has generally been reactive and opportunistic, depending largely on staff resources and public health risk. The City works in partnership with the TRCA to manage select invasive plant species, including Giant Hogweed (*Heracleum mantegazzianum*), Poison Ivy (*Toxicodendron radicans*), and Wild Parsnip (*Pastinaca sativa*) (North-South Environmental Inc. and Dougan & Associates, 2021). The City is currently undertaking a pilot program to manage Dog-strangling Vine through a biological control agent (*Hypena* moth) which was released at two locations in the City of Markham.

Under the City's Emerald Ash Borer (EAB) Management Plan, dead and hazardous ash trees, including stumps, are removed and EAB-infested ash trees are treated to control the EAB infestation. In natural areas, logs, branches, debris, and woodchips are left to decompose naturally. In conjunction with the York Region, the City has implemented an Integrated Pest Management (IPM) strategy to manage Spongy Moth, a pest of hardwood tree species. IPM efforts for this species include egg mass removal, insecticide injections of high-value oak trees, burlap banding traps kits distributed to Markham residents, and ongoing monitoring.

As part of ongoing stormwater management facility maintenance, the City identifies invasive species removal opportunities around wet ponds undergoing maintenance. As part of the Parks Refresh Plan for Swan Lake Park, invasive shoreline species were recently removed around the lake and adjacent wet ponds to improve terrestrial habitat.

Currently, the City does not actively manage invasive species that are not known to pose a risk to humans. The City supports a number of active community/park groups to control or eradicate invasive plant species in natural areas such as buckthorn at Grandview Woodlot, or Phragmites at Milne Dam Park and Pomona Mills Park.

5.5.2 Recommended Management Practices

Strategy 5.1: Prevent the introduction and spread of invasive species.

Practices*:*

a) Adopt and implement an Early Detection, Rapid Response strategy for invasive species, with the departments/individuals responsible for detection and response clearly identified. Criteria to determine invasive species should be based on the TRCA's Invasive Species Management Strategy or other criteria used by the City of Markham.

b) Implement an equipment cleaning protocol for City equipment and staff and require external contractors working within natural areas to adhere to the protocol. Refer to the Clean Equipment Protocol for Industry (Halloran *et al.* 2013).

c) Consider a public education campaign to increase awareness of the impacts of invasive plants.

Strategy 5.2: Reduce the impacts of established invasive plants and pests.

Practices*:*

a) Implement the Invasive Plant Species Management Plan, when approved.

b) Consider developing monitoring and management plans for other invasive species (e.g., tree pests and pathogens, earthworms, exotic fish and reptiles, etc.).

c) Follow IPM principles for managing and responding to tree pests and pathogens.

5.6 Public Infrastructure Maintenance

Objective 6: The footprint and ecological impacts of public infrastructure construction and maintenance in natural areas shall be minimized.

Many public and private utilities overlap with Markham's natural areas, including roads, sewers, stormwater management facilities, public amenities, pipelines, railroads, and transmission lines. It is important that ongoing maintenance of these utilities be undertaken in a way that minimizes ecological impacts and landscape footprint. Construction of new utilities within natural areas should be avoided.

5.6.1 Current Approach

Construction within natural areas is generally required to follow standard mitigation measures (e.g., erosion and sediment control, respecting wildlife timing windows, preventing/offsetting harm to species at risk and fish habitat, where required). For new road/utility infrastructure (e.g., bridges) in the Greenway System, the City will generally conduct its own or participate in the review of other proponent-led Class Environmental Assessments to ensure that environmental impacts have been studied and appropriately addressed.

5.6.2 Recommended Management Practices

Strategy 6.1: Avoid or minimize the impacts of public infrastructure construction and maintenance on natural heritage features and functions.

Practices*:*

- **a)** Situate new roads, sewers, watermains, and other utilities away from City-owned natural areas as much as possible.
- **b)** Where construction or maintenance of public infrastructure within City-owned natural areas is unavoidable, strictly enforce the implementation of best practices for environmental management (e.g., erosion and sediment control, wildlife exclusion, migratory bird protection, fish habitat protection, etc.).
- **c)** All construction activities within City-owned natural areas should be required to restore the site to pre-construction condition or a better condition using native species, except in cases where the installation of accessways to facilitate construction is being maintained to support future access and maintenance.
- **d)** Collaborate with other agencies (e.g., York Region, Ontario Ministry of Transportation, Parks Canada) to minimize the impacts of their infrastructure on City-owned natural areas.
- **e)** Collaborate with utility and infrastructure companies (e.g., Hydro One, Enbridge, Metrolinx, CN and CP railways) to minimize the use of herbicides for vegetation management and generally reduce ecological disturbance within their rights-of-way.

5.7 Public Use

Objective 7: Public enjoyment and community stewardship of natural areas shall be encouraged through education, collaborative partnerships, and enforcement.

Access to nature is an important contributor to the mental and physical wellbeing of Markham's residents, and the City will continue to provide safe, equitable opportunities for public enjoyment of its natural areas. However, public use of natural areas can incur stress and pressures on natural habitats, such as littering, creation of informal trails, off-leash dogs, and illegal plant harvesting. Trails, parks, and other public amenities will be designed to minimize ecological impacts while allowing for community enjoyment of natural space.

5.7.1 Current Approach

Since 2015, the City has installed educational signage about the benefits of natural areas (e.g., "Natural Spaces, Wildlife Places" and "Butterfly Parking Only"). Along formal trails, shoulders are mowed on a 12-to-14-day cycle cycle in the summer and maintained according to legislated safety requirements. The City has generally had a hands-off approach to informal trails, except where there are clear risks to natural habitats or public safety.

The City provides trash receptacles along public trails and Parks staff pick up litter along trails and in parks. There is a community litter pick-up event during Earth Month that focuses on natural areas. Parks staff respond to public complaints about littering and dumping.

The City has limited ability to enforce penalties for harvesting plants and wildlife, but illegal harvesting of fish and certain terrestrial animals can be enforced by MNRF under the *Fish and Wildlife Conservation Act*. Releases of carp, goldfish, and pet turtles to stormwater management ponds is an issue with no clear management response. Educational signage may be a solution to plant and wildlife harvesting and releases of pets.

Currently, the City builds and accepts trails in the Greenway System after an Environmental Impact Study or Class Environmental Assessment has been completed. The City generally directs trails to the outer edge of the Greenway System and/or the buffers to minimize habitat fragmentation. The City has accepted 3-metre multi-use pathways in areas where sufficient protection is provided to natural heritage features. In areas where there is a narrow buffer, narrower trails or other types of mitigation have been required. Trail surfacing is generally pervious and constructed of limestone screenings, except where there are erosion concerns or where there is an overland flow route.

5.7.2 Recommended Management Practices

Strategy 7.1: Provide opportunities for community enjoyment of natural areas while reducing recreational pressure on natural habitats.

Practices*:*

- **a)** Establish formal recreational trails in buffer zones around natural areas and around the edges of sensitive habitats within natural areas.
- **b)** Develop guidelines for trail placement, surface treatment, and maintenance in natural areas (see, for e.g., the City of London's Guidelines for Management Zones and Trails in Environmentally Significant Areas, 2016).
- **c)** Keep formal trails well maintained and clear of obstacles to prevent trail braiding and creation of informal trails.
- **d)** Block informal trails with natural obstacles and install signage indicating that they are closed for ecological restoration.
- **e)** Install interpretive signage to inform recreational users about important species, habitats, and ecological functions.

Strategy 7.2: Reduce negative outcomes of recreational use of natural areas through enforcement and community outreach.

Practices*:*

- **a)** Provide waste bins that are easily accessible along public trails such as trail heads [*Note: consider promoting no waste bins to encourage bring-in-bring-out policies of provincial parks*].
- **b)** Enforce penalties for littering, dumping, construction of informal trails, tapping of maple trees, etc.
- **c)** Maintain existing signs and install new signage informing users about the impacts of off-leash dogs, wild plant harvesting, littering, releasing pet fish, etc.
- **d)** Continue to support community cleanup events in natural areas.
- **e)** Collaborate with provincial and federal agencies (e.g., DFO, MNRF) to install fishing regulation signage at locations where illegal fishing is problematic.

6 Implementation

Implementing a natural area management plan involves translating the goals, objectives, and strategies outlined in the plan into actionable steps on the ground. The City of Markham has taken several important steps to develop and implement a comprehensive natural area management strategy and plans, including the Natural Heritage Inventory and Assessment Study and this Guidebook. Steps to implement the management plan are outlined below.

- Assign responsibility and priorities and to allocate resources to support the implementation of the management plan (see Section 6.2).
- Engage relevant stakeholders in the implementation process, including local communities, to ensure that management actions and community priorities are aligned. Keep stakeholders informed and engaged through regular communication.
- Carry out the specific management actions outlined in the plan, such as habitat restoration, invasive species control, prescribed burning, monitoring, enforcement of regulations, and public education programs. Follow established protocols and best practices to ensure the effectiveness and safety of these actions.
- Monitor the progress of management actions and assess their effectiveness in achieving the desired outcomes. Collect data on key indicators of ecological health, biodiversity, and ecosystem function according to established monitoring protocols. Use monitoring data to evaluate the success of implemented actions and adapt management strategies as needed.
- Periodically review and evaluate the overall progress of the management plan implementation against the established goals and objectives. Identify areas of success, areas for improvement, and any emerging issues that may require attention. Use this information to refine strategies, reallocate resources, and set new priorities as necessary.

6.1 Stakeholder Engagement

Public participation in natural areas enhancement and restoration is encouraged to reduce costs and labour involved and to educate the public. The public can be involved in activities such as mechanical control for invasive species including hand-pulling, clipping and tarping, restoration activities such as tree planting, monitoring and research. Opportunities exist for involving the public from local and neighbouring municipalities, educational institutions, and community groups. The City has a well-established program that engages thousands of people annually on tree planting activities with partners such as Tree Canada, Ontario Stream, Friends of the Rouge Watershed, and 10,000 Trees for the Rouge. As the City evolves, opportunities to expand stewardship opportunities with these partners to also include invasive species and ecological monitoring can be explored.

Neighbouring municipalities within York Region may be willing to partner with the City to collaborate on invasive species management and baseline invasive species inventories, particularly on interconnected natural areas. Local educational institutions such as York University, Glendon College, Seneca Polytechnic, and University of Toronto Scarborough have environmental studies programs and may be interested in collaborating with the City on natural area and invasive species management projects. There is opportunity for collaboration on research and monitoring programs, as well as implementation of projects.

6.2 Prioritization of Management Practices

It is recognized that undertaking all of the management practices recommended in this document across the entirety of City-owned natural areas is impractical because of inherent resource limitations. A conceptual prioritization framework for management sites and actions in City-owned natural areas is provided below; a more detailed tool or modified tool with different factors, and weights applied to those factors, may be preferable depending on City objectives. Priority sites and management actions that will have the most beneficial outcomes for ecosystem integrity and community enjoyment of natural areas should therefore be identified. Many factors can be considered in the prioritization of management sites and actions. For prioritization of invasive species management activities, refer to the framework in the Invasive Plant Species Management Plan. For other activities, the following factors should be considered:

- Presence of significant natural features identified using standard methods and criteria - areas with high ecological significance should receive higher priority for management and protection.
- Landscape-level connectivity - prioritize areas that can enhance ecological connectivity.
- Climate change resilience - consider the potential of natural areas to mitigate climate impacts, such as carbon sequestration, flood regulation, and heat island reduction.
- Recreational and educational opportunities - prioritize areas that provide opportunities for public enjoyment and environmental education, as they can contribute to community well-being and support conservation efforts.
- Cost (e.g., per area or unit) to implement the management activities.
- Value of natural area - consult the City of Markham Natural Assets Inventory and Evaluation, which is currently under development.
- Ecological benefit - focus on areas where management interventions can have a significant positive impact on restoring or conserving ecosystems.
- Feasibility of managing and conserving natural areas based on available resources, expertise, and infrastructure.
- Probability of positive social or ecological outcomes - prioritize areas where interventions are achievable and sustainable in the long term.
- Opportunities for community involvement or collaboration with partners to leverage resources, expertise, and public support for effective natural area management. Partners, particularly engaged community residents, can be a tremendous asset to monitor management works and to complete follow-up maintenance.

Conceptual Prioritization Framework for Management Sites and Actions in City-owned Natural Areas

Factor	Circle One			Score
Significant natural features	No significant natural features (1)	Significant natural feature (2)	Two or more significant natural features (3)	
Landscape-level connectivity	Connectivity already established (1)	Some connectivity, but can be improved (2)	No connectivity (3)	
Climate change resilience	No increase in resilience (1)	Moderate increase in resilience (2)	Significant increase in resilience (3)	
Recreational and educational opportunities	No opportunities (1)	Possibly provides 1 opportunity (2)	Provides 2 or more opportunities (3)	
Cost	High cost (1)	Moderate cost (2)	Low cost (3)	
Value of natural area	Low value (1)	Moderate value (2)	High value (3)	
Ecological benefit	Low benefit (1)	Moderate benefit (2)	Significant benefit (3)	
Feasibility	No resources available (1)	Some resources available (2)	All resources available (3)	
Probability of positive outcomes	Low probability (1)	Moderate probability (2)	High probability (3)	
Opportunities for collaboration	No opportunities (1)	Possibly provides 1 opportunity (2)	Provides 2 or more opportunities (3)	
TOTAL SCORE >20 = High Priority; 10 to 20 = Medium Priority; <10 = Low Priority				

Instructions: circle the appropriate scoring box for each factor and write the value in the score column; the total score determines the priority for management.

6.3 Integration into City Practices

Integrating natural area management guidelines into municipal practices involves a holistic approach that considers environmental conservation, urban planning, municipal resources, and community engagement. The City's existing natural areas management practices are outlined in the Management Practices section of this document (Section 5). This NAMG provides a consolidated source of information on existing and recommended natural area management practices. Communication among the City's departments responsible for any aspect of natural area management, along with training and feedback, will facilitate integration of the NAMG into City operations.

Integration of natural area management guidelines with urban planning can include zoning regulations, land-use planning, and development guidelines that prioritize the preservation of green spaces and the integration of nature into urban landscapes. Promotion of green infrastructure in development applications, such as green roofs, permeable pavements, and urban forests, can be considered to enhance the ecological value of urban areas and mitigate the impacts of development on natural habitats.

The City has educational programs and outreach initiatives to raise awareness among residents on aspects of natural resource conservation and these can be bolstered with additional messaging on importance of natural area management and the benefits of preserving biodiversity.

6.4 Monitoring and Reporting

Monitoring a natural area management plan involves systematically observing and assessing the ecological health, biodiversity, and effectiveness of conservation and management efforts within a specific area over time. Regular monitoring of the natural areas over the long term can be used to track changes, evaluate the effectiveness of management actions, and adaptively manage the areas in response to dynamic environmental conditions and evolving conservation priorities. A series of monitoring plans will be necessary to effectively monitor and report on the effectiveness, with each focussed on a specific strategy or objective, for example protection and restoration of aquatic habitats or mitigating the impacts of invasive species.

Monitoring programs will be led by City staff or other agencies through partnership agreements. Each Monitoring program will be developed based on the management priorities and resources available. The following aspects should be considered in the development of the monitoring programs and plans:

- Monitoring Objectives – Clearly define the objectives of the monitoring program. These objectives may include assessing changes in biodiversity, habitat quality, species populations, ecosystem functions, and the effectiveness of management interventions.
- Monitoring Indicators – Identify key indicators that reflect the health and status of the natural area and its ecosystems. These indicators may include species richness, abundance, vegetation cover, water quality, soil health, and habitat connectivity.

- Baseline Data – Collect baseline data on selected indicators before implementing management interventions. This provides a reference point for assessing changes over time and evaluating the success of the management plan.
- Monitoring Protocols – Develop standardized protocols for data collection, including sampling methods, survey techniques, measurement procedures, and frequency of monitoring. Protocols should be scientifically rigorous, feasible, and consistent across monitoring sessions.
- Data Management and Analysis – Organize and manage monitoring data using appropriate databases, software, and analytical tools. Analyze the data to identify trends, patterns, and changes in key indicators over time, using statistical methods and spatial analysis techniques as needed.
- Interpretation of Results – Interpret monitoring results in the context of management objectives, baseline data, and ecological principles. Assess whether observed changes are within expected ranges, identify potential causes of changes, and evaluate the implications for management decision-making.
- Reporting – Communicate monitoring findings to stakeholders, decision-makers, and the public through written reports, presentations, workshops, and online platforms. Clearly communicate the significance of the results, any management implications, and recommendations for future actions.

By systematically monitoring natural areas according to these principles, the City can effectively evaluate the success of their management efforts for the long-term conservation of biodiversity and ecosystem services, and adaptively manage these resources for future generations.

6.5 Adaptive Management

Adaptive management is an iterative process of decision-making and learning that can allow the City to adjust management strategies in response to new information, changing conditions, and outcomes. We are living in a period of global environmental change. Climate change, pollution, and other externalities are expected to have significant impacts on Markham's natural areas, many of which are difficult to predict. At the same time, new technologies, scientific knowledge, and best practices for conservation may emerge which could be adopted and incorporated into the City's approach to natural area management. Management decisions should consider how externalities (e.g., climate change) might affect management outcomes, and management practitioners should educate themselves on new technologies and practices (e.g., for invasive species management, pollution attenuation).

To address the inherent stochasticity of ecological integrity in a changing world, adaptive management should be an intrinsic principle of natural area management in Markham. Adaptive management means that elements of this document—the objectives, strategies, and practices—can be modified to respond to emerging threats, unforeseen impacts, and new technologies or scientific knowledge. Monitoring of ecological indicators, threats, and management outcomes will be critical to efficient and effective management of natural areas in the City. Where new impacts or threats are identified, or successes and deficiencies of management activities are observed, management practices should change in response. This could mean reprioritization of specific

management activities, initiation of new partnerships and collaborations, or addition of new objectives, strategies, and/or principles to this document, among other responses. The practices outlined in this Guidebook should not be interpreted as static, but as flexible directions for achieving the fundamental goal of natural area management in Markham.

Through the implementation and monitoring, the City will analyze data to evaluate the outcomes of management actions and assess whether they are achieving the desired results. Observed changes will be compared against predicted outcomes to identify any discrepancies or unexpected trends. The City can use the knowledge gained from monitoring and evaluation to adapt management strategies and make informed decisions about future actions. Existing management plans may need to be modified, new initiatives prioritized, or resources reallocated based on the emerging understanding of the system. The adaptive management cycle will be reiterated by repeating the process of monitoring, evaluation, learning, and adaptation over time. New knowledge, feedback, and emerging priorities will be incorporated into management decision-making to improve the effectiveness and sustainability of the natural area management program.

By embracing adaptive management principles, natural resource managers can enhance the resilience of ecosystems, optimize the allocation of resources, and achieve long-term conservation goals in the face of uncertainty and complexity.

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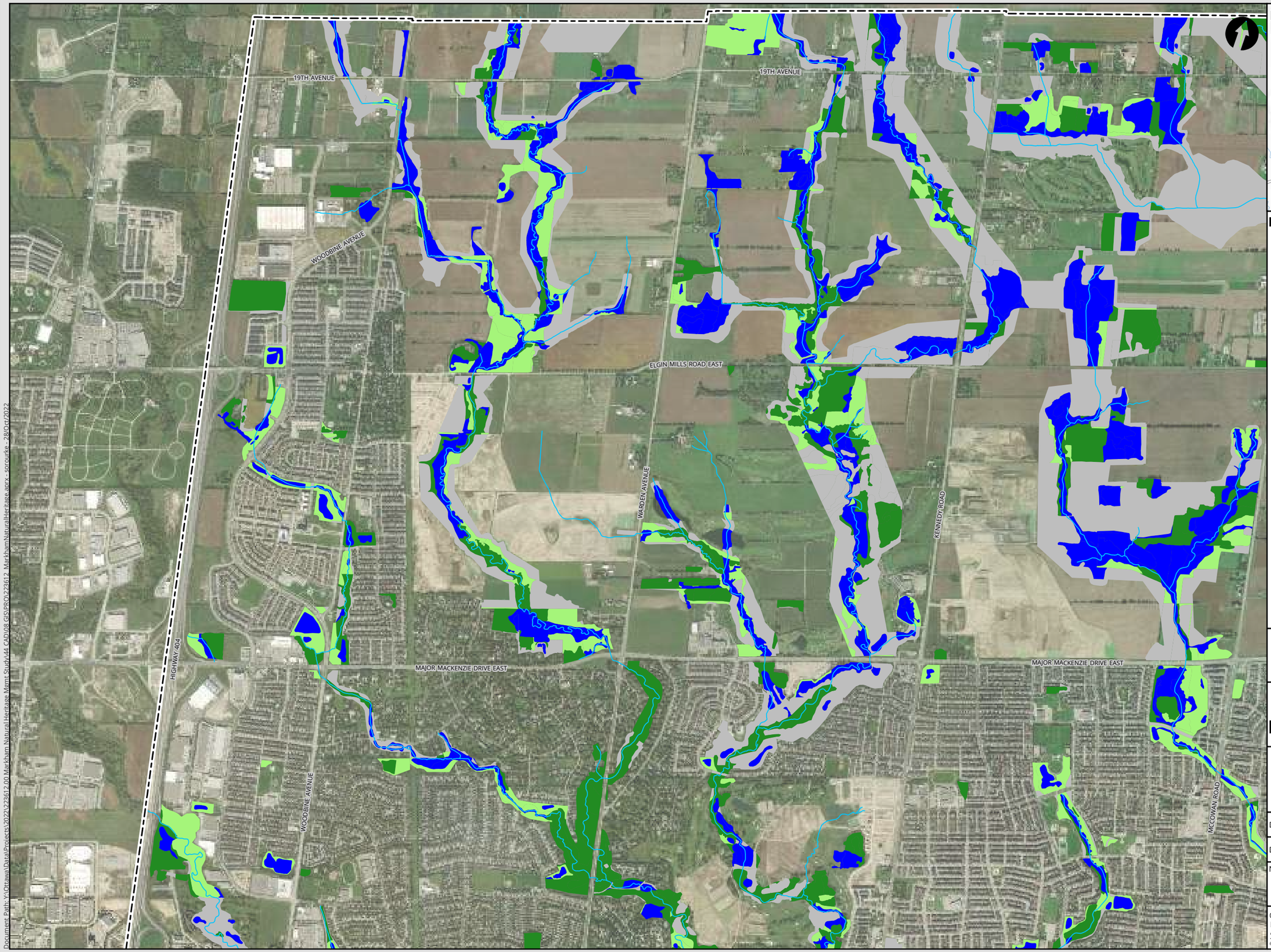
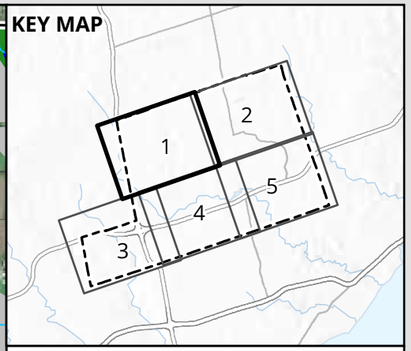
APPENDIX A

City of Markham Greenway System Land Cover Map Series



KEY MAP



LEGEND

- Anthropogenic
- Open Country and Early Successional
- Woodland
- Wetlands and Waterbodies
- Other
- Markham Boundary
- Watercourse

CBCL

CITY OF MARKHAM NATURAL HERITAGE STUDY

LAND COVER

DATE: 28/10/2022	PROJ N°: 223612.00	FIGURE: **1 of 5**
DRAWN BY: SMO	CHECKED BY:	APPROVED:

NOTES:

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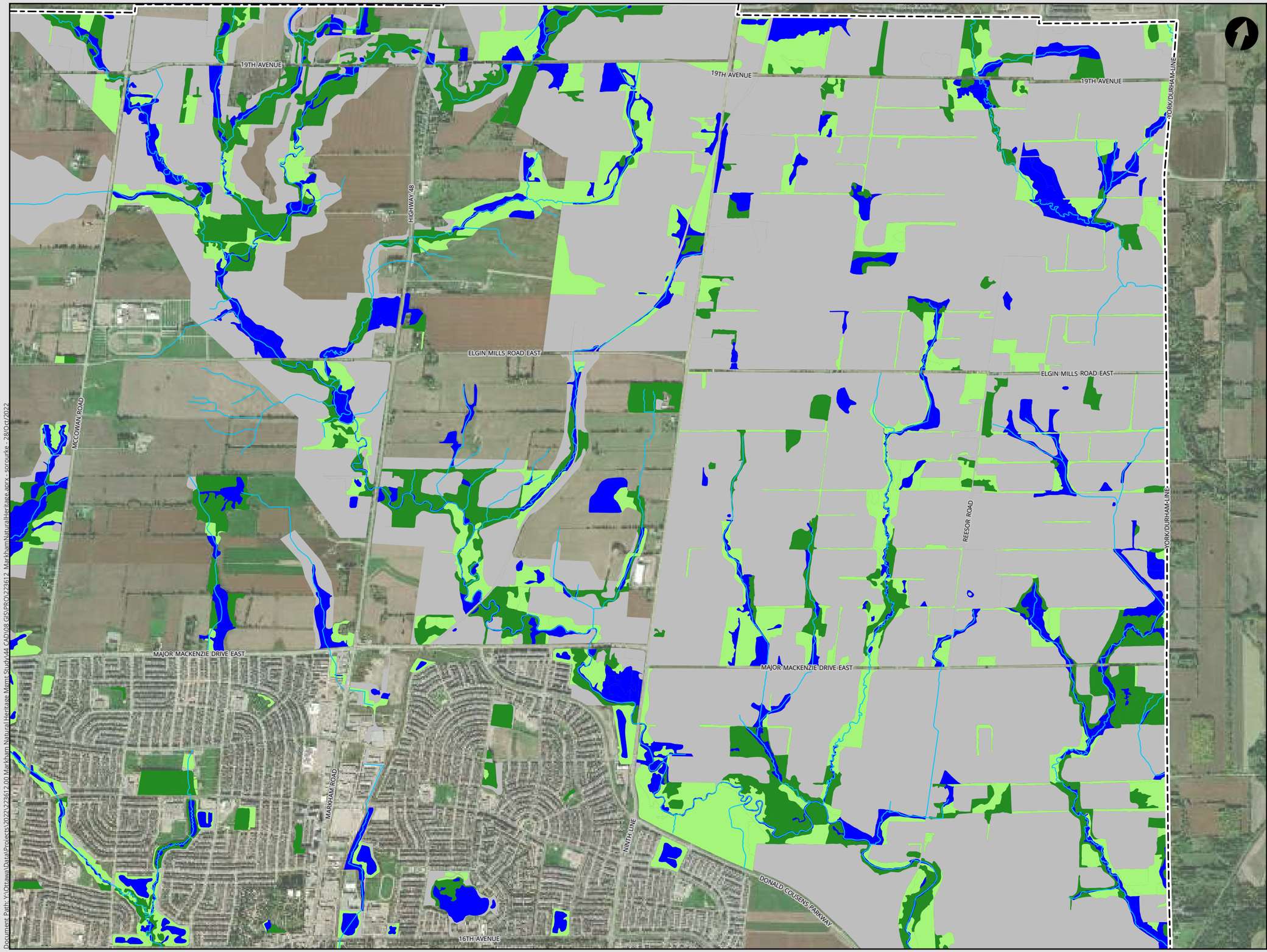
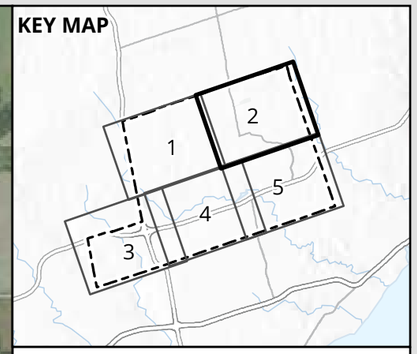
SCALE: 1:25,000 @ 11 X 17

Coordinate System: NAD 1983 UTM Zone 17N
Units: Meter





LEGEND

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CITY OF MARKHAM NATURAL HERITAGE STUDY

LAND COVER

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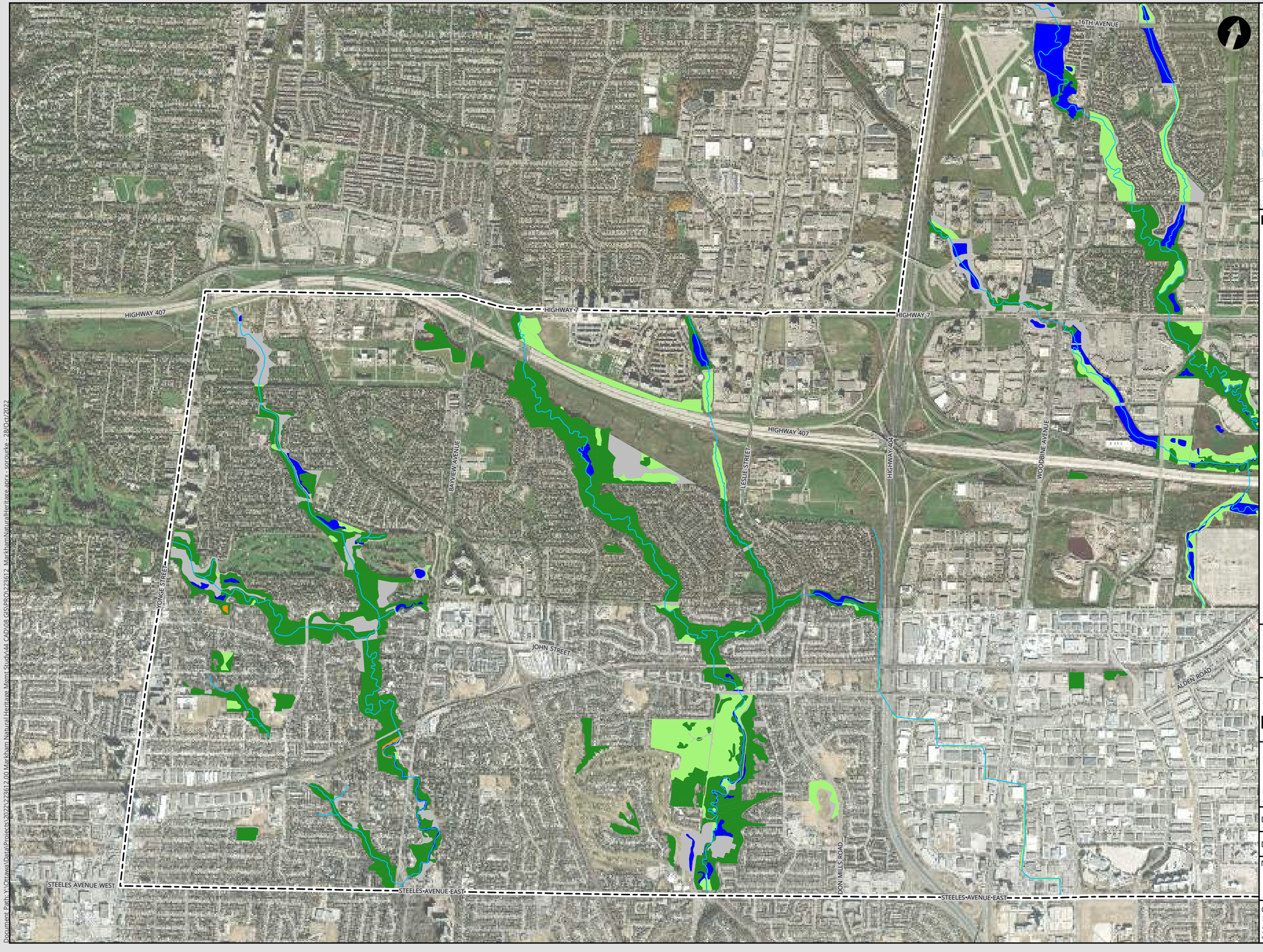
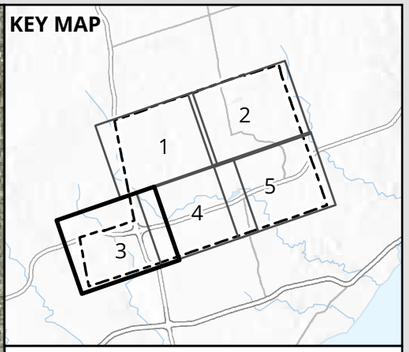


KEY MAP



LEGEND

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CITY OF MARKHAM NATURAL HERITAGE STUDY

LAND COVER

DATE: 28/10/2022	PROJ N°: 223612.00	FIGURE: **3 of 5**
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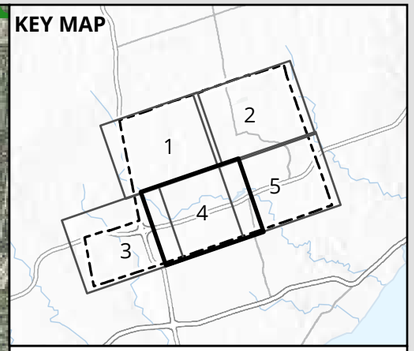
16TH AVENUE
HIGHWAY 7
HIGHWAY 407
14TH AVENUE
STEELES AVENUE EAST
WOODBINE AVENUE
WARDEN AVENUE
KENNEDY ROAD
MCCOWAN ROAD
MAIN MARKHAM STREET SOUTH
MARKHAM ROAD
ALDEN ROAD

KEY MAP



LEGEND

- Anthropogenic
- Open Country and Early Successional
- Woodland
- Wetlands and Waterbodies
- Other
- Markham Boundary
- Watercourse

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CITY OF MARKHAM NATURAL HERITAGE STUDY

LAND COVER

DATE: 28/10/2022	PROJ N^{O}: 223612.00	FIGURE: **4 of 5**
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Units: Meter

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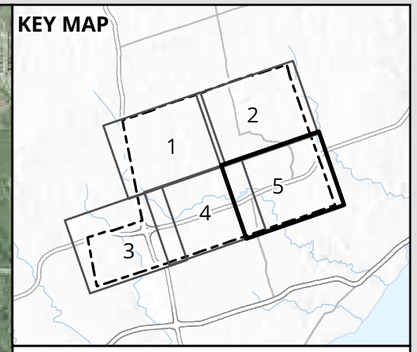
16TH AVENUE
MAIN MARKHAM STREET NORTH
NINTH LINE
CORNELL CENTRE BOULEVARD
DONALD COUSENS PARKWAY
HIGHWAY 7
MAIN MARKHAM STREET SOUTH
REESOR ROAD
YORK/DURHAM LINE
HIGHWAY 407
11TH CONCESSION
14TH AVENUE
MARKHAM ROAD
BOX GROVE BYPASS
STEELES AVENUE EAST

KEY MAP



LEGEND

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- Watercourse

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CITY OF MARKHAM NATURAL HERITAGE STUDY

LAND COVER

DATE: 28/10/2022	PROJ N°: 223612.00	FIGURE: **5 of 5**
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SCALE: 1:25,000 @ 11 X 17

Coordinate System: NAD 1983 UTM Zone 17N
Units: Meter

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