PEEL REGION URBAN FOREST BEST PRACTICE GUIDE 2

Urban Forest Management Best Practices Guide for Peel

October 2021

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Best Practices Guide for Peel

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Working together as part of the Peel Climate Change Partnership

Acknowledgments

This guide is the second in a series of five deliverables developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. This guide, like all the deliverables for this project, has been developed collaboratively with input and guidance from members of the Project Team, Peel Urban Forest Working Group, Peel Climate Change Partnership and other urban forestry and arboriculture professionals. Specific thanks are extended to:

- REGION OF PEEL: Heather Hewitt, Mark Head, Samantha Paquette, Liz Brock, Kevin Farrugia
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This guide has been developed collaboratively by Ecologists, Arborists and Landscape Architects from Beacon Environmental Limited (Margot Ursic, Todd Smith, Stephan Crispin, Ash Baron, Dan Westerhof, Natasha Collins) with input and technical review from Jana Joyce and Mike Hukezalie of the MBTW Group and Steve Colombo of EcoView. While every attempt has been made to include current information in an accurate manner, the authors from Beacon take responsibility for any errors or omissions.

Disclaimer

The guidance provided in this document is primarily intended for street and park trees in the Region of Peel and its local municipalities (i.e., the Town of Caledon, City of Brampton and City of Mississauga) in a climate change context. Aspects of this guidance may be applicable to trees in natural areas and to other urbanizing areas in southern Ontario and beyond. The guidance in this document is intended to serve as a resource for application at the user's discretion; it does not reflect the position or direction of any of the partner agencies listed above.

Cover image credit: City of Mississauga

Executive Summary

Having more trees in urban and urbanizing centres is widely considered one of the simplest and most cost-effective solutions to help communities mitigate and adapt to climate change. However, establishing and maintaining healthy trees in urban settings can be challenging, particularly for trees outside of wooded natural areas in streetscapes, urban parks and open spaces. Two fundamental strategies to address these challenges are to optimize urban forest resilience by: (1) selecting species and stock best able to tolerate difficult growing conditions, and (2) ameliorating the conditions or habitat into which trees are being placed.

Urban tree canopy (UTC) cover across the Region of Peel is 34% and is about 20% across the urban areas (i.e., all of Mississauga, almost all of Brampton and the service centres, villages and hamlets in Caledon). The focus of this report in on best practices for tree establishment and management in Peel's urban areas, where management can be most challenging and where trees can provide the most direct benefits to the most people. The best practices in this report are intended primarily for trees in urban streetscapes, rights-of-way, parks and open spaces. Additional considerations appropriate for wooded natural areas were not included in this work, although some of the identified best practices may also be appropriate for natural settings.

This the second in a series of five guidance documents developed as part of the Peel Region Urban Forest Best Practices project. The purpose of this project was to provide guidance that will help sustain and expand tree cover in Peel's urban areas where it can provide benefits to the greatest number of people while also contributing to climate change mitigation and adaptation. The guides in this series are:

- Guide 1: Best Practices Guide for Urban Forest Planning in Peel
- **Guide 2: Urban Forest Management Best Practices Guide for Peel**
- Guide 3: Guide for Tree and Shrub Standards and Specifications for Regional Roads in Peel
- Guide 4: Potential Street and Park Tree Species for Peel in a Climate Change Context, and
- Guide 5: Working with Trees: Best Practices for a Resilient Future.

The best practices in this guide have been identified based on:

- A targeted review of existing and relevant best practices in the applied technical literature from a range of local, national and international sources (see **Appendix A**)
- An understanding of Peel's biophysical, land use and community context
- Input from the Project Team and a range of arboriculture and urban forestry professionals, including a cross-section of local municipal forestry and planning staff (see **Appendix B**), and
- Knowledge gathered from the consulting team's experience in Peel and in other municipalities.

The best practices identified have been selected based on their relevance and suitability for trees in Peel's built and urbanizing areas but may be applicable in comparable contexts outside Peel.

An entire manual could be (and in some cases has been) written for each topic covered in this guide. As such, this guide is not intended to provide a comprehensive review. Rather, it is a concise overview with high-level guidance and references to selected resources for more in-depth reading.

Mississauga, Brampton and Caledon have already adopted some of the best practices identified in this guide. This guide builds on this direction and provides an overview of the full range of potentially suitable urban forest management best practices to maximize urban forest resilience for individual trees outside of natural areas in a context of urbanization and climate change in Peel Region. While it is not anticipated that it will be feasible or appropriate for the local municipalities and the Region of Peel to adopt all the best practices identified in this guide, it is hoped that this document will serve as a useful reference for the municipalities as deemed appropriate.

A summary of the best practices identified in this guide related to municipal urban forest: administrative processes, site assessment, tree selection and procurement, tree establishment, tree maintenance and management, and inventory and monitoring is provided below with cross-references to the relevant report sections where additional discussion and details can be found.

Table ES. Summary of municipal urban forest management best practices for trees in Peel's urban areas

ADMINISTRATIVE PROCESSES

Topic (Report Section)	Best Practices and Opportunities for Peel
Administrative Organization (Section 2.2)	• Have a stand-alone team within the municipality dedicated to various aspects of urban forest management. • That team must be able to operate in an integrated and collaborative manner with other municipal staff whose work impacts the protection, establishment, maintenance and removal of trees and forests. • Foster broad support for urban forestry initiatives among municipal decision-makers (e.g., senior management, Council).
Urban Forest Maintenance Processes (Section 2.4)	Consider the Society of Municipal Arborists (SMA) best practice guidance (2018), including: • Max. 10,000 street trees per climbing arborist • Min. 20 hours training per staff member per year • Min. one in five staff should be ISA Certified or equivalent • Min. of 30% of budget on tree maintenance and 5% on tree establishment • Max. 30% of budget on tree removal and 30% on administration, and • Max. 30% of labour time on request-based maintenance.

SITE ASSESSMENT

General (Section 3)	A thorough site assessment that considers above and below-ground conditions should be undertaken by a knowledgeable professional before planning or planting any trees or shrubs. (See **Appendix C** for a sample checklist).
Key Site Considerations (Section 3.1)	• Physiography, topography, soil texture, soil structure, soil chemistry, drainage and water availability, light and microclimate are all important physical site conditions that can affect plant growth and establishment and should be considered. **SOILS** • Best practices for healthy soils in Peel's urban areas (including guidance for assessment and management) are found in the *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* prepared for the City of Toronto (DTAH 2013); *Preserving and Restoring Healthy Soil: Best Practices for Urban Construction* (TRCA 2012); and *Healthy Soils Guideline for the Natural Heritage System* (CVC 2017). • Loam, sandy loam, sandy clay loam and silty loam soil textures are generally considered the best for woody plant growth but use of native soils is recommended where they meet basic quality requirements. • Soil testing prior to use is recommended. • Good quality soils should have a "lumpy" structure with different sized peds, pH between 6.0 and 7.5, adequate concentrations of macro and micro-nutrients, and no exceedances of contaminants, particularly those likely to harm plant or human health. **DRAINAGE AND WATER AVAILABILITY** • There must be opportunities for water to get into and move out of the rooting zone through active (e.g., watering) and passive (e.g., drainage) methods. **LIGHT AND MICROCLIMATE** • Light availability and microclimate (heat and wind) conditions should be assessed. Site planning should consider how trees can mitigate localized heat and wind effects, thereby creating a positive feedback loop as the vegetation matures. • Where tall buildings are being introduced, shade impacts on existing and proposed trees or natural areas should be evaluated.
Key Built Environment Considerations (Section 3.2)	Provision of adequate conditions below-ground: • Ensure adequate soil volumes, preferably shared by multiple trees and other companion plantings (see Urban 1992 and DTAH 2013 for specifics) • Ensure adequate (but not too much) water availability and drainage for trees and other vegetation in relation to permeable versus impermeable areas • Support re-use and re-conditioning of locally available soils wherever possible, and ensure soils are not subject to excessive compaction, salt accumulation or other contaminants, including those that affect pH, and • Work with other municipal staff and experts to look for opportunities to use trees in urban design to meet multiple objectives (e.g., combining tree soil cells with above or below-ground rain gardens to help meet stormwater management objectives).

TREE SELECTION AND PROCUREMENT

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Seed Source and Provenance (Section 4.1)	• Preferentially work with southern Ontario nurseries that purchase source-identified seed from certified collectors. • Support and participate in trials with different potentially suitable woody genera, species, cultivars and (if possible) provenances to expand the list of stock considered "proven" in Peel's urban areas in partnership with other agencies and organizations. • Consider woody species from the list of potentially suitable species for Peel developed for this project.

Species Selection (Section 4.2)	**SPECIES-SPECIFIC CONSIDERATIONS**
	• Species selection should be undertaken in conjunction with site assessment data (see Section 3). Select trees from nurseries which have similar soil to the site where they are being planted.
	• Species selection should prioritize eco-physiological factors over practical, service-based and aesthetic or cultural considerations, in the following order:
	    o PRIMARY SELECTION FACTORS
	        ▪ Hardiness and health
	        ▪ Successional niche
	        ▪ Tolerance of site conditions
	        ▪ Growth form and/or size, and
	        ▪ Contribution to diversity.
	    o SECONDARY SELECTION FACTORS
	        ▪ Functional value
	        ▪ Maintenance requirements, and
	        ▪ Aesthetic and/or cultural attributes.
	• Tools and other resources that provide species-specific information should be used by a person with knowledge of ecological, silvicultural and horticultural requirements and in conjunction with an understanding of site conditions.
	
	URBAN FOREST DIVERSITY CONSIDERATIONS
	• Implement species diversification at multiple scales (e.g., street level, site level, neighbourhood, ward level).
	• Enhance genetic diversity within a species where appropriate, by planting a range of suitable provenances of a species.
	• Strive to diversify species and genus level diversity among street and park trees while also incorporating species from genera other than those that are already widespread and those with pests/pathogens that are known to be problematic in eastern North America.
	• Work towards a target of having no more than 5% genus-level diversity by stem count for trees outside natural areas with the understanding that this can be a challenge as long as a limited number of suitable species are known and available, particularly for street trees.
	
	Note: Discussion of assisted migration is provided in Peel Urban Forest Best Practice Guide 4 and further discussion of diversity is provided in Guide 5.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Nursery Stock and Standards (Section 4.3)	• Use smaller stock for restoration or naturalization plantings and larger stock for plantings in rights-of-ways. • Carefully select and inspect stock in the nursery prior to it being delivered to the project site, referring to standardized cue cards describing best practice criteria, and again upon delivery to the project site or municipal yard. This should include a random inspection of root structure and mechanical damage of delivered stock. • To facilitate inspections, it is recommended that procurement tenders specify that the municipality has the right to inspect and reject suspected problem or damaged stock at the provider's expense.

Sources of Nursery Stock (Section 4.4)	**REQUEST AND SUPPORT BETTER SOURCING**
	• Support those providing local seed collector training and seed collection (i.e., the Forest Gene Conservation Association) and collaborating with those in the U.S. doing the same.
	• Request provenance information before purchasing stock, work with growers who provide source-certified stock, and lobby local organizations (e.g., OALA) and government to establish standards for tracking provenance.
	• Lobby the Nursery Trades Association to develop a mechanism to better track demand for different species that accounts for species requests, even if such requests are not filled.
	• Work with nurseries to produce trees with better form.
	
	WORK WITH LOCAL PARTNERS TO TEST AND OBTAIN A GREATER DIVERSITY OF STOCK
	• Engage with local conservation authorities as well as other partners to explore opportunities for both testing and providing potentially suitable woody stock of a wider range of species from an increased number of provenances.
	
	ENGAGE IN CONTRACT GROWING
	• Develop a plan which allows for a mutually beneficial partnership between the Region/its municipal partners and the growers. Key elements in this partnership could include:
	    o Tools for forecasting stock requirements
	    o Compensation up front to cover a portion of seed collection and nursery costs
	    o Mechanisms for improved coordination between seed collectors and municipalities (to offer access to a broader range of native species)
	    o Consideration of mixing seed from different provenances within climatically similar ecodistricts, and
	    o Providing municipalities with preferred access to stock as it becomes available.
	• Facilitate setting up contract growing in Peel by having the Region coordinate contract growing for its local municipalities through its Operational Efficiencies and Access Control Committee - Joint Contract Sub-Committee tasked with combining contracts for greater financial and logistical efficiencies.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Use of Native Species (Section 4.5)	• Avoid all woody species considered potentially invasive • Preferentially select among suitable native species, including trial selection of some native species with provenances from more southerly ecodistricts (per MNRF 2020), to the greatest extent possible • Allow for inclusion of some non-invasive non-native species in difficult sites outside of areas regulated by CVC or TRCA where no or insufficient native alternatives exist, and • Work with local partners to expand the repertoire of suitable native species for planting in Peel's urban areas by undertaking trials for unproven but potentially suitable species in Peel's urban streetscapes and parks.

TREE ESTABLISHMENT

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Site Selection and Preparation (Section 5.2)	Site assessment and soil testing should always be undertaken to inform tree establishment. (More details are provided in Table 8).
Soil Management (Section 5.3)	**MINIMUM SOIL VOLUMES AND DEPTH** • Small trees at maturity (20 – 39 cm dbh) 17 m^3/tree, 11 m^3/2 trees • Large trees at maturity (40 – 59 cm dbh) 28 m^3/tree, 18.5 m^3 /2 trees • Very large trees at maturity (≥ 60 cm dbh) 45 m^3/tree, 30 m^3/2 trees • Min. soil depths of 90 cm and max. 1 m • Tree planting soil volumes should be integrated with utility zones to the extent feasible using "vertical zoning" • Where soil is shared, trees should be spaced 6 to 10 m on center **ACCEPTABLE SOIL COMPOSITION FOR *IN SITU* SOILS** • Generally free of coarse vegetation, debris and large stones and characterized by: 40 – 60% sand, 30 – 40% silt, 10 – 25% clay; min. 4% to 5% organics; and a pH of 6.0 to 7.5. **COMPACTION MANAGEMENT** • Prevention of soil compaction is much more time and cost-effective than remedial measures and can be achieved by: excluding foot and vehicular traffic from root zones of trees, especially when soils are wet, avoiding use of screened soil and adherence to proper soil installation procedures. • If traffic within rooting zone unavoidable, use of plywood over a min. 10 cm layer of wood chip mulch over root zone. • Mulching can also be effective for mitigating post-construction compaction, and more so in conjunction with co-plantings, a raised bed and/or some type of barrier around the rooting area. **AMENDMENTS:** A range of amendments can be considered (see Table 9) where needed based on testing. In some cases, the soil will be too degraded to amend and replacement will be required.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	IMPORTED SOILS • Imported soils, where required, should be 45-50% coarse sand, 40-45% topsoil and 12-15% compost (tilled up to 5 cm in to the upper 10 cm soil). • Favour soils with 15-25% clay content. • Structural soils are not recommended. **INSTALLATION** • Roughen the subgrade, ensure adequate drainage where planting soil is to be installed adjacent to compacted subsoil, and consult with an Engineer to ensure the excavation is at an angle appropriate for the subgrade and expected loading where appropriate. • In larger planting areas topsoil should be placed in layers or "lifts" 30 to 45 cm thick and compacted to approx. 75 - 80% proctor density; in smaller planting areas lifts of 15 to 20 cm are recommended. • Final soil height should consider settling and decomposition of organic matter over time.
Tree Planting Practices (Section 5.4)	**TEMPORAL:** Deciduous and coniferous trees should be planted in early spring or fall. **HANDLING** • Trees should be transported in a covered vehicle and protected from drying winds. In all cases, trees should be well-watered prior to transport. • Trees with soil intact should never be moved by the trunk or branches. **HOLDING** • Time delivery of plant material to minimize on-site holding times. • Bare-root plants should be installed within 24 hours and no plant should be left on site longer than 36 hours. • If large quantities of planting material are to be held for an extended period, municipalities should consider a dedicated holding yard. **PLANTING PIT** • The planting hole width should be 2 – 3x the diameter of the root ball. • Undertake manual scarification and loosening of the planting hole side walls. **INSTALLATION** • Root balls to be placed flat against the base of the planting pit; girdling roots should be pruned. • Backfill with soil dug from the planting pit or imported soil. • Plant so that the final settled grade will be about 7.5 to 0 cm below the root flare and with the root collar at or slightly above the final grade, regardless of where the root collar is in the container or basket when received. • WIRE BASKET AND BALLED AND BURLAPPED STOCK: There are risks and benefits to removing containment materials versus leaving them intact; at minimum the top third of the tying and containment materials should be removed after positioning within the planting hole, but preferably as much of the wrapping material should be removed as possible.

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	• CONTAINER STOCK: Remove from containers prior to planting; roots may need to be pruned; rootbound plants should have their outer roots shaved. • In all cases, the final settled soil grade (i.e., ground level) should be just below (e.g., 7.5 – 10 cm) the root flare. **STABILIZATION AND PROTECTION** • In general, rigid stabilization should be avoided but temporary protection for newly established trees is often required (from both wildlife and/or humans). • Where needed, stabilization materials should be removed as soon as the tree is able to support itself (i.e., usually within a year). • Temporary tree protection measures – both for the stem and roots - should be flexible in that they can readily accommodate or be adjusted to accommodate tree growth. • Although it can be "messy" one of the simplest and best protections for newly established trees is mulch and, if space permits, small shrub and perennial herbaceous co-plantings. • In built-up urban settings, trees protected with mulch and co-plantings can be effective in conjunction with a clearly defined planting area either raised or bounded by some type of barrier such as a concrete curb or very low fence. **SHARED PLANTING BEDS** • Shift, wherever possible, to a more ecologically-based approach that provides a shared planting space for large caliper stock combined with smaller shrubs and/or perennial herbaceous species in the understory. • Consider opportunities for integrating other services, such as stormwater management, into shared planting beds.

TREE MAINTENANCE AND MANAGEMENT

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Watering (Section 6.1)	Young, mid-aged and mature trees should be monitored during periods of drought, especially if species are known to be drought sensitive. To mitigate water stress for woody species trees and shrubs should be planted in: • adequate volumes of good quality soils including 5% organic matter • sites that provide permeability, at least to the tree's dripline, and • sites where the soil covering the rooting area, at least within the dripline, supports the retention of moisture (e.g., mulching and/or co-plantings). Watering requirements vary with the species and site, but in all cases: • New plantings all need to be irrigated after transplanting and regularly during the establishment phase • All trees need to be monitored during periods of drought, and

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	• Water should be applied slowly and directly to the root ball after planting and should extend past the tree's dripline. Based on applied results from Toronto and York Region it is recommended that in Peel: • Watering bags or comparable tools able to hold 40 to 75 L be used • Watering occur once every two weeks May to September with an increase to weekly over July and August (i.e., about 14 times per year), and • This approach and frequency be maintained for the first three years after planting.
Pruning (Section 6.2)	**YOUNG TREE PRUNING:** • Prune only dead or broken branches when the tree is planted and postpone other pruning until the tree is established, two or three years after planting. • In general, no more than 25% of live growth should be removed at one time. • Generally, it is a good practice to reduce multiple leaders to allow dominance of one main upright leader to prevent crown breakage. **MATURE TREE PRUNING:** In general, no more than 10% live growth should be removed from mature trees at one time, unless required to correct severe defects. **GENERAL PRUNING AND RISK MANAGEMENT** • A municipal structural pruning program is recommended. General best practices include between 5 to 7 years as a pruning cycle, with three pruning interventions (or at least inspections) in the first 10 years after planting. • Municipalities should develop prescriptions or specifications for tree pruning based on the ANSI 300 standards and ISA Best Management Practices. • Municipal and utility tree-related standards, including pruning and planting, should be reviewed and coordinated.
Competition and Herbivory Management (Section 6.3)	**MULCHING:** General best practices around use of organic mulch around a tree or shrub which is presumed to have been installed at the right soil level are as follows: • Apply in a 1 m circle around the tree base or to the drip line of the established tree, whichever is greater • Apply as a "top dressing" on the surface – do not incorporate into the soil matrix • Apply mulch 5 to 10 cm (2 to 4 in) thick (i.e., no mulch "volcanoes") but closer to 7.5 cm (3 in.) if the soils are poorly drained • Keep mulch at least 7.5 to 15 cm (3 to 6 in) away from the trunk of young trees and 20 to 30 cm (8 to 12 in) from mature trees • Fine-textured mulches (e.g., double-shredded bark) should be applied more thinly than coarser mulch (e.g., wood chips) but coarse woodchip mulch is preferred to fine textured mulches, as it takes longer to break down and provides greater aeration and moisture permeability, and

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	• Freshen or replace the mulch every two years, making sure the total depth remains at 5 to 10 cm (2 to 4 in). **VEGETATION CONTROL:** Manual controls are best undertaken in early spring and caution should be taken when mowing or trimming not to damage the tree/shrub being protected. **HERBIVORY:** Methods that can be employed to deter urban mammals from feeding on newly established woody plants include: installation of physical barriers such as fencing or tree guards, or application of repellents (see Table 13 for details).
Pest and Disease Management (Section 6.4)	Develop a Regional Integrated Pest Management (IPM) program for the urban forest that: • Is developed and implemented with local agency and municipal partners, as well as neighbouring municipalities • Speaks to the extent of tree pests and diseases already in the Region as well as those reasonably suspected to occur in the near future, and • Uses a risk management approach to prioritize species.
Tree Risk Management (Section 6.5)	Based on the considerations above, best practices for municipal tree risk assessment staff and contractors include: • Being familiar and use the ANSI A300 (Part 9) and the companion Best Management Practices, Tree Risk Assessment, Second Edition (ISA 2017) • Having the Tree Risk Assessment Qualification (TRAQ) • Practicing proactive urban forest management practices that are specific to risk management • Seeking an appropriate balance between the valued ecosystem services and the potential costs/consequences of it failing in whole or in part, and • Having a tree risk management plan or policy.

URBAN FOREST INVENTORY AND MONITORING

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Municipal Tree Inventory and Monitoring (Section 7.1)	• Develop and maintain a comprehensive and current inventory of trees on municipal lands. • Integrate an adaptive management approach to urban forest monitoring and management.
Urban Tree Canopy (UTC) Assessments and Related Tools (Section 7.2)	**UTC ASSESSMENTS** • Undertake jurisdiction-wide UTC analyses every 5 to 10 years. • Supplement the remote UTC assessments with scoped field-collected data, ideally collected in accordance with the i-Tree Eco™ model**.** • Use high-resolution aerial imagery and, where possible, combine with LiDAR and/or hyperspectral imagery to maximize accuracy. • Use UTC analyses to inform current and potential canopy cover.

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	• Collect data in formats and using methods that are well-documented and can be readily compared with previous data, even if the newer methods are more accurate or otherwise improved. **URBAN FOREST SERVICE VALUATIONS:** Leverage UTC data collected to estimate the value of key municipal ecosystem services provided by trees in the urban forest using the i-Tree™ suite of tools.
Criteria & Indicators Assessment (Section 7.3)	• Municipalities should develop a C&I assessment as a framework for high-level monitoring of (a) the urban forest itself, (b) the level to which partners and stakeholders are engaged, and (c) the degree to which urban forest management is aligned with established best practices and/or local objectives/targets. • The C&I assessment should be updated every four to five years and informed by data and information collected through ongoing inventory, management and monitoring, as well as input from a cross-section of urban forest stakeholders.

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1. Introduction

The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased; and not impaired in value.

– Theodore Roosevelt

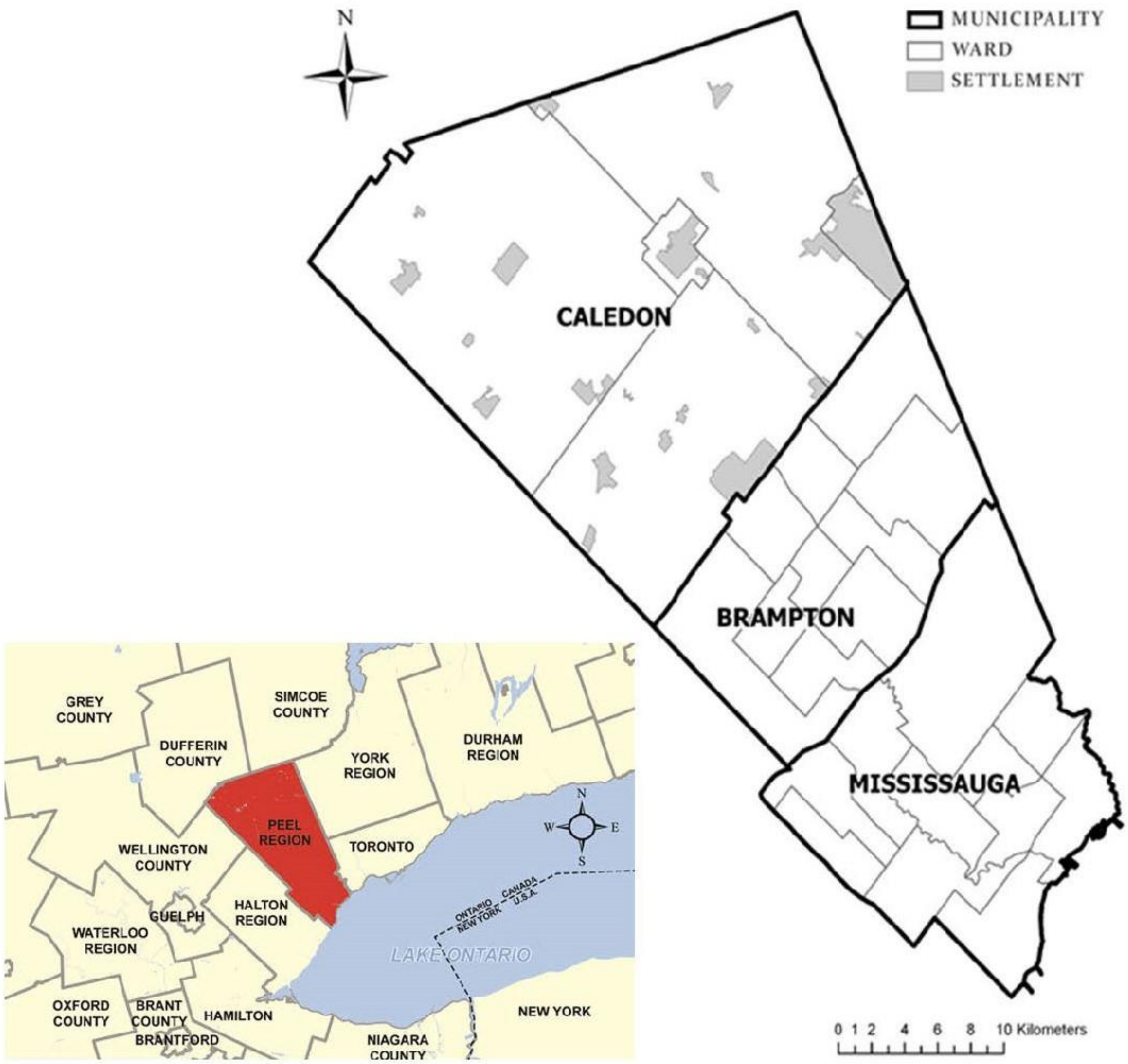
Having more trees in urban and urbanizing centres is widely considered one of the simplest and most cost-effective solutions to helping communities both mitigate and adapt to climate change. However, establishing and maintaining healthy trees in urban settings can be challenging, particularly for trees outside of wooded natural areas in streetscapes and urban open spaces. Trees in these settings are often subject to difficult growing conditions (e.g., constrained above and below-ground growing space, soils that are of poor quality and/or compacted, exposure to elevated levels of airborne and waterborne salt during winter) that are compounded by environmental stressors associated with climate change (e.g., extended periods of heat and drought, more frequent ice and/or wind storms). Two strategies to address these challenges are to optimize urban forest resilience by: (1) selecting species and stock best able to tolerate difficult growing conditions, and (2) ameliorating the conditions or habitat in which trees expected to grow.

This report provides guidance on best practices for selecting, procuring, establishing, maintaining and monitoring trees intended to help them be more resilient to challenges caused by urbanization and climate change, particularly in the context of Peel Region in Ontario, Canada.

Peel Region is just west of the City of Toronto and extends like a rectangle from north of the Niagara Escarpment southwards to Lake Ontario (see **Figure 1-1**). It is comprised of three local municipalities, from north to south: the Town of Caledon, City of Brampton and City of Mississauga, with the latter two being almost entirely urbanized.

Recent assessments found that although urban tree canopy (UTC) cover across the Region is 34%, the average UTC in the urban areas (i.e., all of Mississauga, almost all of Brampton and the areas shown in grey in Caledon in **Figure 1-1**) is only about 20% (B. A. Blackwell & Associates 2017). The best practices identified in this report focus on strategies and tools for management of trees in Peel's urban areas, where management can be most challenging but where trees can provide the most direct benefits to the most people. The best practices described in this report are intended primarily for individual trees in urban streetscapes, rights-of-way, parks and open spaces, and outside of wooded natural areas, but may also be applicable elsewhere.

Peel Region and its partners (i.e., the City of Mississauga, City of Brampton, Town of Caledon, Toronto and Region Conservation Authority [TRCA] and Credit Valley Conservation [CVC]) have been collaborating on urban forest and climate change initiatives for well over a decade and are currently working together to implement the *Peel Climate Change Partnership Plan* (2018 – 2022). This plan aims to leverage the cooling and climate moderation provided by trees in urban areas to mitigate urban heat island effects, while also providing additional co-benefits (e.g., intercepting storm water; filtering air, soil and water; providing wildlife habitat; and contributing to human mental and physical health and well-being).



Credit: *An Assessment of Urban Tree Canopy Cover in Peel 2015* (B.A. Blackwell & Associates 2017)

Figure 1-1. Maps of the location of Peel Region and its local municipalities

Specifically, Strategy 3 and Action 3d of the *Peel Climate Change Partnership Plan* (2018 – 2022) are meant to: "*Increase the number of healthy trees in priority areas to reduce public health risk and enhance social and environmental outcomes*" and "*Develop a Policies, Guidelines and Standards Best Practices Manual for Urban Trees, which includes enhanced standards for tree planting* …", respectively. This report addresses Action 3d and supports Strategy 3, while also supporting actions contained in Peel's *Climate Change Master Plan 2020-2030* to protect and increase green infrastructure throughout Peel including implementing a "*tree planting and management program for new and existing trees*" (Task 14.3).

In addition to supporting ongoing climate change initiatives, this report provides pragmatic and progressive guidance to municipalities seeking to maximize the benefits and services provided by their urban forest assets, with a focus on trees being established and maintained outside of naturalizing and wooded natural areas.

Municipal natural assets are defined as *"the stock of natural resources that are relied upon and managed, or could be managed, by a municipality for the sustainable provision of one or more local government services"* (Government of British Columbia 2018). This compendium of urban forest best management practices is tailored to trees in Peel's built and urbanizing areas to help: (a) guide consistency among local municipalities, and (b) ensure that investments made in the selection and establishment of trees along municipal streets, boulevards and open spaces result in sustained and increasing benefits and services as the trees mature.

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- A targeted review of existing and relevant best practices in the applied technical literature from a range of local, national and international sources (see **Appendix A**)
- An understanding of Peel's biophysical, land use and community context
- Input from the Project Team and selected arboriculture and urban forestry professionals, including a cross-section of municipal forestry and planning staff (see **Appendix B**), and
- Knowledge gathered from the consulting team's experience in Peel and in other municipalities.

The urban forest management topics covered in this guide include:

- Municipal forestry program administration (**Section 2**)
- Site-level considerations (**Section 3**)
- Tree selection and procurement (**Section 4**)
- Tree establishment (**Section 5**)
- Tree maintenance and management (**Section 6**), and
- Tree and urban forest inventory and monitoring (**Section 7**).

The best practices identified have been selected based on their relevance and suitability for trees in Peel's built and urbanizing areas but may be applicable in comparable contexts outside Peel. The research and best practices/opportunities identified in this guide are primarily intended for street and park trees in urban areas where climate change stressors tend to be most intense and not for trees in natural which require some different considerations. However, some of the guidance is also applicable for the broader urban forest, including trees in natural areas. All five guides were also developed for trees in Peel's urban areas, but include some guidance that could be applicable to other urban areas.

An entire manual could be (and in some cases has been) written for each topic covered in this guide. As such, this guide is not intended to provide a comprehensive review. Rather, it is a concise overview with high-level guidance and references to selected resources for more in-depth reading.

Mississauga, Brampton and Caledon have already adopted some of the best practices identified in this guide. This guide builds on this direction and provides an overview of the full range of potentially suitable urban forest management best practices to maximize urban forest resilience for individual trees outside of natural areas in a context of urbanization and climate change in Peel Region. While it is not anticipated that it will be feasible or appropriate for the local municipalities and the Region of Peel to adopt all of the best practices identified in this guide, it is hoped that this document will serve as a useful reference for the municipalities as deemed appropriate.

After collecting and assessing data between 1996 and 2003 the Region of York identified four factors as having the most influence on the survival and performance of street trees:

1. ***available water***
2. ***boulevard soil quality and quantity***
3. ***stock quality and planting practices, and***
4. ***environmental conditions (including salt from winter maintenance and exposure to wind).***

– James Lane, Manager of Forestry, Region of York, 2013

2. Municipal Forestry Program Administration

Municipal forestry program administration is a topic often overlooked in urban forest best practice manuals but is arguably one of the most important aspects because it determines how resources directed towards urban forest initiatives are allocated. In general, municipal forestry program administration encompasses the following topics discussed in this section:

- The identification and valuation of the asset (**Section 2.1**)
- The administrative structure and organization of those involved in managing the asset (**Section 2.2**)
- High-level approaches for managing the municipality's urban forest (**Section 2.3**), and
- High-level approaches for maintaining municipal urban forest assets (**Section 2.4**).

There is very little research or technical guidance available on the topic of best practices as they relate to municipal forestry program administration. This is, at least in part, because municipal urban forest assets are administered so differently among municipalities. Differences in the scale and scope of municipal urban forest administration varies depending on various factors including: the scope and scale of treed assets, the physical size and population of the municipality, the land use context of the municipality, the overall corporate structure of the municipality and the role(s) of forestry staff in that structure, and the operational and capital resources allocated to urban forest management.

In Ontario, most municipalities undertake some level of urban forest management. This can range from basic removal and replacement of street trees to more comprehensive establishment, maintenance and risk management programs for all municipal trees along streets, in parks and in municipal natural areas. This variability among municipalities is illustrated well within Peel itself, which contains two highly urbanized jurisdictions (i.e., Brampton and Mississauga) that invest substantially in urban forest management, in contrast to the predominantly rural Town of Caledon and the Region itself, which manage many fewer trees and have limited investment in urban forest management. Although the Region and its local municipalities work together and with the local agencies to support maintenance and enhancement of their respective and shared urban forest assets, there is a large variation in administrative structures and resources allocated to managing those treed assets.

As a result of this wide variability, it is challenging to identify best practices that are applicable to all four municipal jurisdictions in Peel. Nonetheless, this section aims to identify some key best practices for trees in Peel's urban areas, recognizing that they may not be equally applicable across all jurisdictions.

This section has drawn on the limited available information from the technical literature, the partners' and project team's experience, and information collected by Urban Forest Innovations and Beacon Environmental based on concurrent work on Brampton's *Urban Forest Management Plan*, and from comparable projects for other municipalities in southern Ontario.

2.1 Identification and Valuation of the Asset

> *… there is growing evidence that by considering natural assets within asset management processes, local governments can decrease capital, operations, and maintenance costs; increase levels of service; enhance their ability to adapt to climate change; and reduce the community's unfunded liabilities – all while protecting or enhancing the multitude of other benefits that natural asset bring to communities.*
>
> *Integrating Natural Assets into Management,* Government of British Columbia 2018

Asset management is an established framework traditionally used by municipalities to try and account for the life cycle costs associated with municipally owned and managed built and engineered assets, to inform capital and operational cost planning. The typical municipal asset life cycle components include:

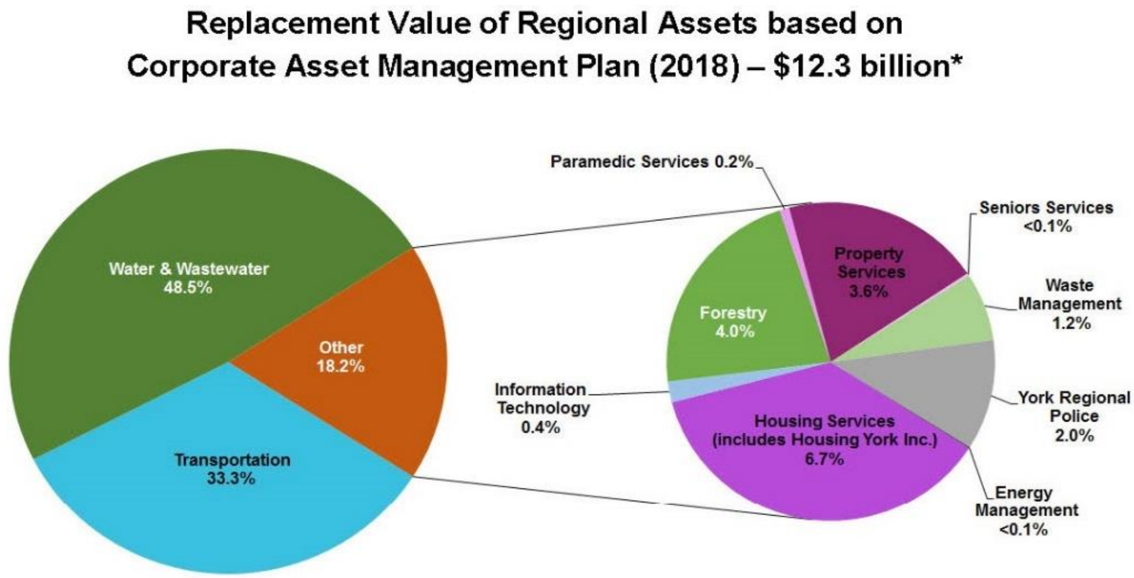
- Acquisition or creation
- Operation and maintenance
- Repair or rehabilitation, and
- Disposal.

Asset management has also been used for intangible assets such as human capital or financial assets, but only recently has this tool been considered for municipal natural assets.

The introduction of Ontario Regulation 588/17 for *Asset Management Planning for Municipal Infrastructure*[1] (which came into effect January 1, 2018) made Ontario the first province in Canada to regulate municipal asset management planning, and to require consideration of both built and natural assets (also referred to as "grey" and "green" infrastructure respectively) as part of this planning. The intent of this regulation is to help "*municipalities better understand what important services need to be supported over the long term, while identifying infrastructure challenges and opportunities, and finding innovative solutions*" (Government of Ontario 2020a).

An asset management framework allows municipalities to optimize returns on investment considering the value and services provided by items acquired in relation to the investment required to replace them over their life cycle. Incorporating municipally owned and managed components of the urban forest into municipal asset management planning helps ensure that these living assets are both valued and appropriately accounted for in municipal budgeting and long-term planning. It also helps ensure that green infrastructure is considered in tandem with its grey infrastructure counterparts for the services it provides and the ongoing management it requires. A municipal natural assets database can also be used to demonstrate the value of services provided by municipal trees and forests, and to forecast the investment required for long-term management of these assets, as illustrated in **Figure 2-1**.

[1] Under the *Infrastructure for Jobs and Prosperity Act* (2015)



Credit: *York Region Asset Management Report* (2018)

Figure 2-1. Estimated replacement value of all York Region's assets, including forestry assets

There are already well-established tools available to help estimate the value of at least some of the key services provided by trees and the urban forest (e.g., pollution mitigation, storm water run-off reduction, carbon sequestration and storage) based on data collected through urban forest inventory and monitoring (discussed further in **Section 7.2**). For example, the recent urban tree canopy cover assessment update for Peel used i-Tree™ tools to estimate that trees in Peel store more than 12 million metric tonnes of CO_2, a service valued at nearly $630 million CAD (B.A. Blackwell & Associates 2017).

CVC has played a lead role in the development of tools to value natural assets[2] and to facilitate the integration of natural features into municipal asset management in Peel and the broader CVC watershed. Recently completed initiatives that consider, among other natural assets, municipal trees and wooded natural area in this context include a *Business Case for Natural Assets in the Region of Peel* (CVC 2020) and *Life Cycle Costing of Restoration and Environmental Management Actions* (Beacon 2020).

In Peel Region, the Cities of Brampton and Mississauga have already begun to integrate municipal urban forestry assets into their asset management programs (M. Hoy, pers. comm, 2020). Best practices related to this topic are discussed in the *Best Practices Guide to Urban Forest Planning in Peel* (2020), which recommends that the Region and its local municipalities should be collaborating to establish consistent methodologies for incorporating municipal natural assets into their respective asset management programs, with support from the Federation of Canadian Municipalities.

[2] https://cvc.ca/watershed-science/our-watershed/ecological-goods-services/

2.2 Approaches for Administrative Organization

Municipalities in Ontario range from having a few staff in various departments dealing with tree-related issues to having stand-alone sections or departments with numerous staff entirely dedicated to the selection, establishment, maintenance and management of trees.

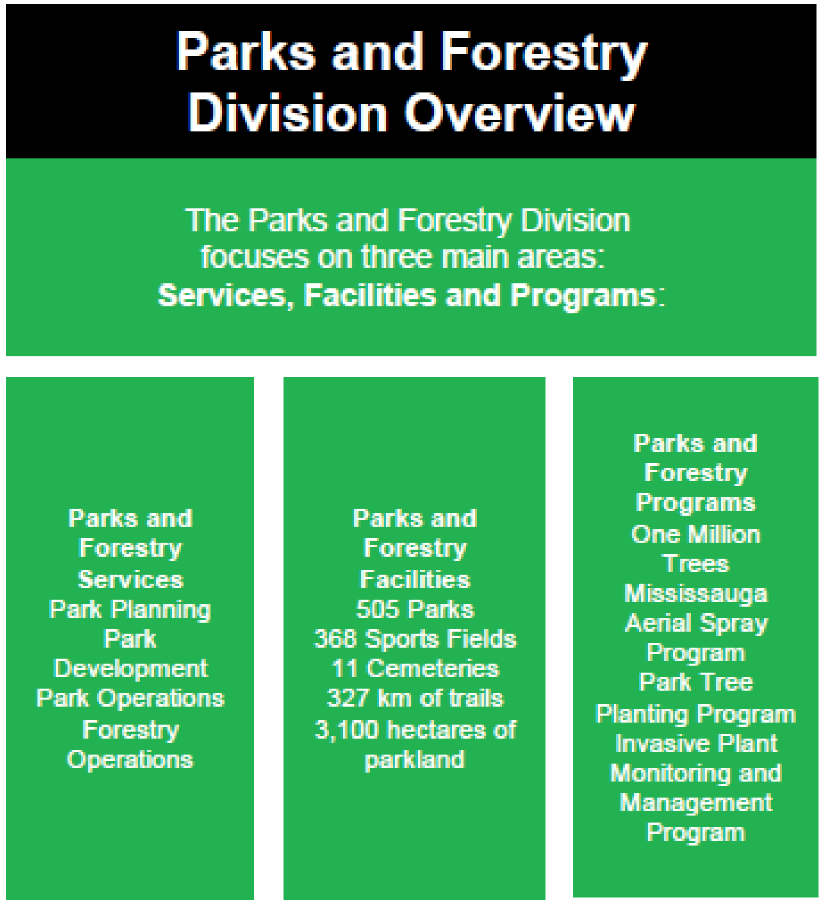
In Peel, wide variations in administrative structures exist across municipalities, as shown in **Table 1**. The Region currently has one dedicated urban forester who focusses on maintenance of the Region's street trees, with part-time support by various staff in the planning and transportation departments. At the other end of the spectrum, the City of Mississauga currently has more than 40 arborists, ecologists and other professionals within the Forestry Section of their Community Services department dedicated to a wide range of tasks, as illustrated in **Figure 2-2**.

Table 1. Overview of current municipal urban forest administration in Peel

Municipality (size, population)	**Administrative Organization****	**UTC***	**Municipal Treed Assets****
City of Mississauga 29,240 ha 668,600 residents	• Forestry responsibilities shared among: Forestry Section, Parks and Forestry Division, Community Services Department • Forestry input to plan review and oversight is provided by Planning and Building Department	19%	+270,000 street trees ~2,750 ha of natural heritage system including 232 ha of residential woodlands and 132 wooded natural areas**
City of Brampton 26,670 ha 603,500 residents	• Parks Maintenance and Forestry (within Public Works and Engineering) responsible for municipal forestry operations • Forestry input to plan review and oversight is provided by Planning & Development staff	18%	+250,000 street trees ~4,600 ha of natural heritage system including wooded ravines and some upland wooded natural areas**
Town of Caledon 37,860 ha 72,900 residents	• Park Operations has a seasonal forestry crew dedicated to urban tree management • Rural roadside trees are managed by the Roads department • Open Space Design and Planning responsible for forestry input to plan review and approvals	35% Town's urban areas only	~10,000 street trees ~5,000 park trees ~ 185 km of Town-owned trails** No proactive management program of wooded natural areas
Region of Peel 93,770 ha 1,345,985 residents	• No Forestry section • Forestry staff within Roads Department oversee management of trees in regional rights-of-way	34% (entire Region) 20% (urban areas only)	+15,000 street trees No regional forests, parks or natural areas

* UTC = Urban Tree Canopy (UTC) Cover, from *An Assessment of Urban Tree Canopy in Peel Region 2015* (B.A. Blackwell & Associates 2017)

** Data provided by municipal staff or accessed from municipal websites 2020



Credit: City *of Mississauga Parks and Forestry Master Plan* (2019)

Figure 2-2. City of Mississauga Parks and Forestry Division overview

There is not a best practice *per se* with respect to administrative structure, as each municipality is working in a unique context and strives to do the best they can with the resources and support at their disposal. However, the project team's experience suggests it is generally easier to move urban forestry objectives forward when:

- There is a stand-alone team or departmental section within the municipality dedicated to urban forest management
- That team can operate in an integrated and collaborative manner with other municipal staff whose work impacts the protection, establishment, maintenance and removal of trees and forests, and
- There is broad support for urban forestry initiatives among municipal decision-makers (e.g., senior management, Council).

Region of Peel staff have specifically identified the need for a regional-level municipal forestry team to ensure their practices (e.g., in terms of sourcing and selecting tree stock, inspecting stock, handling and establishing trees, etc.) are consistent and reasonably well-aligned with urban forestry practices at the local municipal levels, and to collaboratively strive towards consistent implementation of urban forestry best practices across the Region.

2.3 Approaches for Urban Forest Management

> *The objective of urban forest management is to optimize the leaf area of the entire urban forest by establishing and maintaining a canopy of genetically appropriate (adapted and diverse) trees and shrubs with minimum risk to the public and in a cost-effective manner.*
>
> **Dr. W. A. Kenney, Senior Lecturer Emeritus, University of Toronto**

Having an Urban Forest Management Plan (UFMP) is recognized as an important tool by a growing number of municipalities across North America, as it provides (a) strategic guidance and proactive direction to management efforts, and (b) a basis for securing funding from the municipal tax base and other sources. UFMPs can also: direct the effective allocation of available resources, help manage risk related to trees on municipal lands, support efforts to secure funding from internal and external sources and help standardize policies and practices surrounding activities related to trees (Bardekjian 2020, APWA 2019, Ordóñez and Duinker 2013).

To be effective, UFMPs should examine the full range of challenges and opportunities related to urban forestry for a given municipality's biophysical and land use context, on both public and private lands. Best practices with respect to the components to be addressed through a comprehensive urban forest management plan include assessment, planning, protection, establishment, maintenance and monitoring of trees and forests on lands throughout the jurisdiction.

For trees and forests directly under municipal jurisdiction, management efforts should ensure safety and risk management while also striving to maximize the benefits and services these assets are able to provide the community. This requires consideration of a range of operations, including:

- Tree selection and procurement
- Tree establishment
- Tree maintenance and management (including risk management)
- Tree assessment and inventory
- Municipal natural area protection and management, and
- Community outreach and engagement to foster support for tree-related operations.

In addition, UFMPs should include landscape-scale and ecological factors (such as the use of native species and landscape connectivity of tree cover) as well as climate change, community partnerships and economic incentives for supporting urban forest objectives (Ordóñez and Duinker 2013).

Best practices related to municipalities developing and implementing UFMPs is included in the Peel Urban Forest Best Practice Guide 1 and is not reiterated in this document.

2.4 Approaches for Urban Forest Maintenance

As noted above, most municipalities engage in some level of urban forest management and maintenance, even if it is limited to removal of hazardous street trees and replacement when required. For municipalities able to engage in more comprehensive urban forest management with dedicated forestry staff, typical tasks include:

- Administration and enforcement of tree bylaws on private lands
- Planning and plan review related to tree/woodland protection and site inspections on private lands and public lands not owned by the municipality (e.g., institutional lands)
- Inspection and acceptance of tree assets as they come off of the maintenance period from construction projects including roads, water and wastewater projects
- Programming, education and outreach related to trees and forests on public lands
- Forestry operations, including planting, maintenance, pest and disease control, risk management and removals on lands under municipal jurisdiction, and
- Park tree and natural area planning and operations on lands under municipal jurisdiction.

As with administrative organization related to forestry, there is no widely accepted best practice *per se* for such activities in North America. However, the Society of Municipal Arborists (SMA), an organization based in the United States that provides accreditation to municipalities that implement excellent and comprehensive urban forest management practices in North America, has developed some guidance. In 2018 the SMA provided the following best practice guidance for urban forestry departmental maintenance practices, based on experience from American cities.

- Maximum 10,000 street trees per climbing arborist
- Maximum 10-year pruning cycle
- Minimum 20 hours training per staff member per year
- One in five staff should be ISA Certified or equivalent
- Minimum of 30% of budget should be spent on tree maintenance
- Maximum 30% of budget should be spent on tree removal and administration (each)
- No more than 30% of labour time should be spent on request-based maintenance
- Minimum 5% of forestry budget should be for tree establishment, and
- At least $2.00 USD per capita (2018 dollars) should be spent on a municipality's urban forest budget.

No comparable guidelines have been identified for Ontario or Canada, however some of the SMA guidelines provide useful benchmarks that could be applied in a Canadian context and considered for Peel. However, as noted by Town of Caledon staff, the budget allocations suggested by the SMA are likely more appropriate for more urbanized municipalities with stand alone forestry sections or departments than predominantly urban jurisdictions like Caledon.

2.5 Summary of Municipal Forestry Program Administration Best Practices

Municipal forestry program administration determines how resources directed towards urban forest initiatives are allocated. Best practice recommendations for Peel related to high-level urban forest asset management and planning are provided in the Best Practices Guide to Urban Forest Planning in Peel (2020) and are not reiterated in this document. **Table 2** provides an overview of some additional best practices identified for forestry program administration in Peel.

Table 2. Summary of municipal forestry program administration best practices

Topic (Report Section)	Best Practices and Opportunities for Peel
Administrative Organization (Section 2.2)	• Have a stand-alone team within the municipality dedicated to various aspects of urban forest management. • That team must be able to operate in an integrated and collaborative manner with other municipal staff whose work impacts the protection, establishment, maintenance and removal of trees and forests. • Foster broad support for urban forestry initiatives among municipal decision-makers (e.g., senior management, Council).
Urban Forest Maintenance Processes (Section 2.4)	Consider the Society of Municipal Arborists (SMA) best practice guidance (2018): • Max. 10,000 street trees per climbing arborist • Min. 20 hours training per staff member per year • Min. one in five staff should be ISA Certified or equivalent • Min. one in five staff should be ISA Certified or equivalent • Min. of 30% of budget on tree maintenance and 5% on tree establishment • Max. 30% of budget on tree removal and 30% on administration, and • Max. 30% of labour time on request-based maintenance.

Credit: M. Ursic

Figure 2-3. Raised planter in the City of Toronto with co-plantings and a sewer integrated

3. Site Level Considerations

An urban environment is profoundly different from a natural one. For plants, the physical, chemical and biological nature of the substrate in which the plant is rooted (e.g., rooting space, exposure to pollutants, microenvironment and drainage) is often quite different in urban areas compared to the conditions in which a species evolved. This tends to be particularly true for trees and shrubs being established outside of wooded natural areas; in municipal boulevards, along rights-of-way and in well-used municipal open spaces, such as parks. Therefore, understanding the biophysical and environmental conditions into which a tree or shrub is being planted (discussed in this section) and understanding the intrinsic environmental tolerances and sensitivities of a species (discussed in **Section 4**), are critical to laying the groundwork for successful tree establishment and growth.

Trees in urban settings are often subject to difficult growing conditions (e.g., poor or inadequate soil, compacted soils, airborne and waterborne salt during winter), which are now compounded by environmental stressors associated with climate change (e.g., extended periods of heat and drought, more frequent ice and windstorms).

Even prior to experiencing the increasing effects of current climate change, built spaces in urban settings challenged the establishment and health of trees and shrubs (e.g., due to constraints on above and below-ground growing space, poor quality and compacted soils, exposure to excessive salt, wind and heat). Urban trees are also subject to the same pests and diseases as trees in natural areas, but in urban setting trees are often more susceptible, due to environmental stresses. In addition, climate change introduces additional stressors, such as greater and more frequent extremes in temperature and more frequent storm events. Understanding the existing and anticipated tree and shrub stressors is an important first step that can inform site design decisions, planting locations and species selection (discussed in **Section 4**), to try to maximize the intrinsic resilience of tree and shrub plantings in urban areas.

A site assessment should provide a thorough and detailed evaluation of site conditions that can indicate the potential limitations on and opportunities for vigorous plant growth and tree canopy health (Bassuk 2019). Without this vital information, managers risk wasting municipal resources on planting stock that may not be able to meet its genetic potential and may require nearer term supplemental maintenance, if not tree replacement. Key considerations fall into two categories: the natural physical and biophysical factors (e.g., topography, soils, drainage), including climate change (**Section 3.1**) and built environment factors (**Section 3.2**).

This section presents an overview of some key site-specific considerations that managers could consider as part of a site assessment checklist to inform plantings in Peel's urban areas. The considerations discussed below are not exhaustive.

3.1 Physical and Biophysical Considerations

> *The undervaluing of soils is one of the singular failings of conventional development approach.*
>
> from *the Leading Edge in Trees, Stormwater and Urban Design*
> presentation by Albert Key of DeepRoot (2020)

Many physical site conditions should be accounted for when considering urban tree establishment because of their potential to effect plant growth and establishment. These include site physiography, topography, soil texture, soil structure, soil chemistry, drainage and water availability, light and microclimate. Soil quality is touched on briefly below and discussed in more detail in **Section 5.3**.

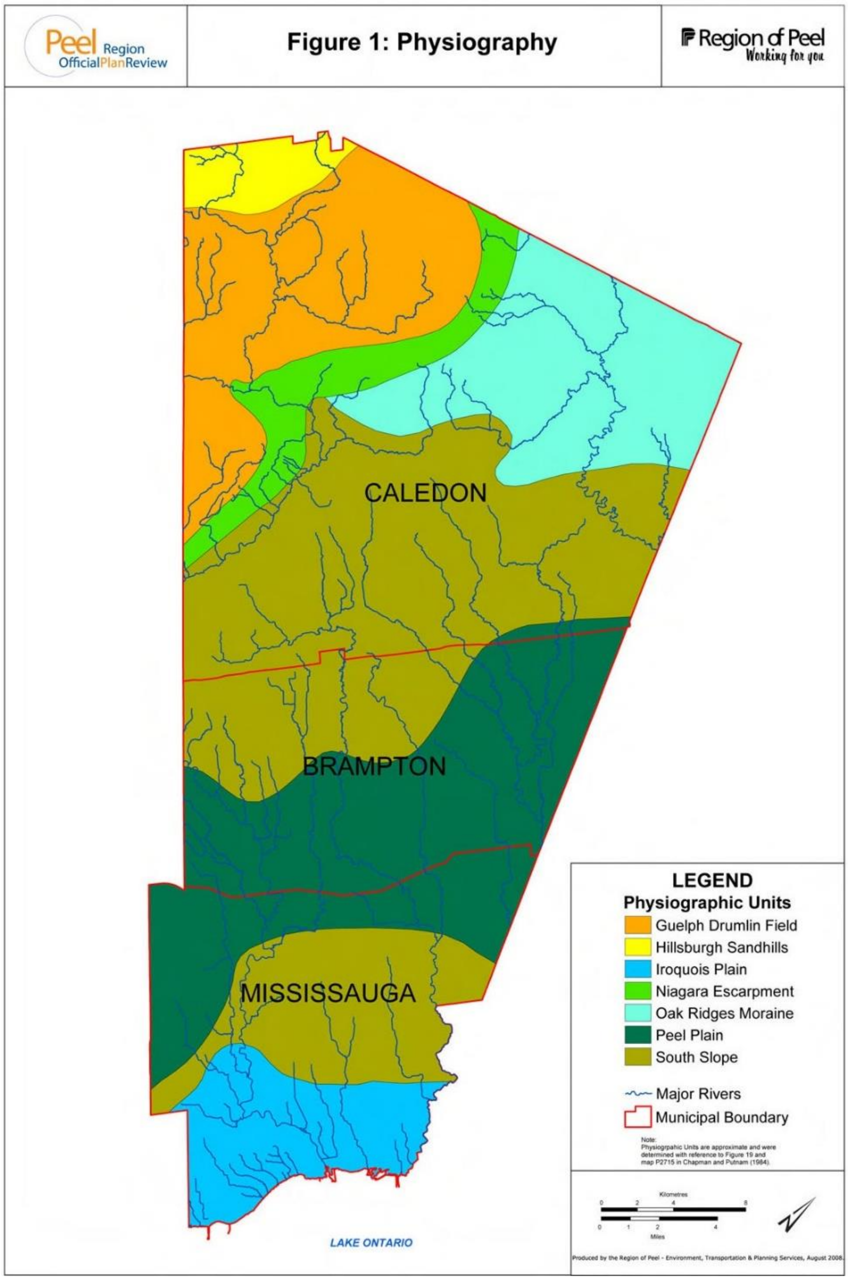
PHYSIOGRAPHY: The physiography (i.e., the surficial geology) of a landscape dictates elevation, drainage patterns, soil texture and chemistry and, at a landscape scale, it also influences local climate, hydrology, and the movement and accumulation of biological material (Lee *et al.,* 1998). The Region of Peel lies within nine distinct physiographic regions, as described by Chapman and Putnam (1984), shown in **Figure 3-1**. Most urban areas in Peel are located within the Iroquois Plain, South Slope and Peel Plain, characterized by sandy soils in the Iroquois Plain and imperfectly drained soils in the South Slope and Peel Plain.

TOPOGRAPHY: Topography relates to land shape and relief. It influences soil formation (and therefore nutrient retention), the infiltration and flow of water, exposure to solar radiation and frost, wind speed and the risk of erosion. Slope and slope aspect (e.g., north versus south facing), are positively correlated with plant growth, although they are less significant than soil factors (Wang *et al.,* 2015; Wang *et al.,* 2016; Scholten *et al.,* 2017). In particular, the influence of topography on soil properties and the potential for erosion should be understood.

SOIL TEXTURE: Soil texture is the term used to describe the varying combinations of sand, silt, loam and clay found in natural soils, as per the soil texture triangle (see TRCA 2012). Loam, sandy loam, sandy clay loam and silty loam soils are generally considered the best soils to support woody plant growth, provided they fall within the central area of the soil triangle (DTAH 2013). However, many of the species native to Peel Region south of the Escarpment are well-adapted to soils with higher clay contents. With experience, soil texture can be determined by feel.

Appropriate best practices for soils in Peel's urban areas are discussed in **Section 5.3** of this report and further guidance on assessment and management is found in:

- Section 6.5 of the *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* prepared for the City of Toronto (DTAH 2013);
- *Preserving and Restoring Healthy Soil: Best Practices for Urban Construction* (TRCA 2012); and
- *Healthy Soils Guideline for the Natural Heritage System* (CVC 2017).



Credit: Natural Heritage Policy Review Paper (Region of Peel 2008)

Figure 3-1. Physiographic regions of Peel

SOIL STRUCTURE: Irrespective of the physiographic region or soil texture of the surrounding area, it is recommended that imported soil contain peds, as illustrated in **Figure 3-2**. So called "peds" are naturally occurring soil aggregates and are preferred over more uniform screened soil (as in **Figure 3-2** to the right), as peds allow for the creation of interstitial spaces in the rooting environment that hold water, air and microbiota essential for plant growth, and also provide pathways for root development and function. Both soil compaction and screening reduce these spaces and peds, thereby degrading the quality and structure of the rooting environment and inhibiting plant establishment and growth.

Loamy growing medium mix with peds is desirable.

Sandy growing medium mix without peds (i.e. screened) should be rejected.

Credit: *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* (DTAH 2013)

Figure 3-2. Soil with peds(left) and without peds (right)

SOIL CHEMISTRY AND CONTAMINANTS: Soil pH varies on a negative logarithmic scale between 0 (acidic) to 14 (alkaline), with 7 the neutral point. Soil pH influences mineral and nutrient availability to plants (e.g., iron, boron), as well as the activity of soil bacteria. Most nutrients have the greatest availability between a pH of 6.0 and 7.0, but soil pH in urban settings can often be higher than 7.5 due to leaching of alkaline substances from concrete-based materials such as sidewalks, roads and other infrastructure (Vineland Research & Innovation Center 2020b). While most of the soils in Peel Region are slightly alkaline, the variability in urban conditions and soil media in which nursery stock is grown means that multiple tests within a potential planting site may be required to ensure a match between the species of plants selected and soil pH. Soil pH meters are widely available and inexpensive tools that are easy to use in the field (and are generally more reliable than dye kits). Testing and assessment services are also available through the Vineland Research & Innovation Center based in Leamington, Ontario.

Good quality soils should also contain adequate concentrations of macro and micro-nutrients, and should not contain exceedances of contaminants, particularly those likely to harm plant health. Many contaminants can occur or be introduced into soils and substrates, particularly in urban environments. Prior to planting, extant soils to be used should be tested for (a) commonly occurring contaminants, and (b) adequate levels of naturally occurring macronutrients and trace elements. Although use of native soils is preferable as a best practice wherever possible, soils containing certain contaminants or lacking adequate levels of inorganic and trace elements may need to be amended or replaced with imported soils.

DRAINAGE AND WATER AVAILABILITY: The water table, soil type and composition as well as features of the built environment such as planters, stormwater conveyance systems and the extent of permeable versus impermeable surfaces, all influence the hydrologic regime of a site. When considering hydrologic regime, it is imperative to consider the groundwater table as well as seasonal variations in both surface and groundwater levels. It is recommended that urban foresters note evidence of high groundwater tables and test soil permeability during site assessment.

How to get water to and away from rooting areas, particularly in compacted clay-dominated soils, is a significant challenge in Peel that should not be overlooked. Fundamentally, there must be accommodation and opportunities for water to get into and move out of the rooting zone. As noted by A. Satel (pers. comm. 2020, **Appendix B**), this can be achieved through a combination of active methods (e.g., use of "gator" bags, bubblers) and passive methods (e.g., drainage directed to the rooting zone).

Good examples and approaches are provided in *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* prepared for the City of Toronto (DTAH 2013) and *Up By Roots* (Urban 2008).

LIGHT: Green plants need light combined with water and nutrients to photosynthesize and produce their own food. Some species are shade tolerant and can tolerate lower light conditions, while other species are shade intolerant. In urban areas, light levels can vary widely due to obstructions by the built environment. With adequate soil moisture, higher light levels result in higher rates of transpirational water loss by plants, which cools leaves. Under these conditions high rates of photosynthesis also take place. However, high light levels when soil moisture is limited and low rates of transpiration can cause plant foliage to reach potentially damaging temperatures. If these conditions persist long enough, they can lead to plant starvation due to reduced rates of photosynthesis, which can also be lethal.

MICROCLIMATE: High temperatures and wind are key site-specific stressors commonly occurring in urban environments that can contribute to woody plant desiccation. These conditions are becoming more common and more widespread in Peel (and elsewhere) due to climate change. Urban heat island effects (UHI)[3] can cause localized elevated temperatures in urban areas and affect both above and below-ground plant parts. For example, woody plants with thin bark (e.g., *Fagus grandifolia, Amelanchier laevis*) are particularly susceptible to the damaging effects of heat. Buildings and other structures in urban areas can produce a "wind tunnel" effect, concentrating wind force in relatively small areas and increasing the risk of damage to trees. Wind can also be a powerful drying agent for trees and soils.

Research in Austria has shown that UHI effects are not uniform throughout urban areas. Trees in "high" UHI intensity zones exhibited physical signs of an extended growing season (e.g., earlier bud break and delayed leaf colouration) compared to their counterparts in "low" UHI intensity zones (Stanley *et al.,* 2019). This illustrates the importance of understanding microclimate variations within urban centres. While vegetation, particularly larger trees and shrubs, can tolerate some of the effects of UHI and wind, exposed trees may eventually succumb to sustained desiccation. Therefore, site planning should consider how trees themselves can mitigate localized UHI and wind effects (e.g., Petri *et al.,* 2019) and how moisture levels in their rooting zones can be adequately sustained, thereby creating a positive feedback loop as the vegetation matures.

[3] Hard surfaces such as buildings, pavement and asphalt hold and radiate heat, contributing to what is known as the "urban heat island effect" and results in urban centres being significantly warmer than adjacent lands in both summer and winter, particularly when winds are low.

3.2 Built Environment Considerations

The existing or anticipated type of land use, site layout and infrastructure can also significantly influence the above and below-ground conditions into which trees and shrubs are planted. Therefore, there needs to be consideration for how tree and shrub planting areas may be altered by existing or planned land use and design elements.

LAND USE TYPE: Land use can have multiple effects on the type and extent of space for trees and should be taken into consideration when selecting plant materials and treatments for a given site. For example, a native species like black maple that gets relatively large at maturity may be suitable for a park setting but not for constrained municipal roadside planting.

There can also be substantial variability within land use types. For example, the type of street (e.g., major arterial, minor arterial, collector, local, scenic, etc.) influences design elements, such as extent of hardscaping, stormwater management, utilities, needs for accommodating pedestrian access, salt management and potential for snow sliding from building roofs, all of which provide opportunities and/or limitations for plant growth or survival. In Peel and other jurisdictions, there are widespread initiatives to get people moving via active transportation, and while space for this needs to be accommodated, trees also play an important role in providing shade for travellers, as well as a sense of safety and contributions to placemaking.

SITE LAYOUT AND INFRASTRUCTURE: When considering above and below-ground planting space, it is critical that municipal staff consider the ultimate size of the tree canopy and tree trunk in relation to the site layout and infrastructure (e.g., proximity to buildings, parking lots, roadways, sidewalks and other hard surfaces, utilities and adjacent trees). Above-ground space should accommodate the ultimate size of the tree canopy and tree trunk. Below-ground, larger soil volumes are positively correlated with larger trees. Soil volumes for trees are discussed further in **Section 5.3.1**.

Consultation and coordination with other municipal departments (e.g., transportation, planning and engineering) as well as utility providers[4] can help the urban forester understand existing and planned infrastructure. In some cases, there may be opportunities to discuss the feasibility of changes to municipal infrastructure design or location that may help support trees and other objectives (e.g., storm water management). For example, installation of curb cuts to allow water to infiltrate into or out of planting sites, vertical zoning with underground utilities, etc.

In addition to the physical space available for trees, the physical factors noted in **Section 3.1** (i.e., soil, water, light and microclimate) also need to be considered in terms of how they are influenced by existing or proposed built form. For example, some urban jurisdictions in southern Ontario (e.g., Toronto, Mississauga, London, Vaughan) increasingly require analysis of the impacts of shading by the addition of tall buildings on existing nearby natural areas, as well as on proposed plantings.

[4] Requirements for planting under utilities may be determined by the local utility provider with their own list of acceptable species.

Key best practices related to trees and urban design focus on the provision of adequate conditions below-ground, as follows.

- Ensure adequate soil volumes, preferably shared by multiple trees and other companion plantings (see Urban 1992 and DTAH 2013 for specifics, also see **Section 5.4.7**).
- Ensure adequate (but not too much) water availability and drainage for trees and other vegetation in relation to permeable versus impermeable areas.
- Support re-use and re-conditioning of locally available soils wherever possible, and ensure soils are not subject to excessive compaction, salt accumulation or other contaminants other contaminants, including those that affect pH.
- Work with other municipal staff and experts to find opportunities to use urban design to meet multiple objectives with trees (e.g., combining tree soils cells with above or below-ground rain gardens to help meet stormwater management objectives).

In cases where negative impacts of site plans are identified, plans and designs should be revised and refined to improve the above and/or below-ground tree habitat. Consideration of planned infrastructure upgrades (e.g., road widening, sidewalk retrofit, etc.) is also good information to have during site assessment.

Municipal requirements related to safety and sight (e.g., Crime Prevention Through Environmental Design or CPTED) can also be considerations for plant selection but are not discussed in this guide.

3.3 Summary of Extrinsic Site Level Consideration Best Practices

Understanding the existing and anticipated tree and shrub stressors on a site can help inform site design, choice of planting location and species selection (discussed in **Section 4**) to maximize the intrinsic resilience of plantings. Therefore, site assessment is a primary, critical and often overlooked step in the tree establishment process.

As a general best practice, a thorough site assessment should be undertaken by a knowledgeable professional before planning or planting trees or shrubs. Assessments must consider the below-ground rooting space and conditions, as well as the above-ground space expected to be required by the tree at maturity.

A good example of a site assessment checklist is provided by Dr. Nina Bassuk of the Urban Horticulture Institute at Cornell University (see **Appendix C**). That checklist could be adapted for southern Ontario based on the information and best practices provided in this guide.

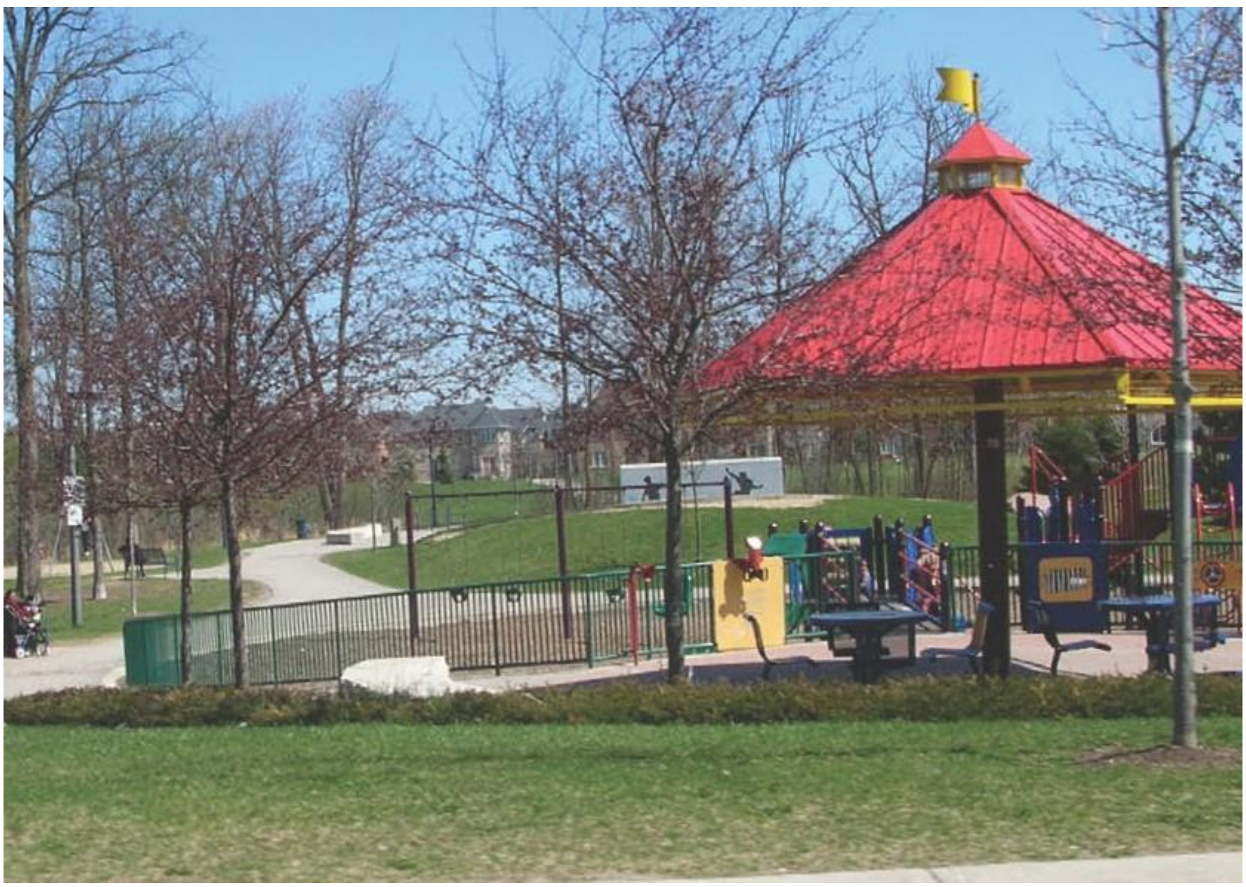
Key site-specific biophysical factors to be considered as part of a site assessment include: physiography, topography, soils (texture, structure and chemistry), drainage and water availability, light and microclimate. These factors tend to be influenced, to varying degrees, by urban conditions and climate change. In addition to this myriad of biophysical factors, site factors related to the existing and/or anticipated built environment also can influence conditions for vegetation significantly. Land use cover type (e.g., open space or park versus street type) and site layout determine proximity to buildings, parking lots, roadways, sidewalks and other hard surfaces, utilities and adjacent trees or natural areas.

Best practices related to critical extrinsic conditions in urban environments in relation to climate change are provided in **Table 3**.

Table 3. Key site-level best practices for extrinsic considerations

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
General (Section 3)	A thorough site assessment that considers above and below-ground conditions should be undertaken by a knowledgeable professional before planning or planting any trees or shrubs. See Appendix C for a sample checklist.
Key Site Considerations (Section 3.1)	• Physiography, topography, soil texture, soil structure, soil chemistry, drainage and water availability, light and microclimate are all important physical site conditions that can affect plant growth and establishment and should be considered. **SOILS** • Best practices for healthy soils in Peel's urban areas (including guidance for assessment and management) are found in the *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* prepared for the City of Toronto (DTAH 2013); *Preserving and Restoring Healthy Soil: Best Practices for Urban Construction* (TRCA 2012); and *Healthy Soils Guideline for the Natural Heritage System* (CVC 2017). • Loam, sandy loam, sandy clay loam and silty loam soil textures are generally considered the best for woody plant growth but use of native soils is recommended where they meet basic quality requirements. • Soil testing prior to use is recommended. • Good quality soils should have a "lumpy" structure with different sized peds, pH between 6.0 and 7.5, adequate concentrations of macro and micro-nutrients, and no exceedances of contaminants, particularly those likely to harm plant or human health. **DRAINAGE AND WATER AVAILABILITY** • There must be opportunities for water to get into and move out of the rooting zone through active (e.g., watering) and passive (e.g., drainage) methods. **LIGHT AND MICROCLIMATE** • Light availability and microclimate (heat and wind) conditions should be assessed. Site planning should consider how trees can mitigate localized heat and wind effects, thereby creating a positive feedback loop as the vegetation matures. • Where tall buildings are being introduced, shade impacts on existing and proposed trees or natural areas should be evaluated.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Key Built Environment Considerations (Section 3.2)	Provision of adequate conditions below-ground: • Ensure adequate soil volumes, preferably shared by multiple trees and other companion plantings (see Urban 1992 and DTAH 2013 for specifics • Ensure adequate (but not too much) water availability and drainage for trees and other vegetation in relation to permeable versus impermeable areas • Support re-use and re-conditioning of locally available soils wherever possible, and ensure soils are not subject to excessive compaction, salt accumulation or other contaminants, including those that affect pH, and • Work with other municipal staff and experts to look for opportunities to use trees in urban design to meet multiple objectives (e.g., combining tree soil cells with above or below-ground rain gardens to help meet stormwater management objectives).



Credit: City of Brampton *Community Design Guidelines* (2013)

Figure 3-3. A municipal park with trees and landscaping integrated

4. Tree Selection and Procurement

Selecting trees and shrubs that are suited to the given planting location is critical to having a healthy urban forest. Municipal staff are often involved in the selection and / or procurement of trees and shrubs on municipal lands and may also have the opportunity to influence the selection and procurement of plants for private lands (particularly if they are to be assumed by the municipality as part of the planning process). Having some knowledge of best practices related to seed source, species selection, and nursery stock selection and procurement greatly improves the chances of having healthier trees and shrubs, which ensures that investments made in growing the urban forest provide returns more quickly and for a longer duration.

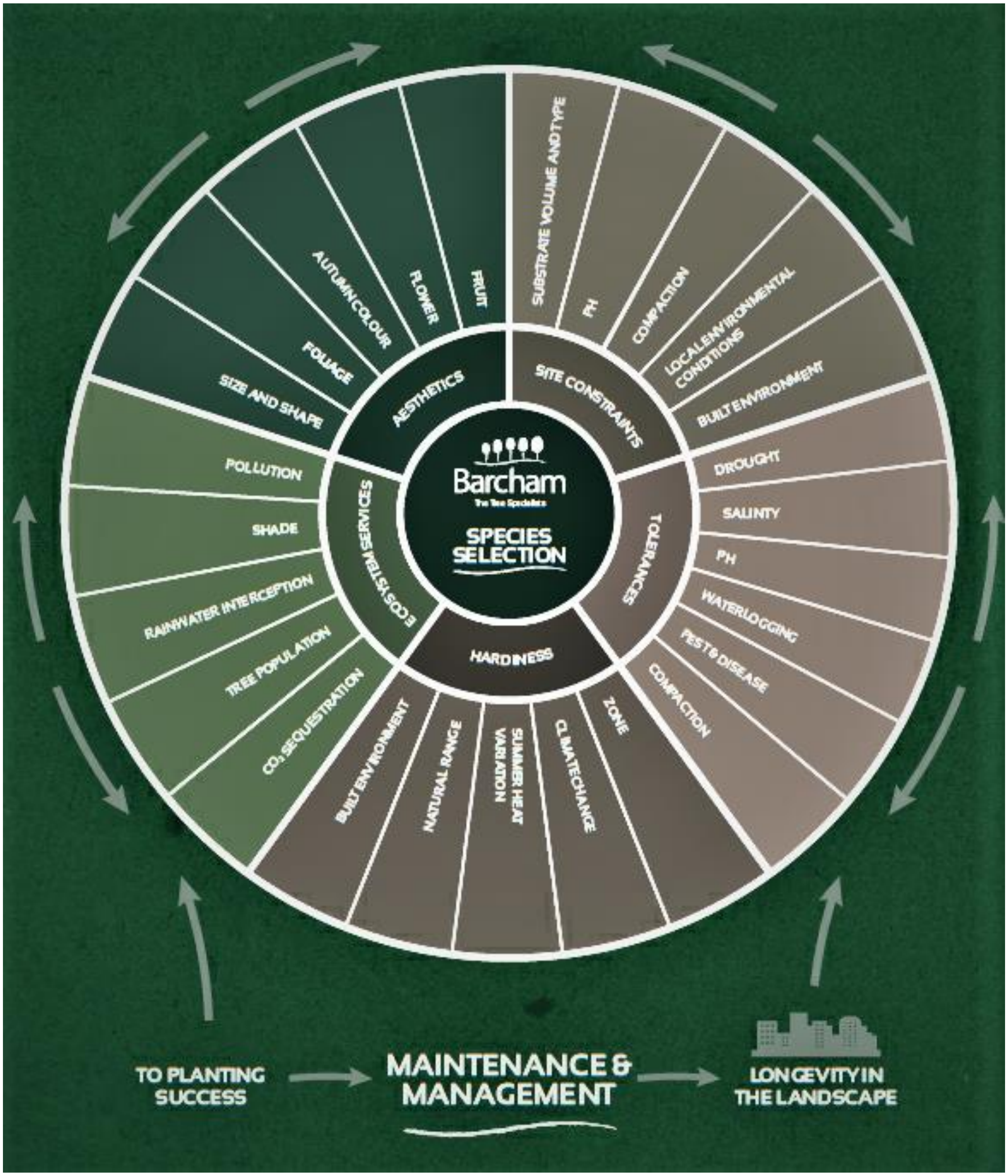
The adage "the right plant in the right place" speaks to the need to ensure that the form, functions, tolerances and aesthetics of individual species are matched with the climate and site conditions. Although the adage is simple, the implementation of it is not and there is no "one size fits all" solution. As illustrated in **Figure 4-1**, selecting a suitable plant for a given location requires a good understanding of a range of intrinsic and extrinsic factors, including:

- The planting site's current opportunities and constraints (e.g., exposure, soil type and condition, drainage, available light and water, above and below-ground utilities, extent of impervious surfaces) (discussed in **Section 3**);
- Species tolerance to anticipated environmental stress (e.g., salt spray, heat island effect, drought, wind, pests); and
- Human use considerations related to ecosystem services and aesthetics.

The following subsections focus on approaches and considerations for selecting species and/or stock that will help build intrinsic resilience in urban settings exposed to increasing stresses due to climate change. Topics discussed include: seed source and provenance (**Section 4.1**), species selection (**Section 4.2**), nursery stock selection (**Section 4.3**), nursery stock procurement (**Section 4.4**) and native versus non-native species (**Section 4.5**).

Specific considerations related to ecosystem services are not included in this report, beyond the discussion of urban forest valuation in **Section 7.2**. It is a given that all trees and shrubs provide a range of ecosystem services and that the value of these services generally increases as the perennial plants mature.

While no single species may respond well to all potential constraints and stressors identified for a site, applying a knowledge and evidence-based approach to select a suite of reasonably suitable species greatly improves the odds of the majority of the species selected performing well.



Credit: *Species Selection* (Barcham 2019a)

Figure 4-1. Range of possible factors to consider in woody species selection

4.1 Seed Source and Provenance

> ***… the importance of seed source cannot be overstated in any tree planting effort … With climate change effects here and increasing, knowledge about seed source can help us relate planting performance back to the seed source, to repeat successes and avoid failures.***
>
> **Forest Gene Conservation Association (FGCA), Sperling 2016**

Studies of woody plant species have shown that the timing and pattern of growth for each species are under genetic control (Sperling 2016). Woody plant genetic variation is a complex topic that is not explored in this guide. However, it is important to understand that in addition to species-specific differences, woody plants of a single species are also known to have unique populations with different ranges of adaptive variation. This means that within a single species there can be multiple genetically distinct populations, each adapted to different climate conditions. Consequently, moving plants without any knowledge of their genetic origin can be risky, especially if the move is into a different plant hardiness zone. For example, a redbud sourced from a northern population in Ohio has a better chance of surviving in Peel than a redbud sourced from the species' southern range in Texas. Planting trees ill adapted to the area where they are being installed results in high mortality rates. There is also the risk of transporting insects and disease when sourcing stock from distant areas. Furthermore, planting a tree which is not genetically adapted to thrive under the conditions in which it is installed often results in additional management being required to maintain and eventually replace this tree.

Experts are increasingly aware of the importance of high quality plant material to the long-term success of planting efforts, but seed source is often not documented and cannot be determined based on plant morphology. Best practices identified by the Forest Gene Conservation Association (FGCA) include obtaining seed from certified seed collectors, so that seed origin is known and high quality seed is assured. As municipal staff in Peel are typically not growing their own plants from seed, the best practice would be to work with southern Ontario nurseries who purchase source-identified seed from certified collectors.

Source-identified seed is tracked from seed origin through all stages of shipping, processing, growing and planting (sometimes referred to as "chain of custody information"). Having this information, and assessing its role in plant performance, can inform whether a given seed source is adapted to a particular site. Of course, there are many factors that influence plant quality, so that seed source-site adaptation assessments should be based on replicated plantings together with control plantings of locally adapted populations.

"Provenance" refers specifically to the original geographic area from which genetic material originally evolved over time (Sjöman *et al.,* 2019). A provenance is site-specific, typically represented by a local stand of trees.

For plant movement purposes, trees can also be identified according to the ecological region from which they come. At this larger (compared to a provenance) spatial scale, called an ecodistrict, it is assumed that plants of the same species from the same ecodistrict are adapted similarly to local environment, since an ecodistrict is an area of generally similar climate, soils and elevation.

Two ecodistricts comprise Peel Region: 6E-7 in the northern part of the region and 7E-4 in the southern part. Native plant material that has been sourced from naturally occurring populations from within or near these ecodistricts will have evolved to tolerate historical local climatic and site conditions. However, for most species, it is not known if local populations have the phenotypic plasticity required to tolerate a broader range of environmental conditions that may occur with climate change. There is evidence suggesting that genetic material of woody species whose range extends southward may be adapted to the projected climate in more northerly areas, although information on their compatibility with local soils and soil biota is not well understood.

The use of "seed zones" is a somewhat similar approach to the ecodistrict method of matching plants to climate. Seed zones were developed in response to the need to manage tree seed transfer within Ontario by the Ministry of Natural Resources and Forestry (MNRF). Seed zones are areas of climate similarity that correspond to patterns of tree growth in large scale provenance trials for a limited number of coniferous species. The Ontario Seed Transfer Policy (MNRF 2020) has now replaced the Seed Zones of Ontario (OMNR 2010). In addition to written guidance[5] for climate-based seed and species-specific seed transfer using the best available science, the Province has also provided open access to data and mapping that can inform seed transfer decisions[6].

MNRF's Ontario Seed Transfer Policy (2020) uses a focal zone approach, whereby "*a suitable deployment area is defined for each seed source location or a suitable seed source area is defined for each intended planting site*". Recommended seed transfer direction is generally from areas of warmer climates to areas of cooler climates that are expected to mirror the current/historic climatic conditions of the seed collection area in the future. For example, as shown in **Figure 4-2,** seed collection areas shown in red are generally considered suitable for use in Ecodistrict 6E-6 (Lake Simcoe area) while seed collected within Ecodistrict 6E-6 is considered suitable for use further north, as shown in **Figure 4-3**.

The Ontario Seed Transfer Policy (MNRF 2020) provides guidance for where seed can be collected and used in Ontario and is intended to ensure that seed used to regenerate forests has a good chance of producing trees that are adapted to their growing environment. It specifically encourages the use of a mixture of local and non-local seed sources from more southerly areas identified as being generally suitable to increase genetic diversity. This approach is considered best practice for Peel, with additional discussion and guidance about diversification and assisted migration of trees provided in the Peel Urban Forest Best Practice Guide 4 and Guide 5.

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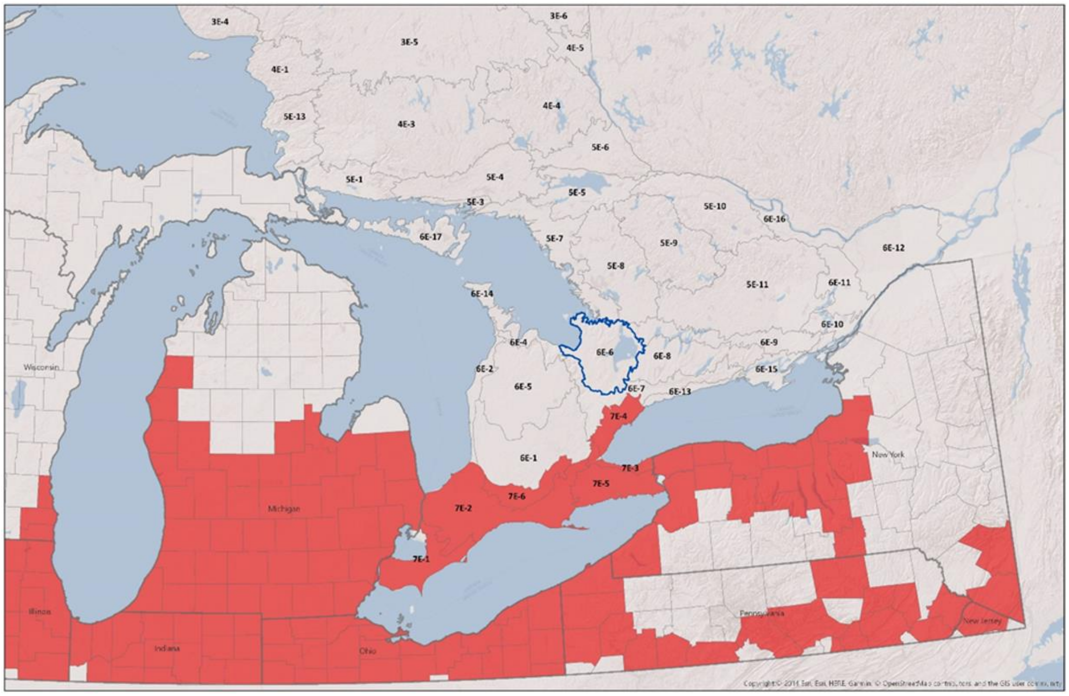
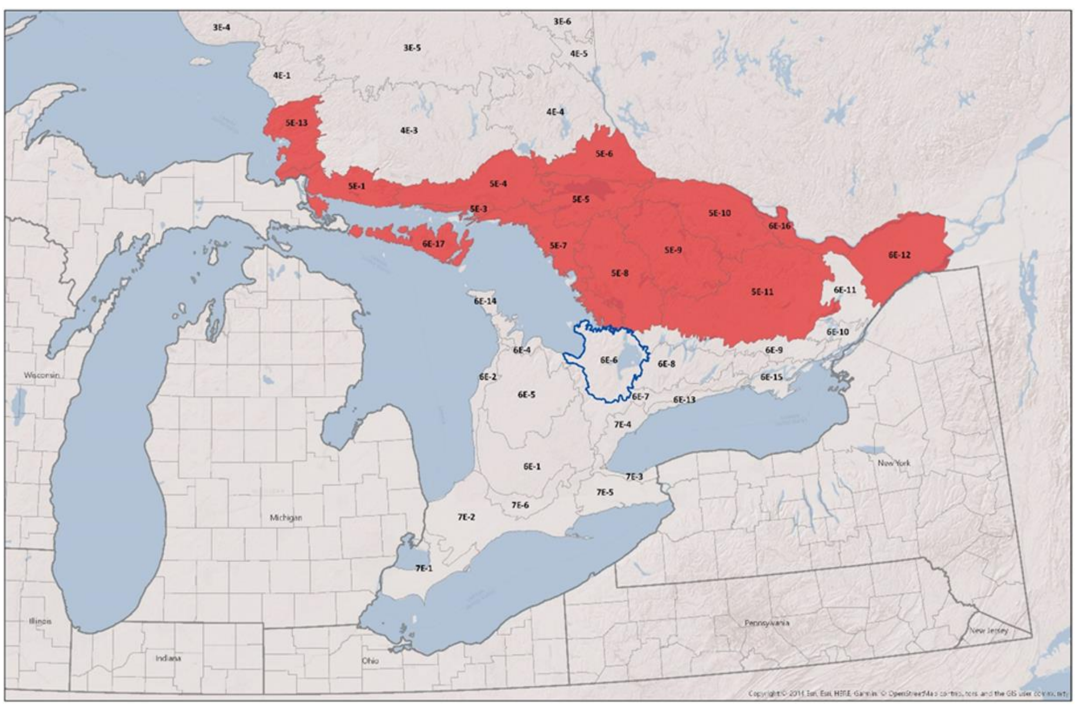
[5] https://www.ontario.ca/page/ontario-tree-seed-transfer-policy

[6] https://open.canada.ca/data/en/dataset/14aef4c1-40d4-40a1-ab72-bdc1a9c30fb5



Credit: Ontario Seed Transfer Policy (MNRF 2020)

Figure 4-2. Map showing Ecodistrict 6E-6 (blue outline), just north of Peel, and more southern areas (red) from which tree seed for planting may be suitable in 6E-6



Credit: Ontario Seed Transfer Policy (MNRF 2020)

Figure 4-3. Map showing Ecodistrict 6E-6 (blue outline), just north of Peel, and more northern ecodistricts (red) in which tree seed from 6E-6 may be suitable for planting

If sources were being tracked, then it would be possible to test and use a mixture of local and non-local seed sources from more southerly ecodistricts to assess their suitability under urban and climate change conditions.

Currently, applied research trials on different species and genera from different provenances are very limited and there are no government requirements or industry-based guidelines that require or recommend nurseries label stock lots by provenance (e.g., ecodistrict) for municipal use. Therefore, at this time nursery clients must request this type of information. In addition, appropriate climate-ready stock lots could be developed if Peel and its partners with nurseries were to help establish and maintain purposely designed production orchards of specified provenances.

Having source-identified stock would allow Peel and its partners to: (a) plant stock from multiple ecodistricts, thereby building resilience by increasing genetic diversity, and (b) work with local research partners (e.g., University of Toronto, ACER, Forests Ontario) to assess the performance of species and genera from different ecodistricts, potentially informing ongoing adaptive management.

4.1.1 Expanding "Proven" Tree Species Lists

Currently, planting stock availability, cost and evidence of proven performance in the urban environment are impediments to increasing species diversity of woody species, particularly in urban rights-of-way and other challenging settings. Only a fraction of species native to a region are available through nursery stock and as a result most municipalities are inadvertently practicing assisted migration without actually evaluating its success in that context (Almas and Conway 2016).

Nonetheless, some managers are understandably reluctant to invest in species without proven track records for their successful establishment. However, there are many native and non-native species and cultivars already available commercially, and others that could become available, even though information is lacking regarding their present and long-term suitability for planting in Peel's urban areas. More work and research in this area is needed to fill this knowledge gap.

For municipal street and park trees, where larger stock is generally used, it can be faster and more cost-effective to import stock grown in appropriate ecodistricts further south for trials (McPherson *et al.,* 2018; R. Vendrig, pers. comm., **Appendix B**). However, there are some local nurseries (e.g., CVC nursery[7]) that have begun to select and breed a range of different species and cultivars for "climate readiness" that may also be able to provide different species for trials in urban areas.

A potential approach to tree trials for currently "unproven" species, including a suggested five-step experimental design and evaluation criteria, is outlined in McPherson *et al.* (2018). A

[7] CVC is preparing guidelines over 2020 and 2021 for assessing a range of species for "climate readiness" with trials set to be implemented in 2022.

recommended best practice for Peel is for the Region to undertake – in association with other agencies and organizations – trials for "unproven" genera, species and cultivars. Local arboreta and botanical gardens (e.g., University of Guelph Arboretum, Royal Botanical Gardens) may also have information on suitability of *ex-situ* plantings of untested species.

Peel Region Urban Forest Best Practice Guide 4 *Potential Street and Park Tree Species for Peel in a Climate Change Context* assesses 88 native and non-native trees and shrubs in terms of their projected climactic suitability for planting in Peel's urban areas in about 2040 to 2070, and is available as an additional resource under separate cover.

4.2 Species Selection

There are numerous factors to consider when selecting woody species for planting in municipal urban spaces outside of wooded natural areas. These include:

- Site factors (such as available rooting and above-ground space, local climate), as discussed in **Section 3**
- Tree ecophysiological factors (such as inherent vulnerability to certain pests or diseases and ranges of tolerances for different environmental conditions related to successional niche and provenance/genetics) as discussed in **Section 4.1**
- Practical constraints (such as species availability and anticipated management requirements)
- Ability to provide valued services (such as shade, climate moderation, air and water quality improvement, human health benefits – physical, physiological and psychological, food provision), and
- Aesthetic or cultural considerations (such as colour, historical or cultural significance).

When considering these factors, which are listed below, the best practice guidance is to:

- Distinguish between "primary selection factors," which will influence whether or not a given species will be likely to survive and even thrive, and "secondary selection factors," which remain important considerations in an urban environment but will not influence the tree's ability to establish and grow (Hirons and Sjöman 2019), and then
- Prioritize the "primary selection factors" of site and tree ecophysiology over practical, service-based and aesthetic or cultural considerations which are considered "secondary selection factors".

The following considerations are recommended for inclusion in the species (and, if possible, the provenance) selection process. These eight factors, discussed briefly below, are listed from most to least important and are grouped into "primary" and "secondary" factors based on a review of species selection literature (e.g., Hirons and Percival 2017; Hirons and Sjöman 2019; Sjöman *et al.,* 2017; Spearing 2016; Urban Horticulture Institute 2009).

PRIMARY SELECTION FACTORS

1. Hardiness and health
2. Successional niche
3. Tolerance of site conditions
4. Growth form and/or size
5. Contribution to diversity

SECONDARY SELECTION FACTORS

6. Functional value
7. Maintenance requirements
8. Aesthetic and/or cultural attributes

1. HARDINESS AND HEALTH: In a context of climate change, species hardiness and health are two of the most critical considerations in helping to ensure successful plant establishment and growth (Sjöman *et al.,* 2019). These factors can differ widely among species and even within species of different provenances (as discussed in **Section 4.1**). Species hardiness to environmental factors (e.g., moisture, heat, light, etc.) is largely determined by genetics, while health potential is determined by a combination of genetic and environmental factors.

Forestry professionals in York Region consulted for this project (see **Appendix B**) have developed a list of suitable street tree species based on those found to exhibit high degrees of hardiness to harsh rights-of-way conditions. However, they also go to the nursery to select the stock in advance of delivery to ensure that the specimens provided appear healthy. This has proven to result in fewer tree replacements being required within the two-year warranty period and beyond.

2. SUCCESSIONAL NICHE: Application of ecological knowledge and having an understanding a species successional niche is also critical to selecting the right species for the right place. The establishment phase of woody plants[8] has a significant impact on their short and long-term viability. The more closely the habitat associated with a plant's natural successional niche is mimicked by the urban "habitat" that it is planted into, the more likely the species is to survive. For example, species adapted to mature woodland habitats that tend to provide relatively high levels of shade, moisture and organic matter (such as American Beech, *Fagus grandifolia*) will generally be intolerant of exposed urban tree planting conditions and are more likely to succeed when underplanted beneath an existing tree canopy in a somewhat natural wooded area. Alternatively, species adapted to younger wooded areas and early successional habitats are generally better suited to environments that are open, provide high-light and have soils with less organic matter, that are typical urban environments.

[8] A literature review of urban tree mortality Hilbert *et al.,* (2019) found mortality to be highest in the first five years after planting.

… [There is a] need to acknowledge the natural heritage of a tree to ensure that the chosen species is capable of thriving on the planting site.

Tree Species Selection for Green Infrastructure, Hirons and Sjöman 2019

In southern Ontario, species such as red and Freeman maples, bur and white oaks, and (until recently) white ash trees have been among the most popular species selected for rights-of-way and other urban settings due to their combined tolerance of open conditions and generally high levels of hardiness. In addition, anecdotal evidence suggests that some woody species typical of floodplain or wetland environments that are naturally kept in an early successional state (e.g., black maple, *Acer nigrum*; swamp white oak, *Quercus bicolor*; bald cypress, *Taxodium distichum*) can tolerance anaerobic conditions of compacted soils and, as such, may adapt well to urban planting sites prone to soil compaction (S. Fox, pers. comm., **Appendix B**).

Generalized ranges of site condition for early to late successional forest habitats are illustrated in **Figure 4-4**. Notably, successional trajectories of other treed habitats, such as savannas, will differ.

Credit: Hirons and Sjöman (2019)

Figure 4-4. Typical range of conditions between early and late successional forest habitats

3. TOLERANCE OF SITE CONDITIONS: Species-specific site tolerances are too varied to discuss comprehensively in this guide. However, understanding the site-specific conditions

and selecting species able to tolerate these conditions are key to woody plant establishment. Tools and resources that provide species-specific information are available and should be used by a person with knowledge of ecological, silvicultural and horticultural requirements, in conjunction with an understanding of the effects of site conditions. Useful resources for Peel include Appendix D of the *Peel Streetscaping Toolbox* (2017)[9], Appendix B of Matheny and Clark (1998) and others listed in **Appendix A**.

4. GROWTH FORM/SIZE: In urban environments, particularly built-up areas like downtown cores, both above and below-ground space are primary constraints to effective tree establishment ad long-term suitability. Although there are various planning and design strategies for improving available space for trees (e.g., introducing soil cell structures beneath concrete, having utilities installed below-ground as opposed to above-ground), there are typically limitations to growing space in urban environments. Therefore, it is important to understand whether a tree is genetically predisposed to become small, medium or large-statured,[10] so that its future above and below-ground space needs can be considered during planning.

5. CONTRIBUTION TO DIVERSITY: Diversification of woody species and genera in the urban forest is widely viewed as one of the cornerstones of improving resilience against pests, disease and climate change-related weather shifts and extremes (e.g., Santamour 1990, Ball 2007, Wade 2013, Pace 2015). More recently, the importance of considering seed provenance in the "diversity equation" has also begun to be recognized, particularly in the context of climate change (Sperling 2016, MNRF 2020) (see **Section 4.1**). The effects of pests such as Chestnut Blight, Dutch Elm Disease, Emerald Ash Borer and Asian Long-horned Beetle on North American urban forests over the past century have clearly illustrated the grave risks of selecting species for urban areas based on a narrow palette. However, while drawing on a more diversified list of species and genera is a well-established best practice, there is no broad consensus on how best to implement such diversity.

One commonly cited target has been the "10-20-30 rule" which recommends that, within an entire urban forest, no single species represent more than 10% of the population, no genus represents more than 20% of the population, and no family represents more than 30% of the population (Santamour 1990). However, applied work in southern Ontario over the past decade (e.g., Wade 2013, Pace 2015) indicates that, while some of these targets may be attainable if all of the trees in a given jurisdiction are considered (including wooded natural areas), they are not feasible when looking exclusively at street and/or park trees on municipal lands (R. Vendrig pers. comm. 2020 and A. Barkowitz pers. comm. 2020, **Appendix B**).

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[9] Note: Species' soil pH tolerances are not included in the Peel list and some species included in the list are unsuitable for planting in basic pH soil common to Peel Region (e.g., Amelanchier arborea, Quercus palustris) and thus users are cautioned to investigate the biophysical requirements of species prior to planting.

[10] There is no standard the consulting team is aware of for defining a "small", "medium" or "large" tree but for the purpose of this report and the Peel urban context, the following definitions adapted from the City of Kitchener (2015) can be used as a reference: Small = ≤ 39 cm dbh, medium = 40 – 59 cm dbh, large =≥ 60 cm dbh.

The reasons targets such as the "10-20-30 rule" may not be feasible in these contexts include: limited nursery tree species availability, limited number of "proven" species, legacy effects of past species selection, challenges with invasive pests and diseases, and harsh growing conditions that limit the range of species that can be planted successfully.

In recognition of these challenges and realities, local experts and practitioners have suggested diversity targets for municipal street and/or park trees that are less prescriptive but still underscore the critical importance of genetic diversification:

- Within species (based on provenance)
- At the species, genus and family levels, and
- At different scales within a given municipality – from street to jurisdiction-wide.

> ***The pool of proven native trees has been narrowed over the years, and there is a reliance on fewer native tree species which are now becoming overplanted. The selection of proven native trees should be broadened so that native species are not overplanted.***
>
> **Dr. Charles A. Wade, 2013**

Drawing on the available guidance for diversity targets for street and parks trees, as well as input from local municipal forestry staff, the suggested best practices for urban forest diversity in Peel's urban areas are as follows:

- Implement species diversification at multiple scales (e.g., street level, site level, neighbourhood, ward level)
- Enhance the genetic diversity within a species where appropriate, by planting suitable provenances of a species (as discussed in **Section 4.1**)
- Strive to diversify species and genus level diversity among street and park trees while also incorporating species from genera other than those that are already widespread and those with pests/pathogens that are known to be problematic in eastern North America (Santamour 1990, Ball 2015)[11], and
- Work towards a target of having no more than 5% genus-level diversity by stem count (UFI and Beacon 2018) for trees outside natural areas with the understanding that this can be a challenge as long as a limited number of suitable species are known and available, particularly for street trees.

6. FUNCTIONAL VALUE: Trees and green spaces in urban areas are increasingly recognized as providing a wide range of benefits and ecosystem services, such as air and water filtration, shading and cooling, habitat for wildlife and support for human mental and physical health (e.g., Bardekjian, City of Mississauga 2014). More recently, trees have been identified as helping communities adapt to and mitigate climate change (e.g., Region of Peel 2019). It is also widely recognized that the benefits and services provided by a given tree increase

[11] See *Guide 4: Potential Street and Park Tree Species for Peel in a Climate Change Context*

exponentially as the trees increase in size, and therefore selecting species that have the capacity to become medium or large statured trees should be a consideration.

A tree's functional value based on the benefits and services it provides is secondary to getting the right tree in the right place to survive. However, when it comes to their role in ameliorating some of the effects of urbanization and mitigating climate change and reducing its impacts on communities, the functional values and co-benefits provided by trees take on heightened importance.

7. MAINTENANCE CONSIDERATIONS: While all woody plants require some basic maintenance soon after being planted (e.g., watering, competition control, pruning), different species have different longer-term maintenance considerations that should factor into tree species selection. For example, some quicker growing maple species (e.g., the native silver maple, *A. saccharinum*, and the invasive Norway maple, *A. platanoides*) have weaker wood than slower growing mid to late successional forest species (e.g., sugar maple, *A. saccharum*), making them more prone to storm damage as they mature and presenting a greater potential cost for and liability to cause damage (Grime 2001). However, species selection based on maintenance should only occur among a subset of species already selected based on their intrinsic hardiness and suitability for the site. Further discussion of maintenance best practices is provided in **Section 6**.

8. HERITAGE AND AESTHETIC ATTRIBUTES: In some cases, a specific species (e.g., an apple tree) may be sought to mimic a historical or heritage landscape. However, to ensure successful establishment and growth, the primary and secondary species selection factors listed above should take precedence. Some specific trees or species may have a cultural or heritage value ascribed to them, often in relation to their location in a specific landscape (e.g., an 19th century homestead) with cultural heritage values or their historical uses. However, such cultural or heritage significance is typically ascribed to established trees and does not usually factor into species selection for establishment *per se*, particularly in an urban setting.

Selection of woody species based on aesthetic attributes is a matter of subjective preferences and for woody species is typically related to colour (e.g., of bark, leaves, flowers and/or fruits), although form and size of the species, as well as whether or not it loses its leaves in the winter (e.g., coniferous versus deciduous) may also be factors. Although aesthetic preferences do not inform a species potential to survive in the short or long term, such preferences do often come into play, particularly in urban areas, and have therefore been included as a minor secondary factor.

Notably, assisted migration is discussed in *Guide 4: Potential Street and Park Tree Species for Peel in a Climate Change Context*.

4.3 Nursery Stock and Standards

I would recommend that municipalities try to hire at least one person who has experience in the nursery industry and understands best practices, how trees are grown, harvested and shipped.

Ray Vendrig, Manager, Urban Forest Renewal, City of Toronto, 2020

This section speaks to general best practices related to the types of woody stock used in plantings and standards for screening that stock.

Currently, there are six types of nursery stock readily available for use in southern Ontario: plug seedlings, potted whips and shrubs, potted large trees and shrubs, bare root, machine dug - wire basket and processed ball in burlap. These six stock types are primarily distinguished by their size, the time required to establish them in the nursery and the type of container they are grown in.

There is no one best practice *per se* as it relates to stock type selection, since each type has advantages and disadvantages, as summarized in **Table 4**, and different stock types are suited to different site conditions and planting contexts. However, a common "best" practice of most municipalities is to use smaller stock (e.g., potted tree whips and shrubs) for restoration or naturalization plantings, and to use larger stock (e.g., larger potted trees and shrubs or ball in burlap trees) for plantings in rights-of-way. In general, smaller stock is more suitable when a greater density of trees and/or shrubs are needed, quicker establishment is more important than initial size and there is less concern about damage related to human traffic or vandalism. Larger stock provides something closer to an "instant tree" and is generally more suitable in higher traffic and/or built-up areas where trees are more evenly spaced and more resources can be allocated to maintenance during the initial establishment period.

In addition to planting smaller stock where possible, some experienced practitioners also strongly recommend the use of bare root trees in urban areas and discourage the use of container stock to reduce costs and increase establishment success. The primary rationale provided is the amount of root damage that tends to occur when trees are grown in and then removed from containers before planting (e.g., James Urban[12]).

A related and strongly recommended best practice in terms of planting design is to establish trees in planting beds in urban areas (whether in hardscape or softscape conditions) in a way that mimics their natural growing conditions, which is discussed further in **Section 5.4.7**).

[12] Alliance for Community Trees (Maryland) Third Thursday Webcast Series - Urban Landscaping Part 1: Bareroot Trees http://www.actrees.org/files/Newsletter/bbls_09jun18.html

Table 4. Nursery stock type comparison table

Stock Types	Description	Practical Applications	Advantages	Disadvantages
Plug Seedlings	• Young trees; an average of 18 cm high with a 10 cm root plug and a 3 mm root collar diameter. Grown with soil plug • Often purchased and planted in bulk	• Commonly used in reforestation work • Useful for community plantings	• Cost-effective, sold in bulk • Many trees can be planted quickly • Easy to plant • Lower resource input and cost to growing trees to this point	• Availability of a diversity of species is low (mostly conifers) • Higher mortality rate • No warranty • Can only be installed in low traffic areas • Takes longer to become mature tree • Uncertainty of more mature structure and growth
Potted: Tree Whips and Shrubs	• Trees and shrubs grown in or transferred to 1 to 7 gallon pots • Trees range in height from 100 to 350 cm • Shrubs range in height from 40 to 100 cm	• Often used for restoration work in natural areas • Shrubs of this size are commonly used in most planting applications	• Cost-effective • Easy to install • Less resources are required to grow stock to this point • Warranty is often provided • Smaller stock often outperforms larger stock over time • Larger diversity of species available in this stock type	• Stock can be small when planted and susceptible to damage during establishment • Potted stock is prone to circling roots and root deformities
Potted: Large Trees and Shrubs	• Trees and shrubs grown in or transferred to 10+ gallon pots • Trees range in height from 150 cm and up • Shrubs range in height from 80 cm and up, based on species	• Used for high profile plantings and residential garden design	• Provides an 'instant garden' effect • Shorter time to tree maturation (if well-established) • Warranty is often provided	• Higher cost than smaller stock • Establishment can be difficult and care requirements high during establishment • Equipment often required to install • Container grown stock is prone to circling roots and root deformities • Limited availability of species; tends to be focused on horticulturally valued species
Bare Root	• Trees and shrubs are field grown and harvested • Available in a range of heights, from seedlings to whips	• Used for reforestation, mass tree plantings, or restorations • Useful for community plantings	• Cost-effective • Easy to install • Very low resource input to grow • Warranty may be provided • Easy to position major roots around utility conflicts	• Due to nursery lifting methods, root systems can be compromised • Establishment can be difficult • Stock may be small when planted and susceptible to damage during establishment

Stock Types	Description	Practical Applications	Advantages	Disadvantages
Machine Dug, Wire Basket	• Trees, predominantly deciduous • Large caliper trees, +30 mm caliper • Large multi-stem shrubs and trees, +80 cm height	• Used for street tree and boulevard plantings, residential design • Provides an "instant" semi-mature tree	• Aesthetic impact • Tree is large and sturdy upon installation • Warranty is often provided	• Higher cost than smaller stock • Establishment can be difficult and slow • High care requirements during establishment • Equipment often required to install • Due to root pruning to maintain root ball size, stock is prone to circling roots and root deformities; if wire basket is not removed root deformities can also occur • Limited species availability; tends to be focused on those which can be most easily grown to this size and horticultural varieties
Processed Ball in Burlap	• Trees, coniferous and deciduous. • Large multi-stem shrubs and trees, +80 cm height	• Used for street tree, boulevard plantings and in residential design • Provides an "instant" semi-mature tree	• Aesthetic impact • Tree/shrub is large and sturdy upon installation • Warranty is often provided	• Higher cost than smaller stock • Establishment can be difficult and slow • High care requirements during establishment • Equipment often required to install • Due to root pruning to maintain root ball size, stock is prone to circling roots and root deformities • Limited availability of species; focus on those which can be most easily grown to this size and horticultural varieties

Stock size and type are important but are considered less important than having healthy stock to start with. As a result, a good best practice is to select and inspect stock in the nursery prior to it being delivered to the project site, and then again at the time of delivery. Where possible, selecting trees from nurseries which have similar soil to the site where they are being planted can also support plant establishment.

The *Canadian Nursery Stock Standards* (CNLA 2017), which are to be used in Ontario, include minimum recommended standards for all stock types to ensure that stock can be successfully established given proper care and maintenance. However, nursery stock is not always consistent with these standards in practice. The following key standards provided by the Canadian Nursery Landscape Association (CNLA 2017) should be implemented.

Identified applicable best practices specify all nursery stock should:

- be clearly identified by botanical name and true to the name and size stated
- have a healthy fibrous root system developed using proper cultural practices
- come with dates when large stock were transplanted and / or root pruned on request
- have roots free of physical defects (see examples in **Figures 4-5a, 4-5b** and **4-6a**), and
- be substantially free from pests, weeds, insects and diseases (Bartram 2019c).

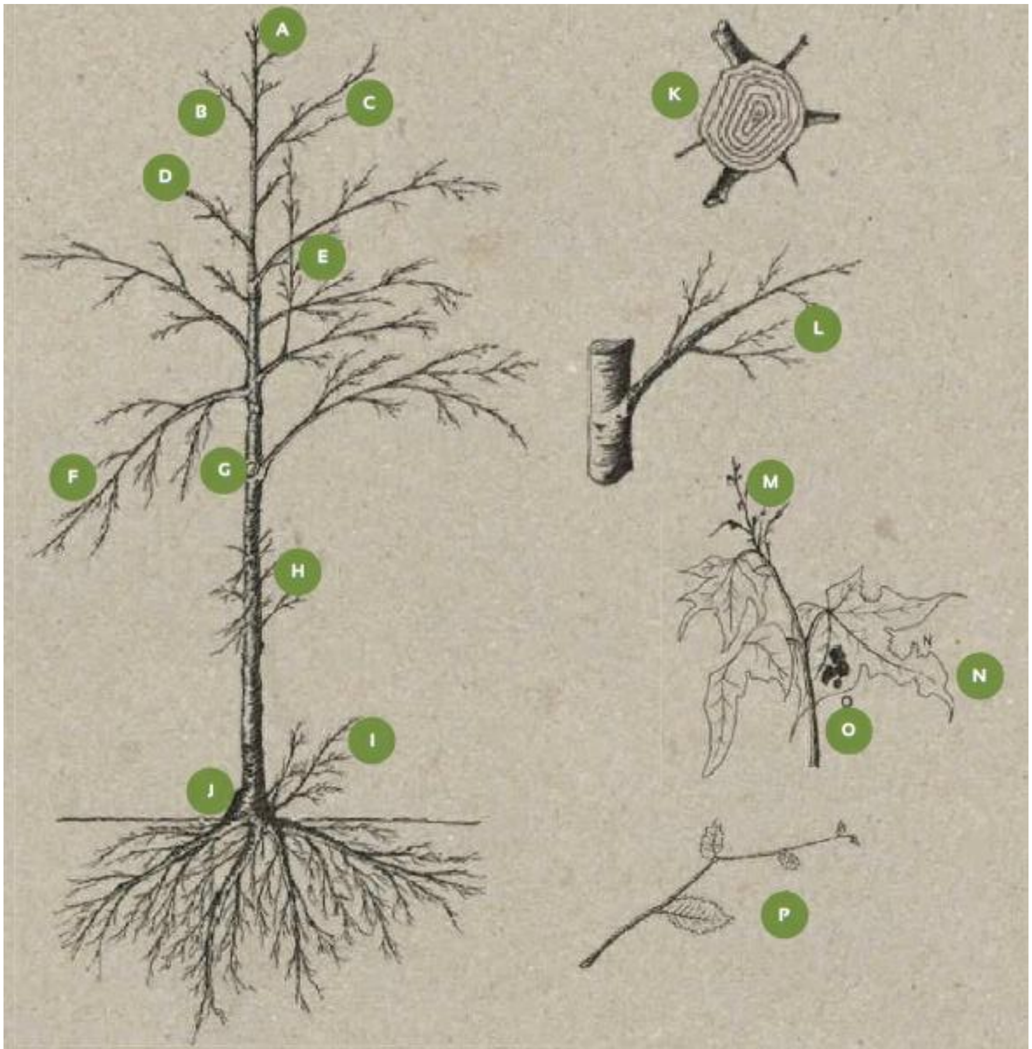
Figure 4-7 illustrates key morphological features to avoid when selecting trees.

Credit: Missouri Botanical Garden website (2019)

Figure 4-5. (a) Circling, deformed root system on newly planted container grown tree (left); (b) long term effect of circling root system on mature tree (right)

Credit: The Plantium website https://theplantium.com/2016/07/05/understanding-plant-nursery-stock-size/ (2020)

Figure 4-6. (a) Circling, deformed root system from container grown tree (left); (b) contained but spreading root system on ball and burlap tree (right)



A	Ill defined leader and or shoot tip dieback
B	Weak laterals with dieback or poor growth
C	Strong growing laterals which may compete with or obscure the leader
D	Stunted or one sided growth
E	Upright branches which run up through the crown
F	Untypical or abnormal growth
G	Large pruning wounds which show no signs of healthy occlusion
H	Large amounts of epicormic growth on the main stem
I	Epicorminc growth emerging from the understock
J	Disproportionate growth of stock or scion wood in relation to each other
K	Abnormal flattening of the main stem which may indicate a degree of vasular dysfunction
L	Poor annual growth in relation to previos years (this may not be apparent where nursery formative pruning has taken place)
M	Shoot tip dieback
N	Abnormal foliar distortions or areas of foliage missing
O	Areas of abnormal discolouration on the foliage
P	Weak, irregular or untypically small foliage

Source: Bartram (2019b)

Figure 4-5. Undesirable morphological characteristics of young nursery trees

Additional good sources of additional information on root health and what to look for in nursery stock include:

- James Urban's article *The Root of the Problem* (Landscape Architecture Magazine, April 2013) (http://www.jamesurban.net/trees)
- The *Tree Grading Cue Card* (2015) (**Appendix D**), and
- Criteria provided by Hirons and Percival (2011), illustrated below in **Table 5**.

Table 5. Important tree nursery stock inspection criteria

Tree specification criteria	
Above ground	**Below ground**
Specimen true to species or variety type	High root ball occupancy
Graft compatibility (if appropriate)	Diversity in rooting direction
Healthy with good vitality	Good root division
Free from pests, disease or abiotic stress	Extensive fibrous root system
Free from injury	Free from root defects (e.g. circling roots)
Self-supporting with good stem taper	Free from pests, disease or abiotic stress
Stem-branch transition height	
Sound branch attachment and structure	
Good pruning wound occlusion	
Canopy symmetry	

Source: Hirons and Percival (2011)

Specific best practices of what to look for in different types of woody nursery stock are summarized below. Recommended root ball to caliper ratios are provided for field grown trees in **Figure 4-8**.

ALL STOCK

- Ensure stock type and size matches size on plant tag.
- Ensure stock is free of pests, pernicious weeds, insects and physical damage.
- Ensure root flare is above the soil line.
- For trees, ensure a straight leader and adequately spaced scaffolding branches. Ensure tree is free of epicormic growth, including water sprouts.
- Ensure roots are not deformed and adequate root material is present to support above ground plant material (see **Figure 4-5**).

POTTED STOCK

- Gently remove the root ball from the pot. If the roots come out without the soil the tree has recently been re-potted and should not be for sale. Roots need to be established within the potting medium prior to being approved for sale.
- If the roots fill the pot completely and the pot is not easy to remove, or roots are fused to the pot, this plant should also be rejected (see **Figure 4-5**).

BARE ROOT STOCK

- Bare root stock is best selected in the field and inspected once harvested. If inspected in the field prior to harvesting potential excessive root damage due to poor harvesting techniques may be missed.
- Select trees in the field based on a straight leader, adequately spaced branches, and general health and vigour.
- Try to ensure the field conditions trees/shrubs are grown in are comparable to conditions in which they will be installed.
- Once trees are harvested ensure that roots are protected from drying and have not been overly exposed to direct sunlight, frost, or excessive wind.
- Minimize the time between bare root stock lifting in the nursery, shipping to the customer and planting.
- Pruning of the above ground portion of a plant to match root loss is not recommended.

WIRE BASKET AND BALL IN BURLAP

- Root ball sizes should be of an adequate width and depth to provide a root system large enough to provide sufficient moisture to the tree during establishment (see **Figure 4-8**).
- Trunks should be centered in the root ball and their diameter should not exceed 10% of the root ball diameter.
- The wire basket should fit the root ball properly and have been installed immediately after digging. Roots are not to be entangled in the wire basket.
- Burlap should contain the entire root ball and associated soil. No soil should be loose or fall out of the burlap during transport.

It is recommended that the urban forester familiarize themselves with these standards and have cue cards on-hand when inspecting stock (a) at the nursery prior to purchase and delivery, and (b) again upon delivery to the planting site or municipal yard. This should include a random inspection of root structure from delivered stock (UFI and Beacon 2018). To facilitate inspections, it is recommended that procurement tenders specify that the municipality has the right to inspect and reject any stock at the provider's expense.

Current examples of the use of these best practices in southern Ontario include:

- The Town of Ajax, which requires all trees intended for municipal plantings to be delivered to a designated municipal yard, where trees are inspected by municipal staff and unacceptable trees are rejected at the supplier's expense; and
- York Region Forestry staff, who go to the nursery to select their stock in advance; this practice (a) greatly reduces the number of trees they need to reject when the stock arrives on site and (b) improves the survival of trees planted on their lands.

Table 7.3.4 Root ball size in relation to caliper for field grown Standard type trees

Caliper (mm)	Minimum root ball diameter (cm)	Approximate root ball depth (cm)	Minimum in-ground fabric bag diameter* (cm)
20	40	20	20
25	45	23	25
30	50	25	30
35	55	27	36
40	60	30	40
45	65	33	40
50	70	40	46
60	75	38	46
70	80	40	50
80	85	43	50
90	95	48	56
100	105	53	60
110	115	58	80
120	125	63	
130	135	68	
140	145	73	
150	155	78	
175	175	88	
200	200	100	

* Adapted from the American Standard for Nursery Stock (ANSI Z60.1-2014) with approximate imperial to metric conversions.

Source: Canadian Nursery Landscape Association (2017)

Figure 4-8. Root ball size in relation to caliper size for field grown trees

4.4 Sources of Nursery Stock

This section touches on current challenges and best practices related to (a) tracking the provenance of nursery specimens, and (b) potential mechanisms for securing adequate quantities of specified species and stock sizes.

Consideration of the source of stock is important when determining suitability for planting within the Region of Peel, as provenance can have a significant influence on survival, as discussed in **Section 4.1**. The Forest Gene Conservation Association (FGCA) has developed a system of certifying seed origin from the time of seed collection through to when plants are ready for sale, based on MNRF's 2010 Seed Zones. However, the practice of planting seed originating from within the same or immediately neighbouring seed zones is evolving in response to the need to consider climate change (Eskelin *et al.*, 2011). Consequently, sourcing at least some stock from more southerly areas identified as being generally suitable (as defined by MNRF's 2019 Draft Ontario Seed Transfer Policy) is an acceptable means of increasing genetic diversity (refer to **Section 4.1**).

… work with, not against, the genetic adaptation that has evolved over many generations, to ensure the long-term success of tree planting efforts; remember that the most expensive planting is a failed planting.

Forest Gene Conservation Association (FGCA), Sperling 2016

In addition to issues associated with provenance, the basic availability of a range of woody species in sizes suited to urban environments is critical to building urban forest resilience. However, the selection of plant species from different provenances is currently and generally limited by nursery stock availability[13], although some nurseries have worked to diversify species and are exploring approaches for meeting specialized project needs.

There are currently multiple barriers to both obtaining the provenance of nursery stock and securing adequate quantities of specified species and stock sizes. Key issues identified are:

- LACK OF SYSTEMS AND REQUIREMENTS IN PLACE FOR SOURCING: Currently, the landscape industry is not required to disclose the genetic sources of their stock and the industry does not actively encourage this practice. Consequently, very few nurseries offer plants that are source-identified from certified seed collectors and many nurseries may not even track this information. This makes it very difficult to obtain source or provenance information related to nursery stock obtained for Peel.

- STRAINED TECHNICAL SUPPORT AND RESOURCES IN ONTARIO: In 2019 the provincial government closed Ontario's long-standing Tree Seed Plant, greatly reducing the FGCA's and others' ability to effectively maintain and manage collected woody species seed in Ontario. The FGCA and Forests Ontario remain the only two organizations in Ontario focussed on tree seed collection, storing and tracking.

- UP FRONT INVESTMENT REQUIRED IN GROWING STOCK: Another key limitation for the industry in growing a greater range of species is the time and resources that need to be invested up front without any guarantee of sale. It takes 5 to 10 years of dedicated maintenance to get larger stock ready for sale.

- ISSUES WITH LONG TERM SEED VIABILITY: Most deciduous woody plant seeds only keep for three to five years[14]. If a large stock of seed from a given provenance is collected in one year it can only be stored for so long before its viability is compromised

[13] Although the example is somewhat dated, Sydnor et al., (2010) found that in Ohio in 2008, nurseries were generally unable to meet the specific requests of urban foresters in terms of the range of species and sizes of nursery stock being sought, particularly for community plantings. Becker (2015) describes the same challenge in the U.S. more recently.

[14] Canada's Tree Seed Centre has successful stored coniferous seed (e.g., white spruce, black spruce, jack pine, red pine) for decades by freezing it at -20°C, but most hardwood species seed (such as oak and silver maple) cannot be dried, do not store well for more than a few years, and must be kept at 4°C with collections made frequently to maintain a viable supply (https://www.nrcan.gc.ca/science-data/research-centres-labs/forestry-research-centres/atlantic-forestry-centre/national-tree-seed-centre/13449).

and it must be planted or discarded. Seed planted which does not translate into plants being sold represents a loss in investment which cannot be recuperated.

- SEGMENTATION OF THE INDUSTRY: Many of the larger nurseries or growing operations are focused exclusively on only one component of production to maximize efficiencies (e.g., whip production, seedling production, ball and burlap). This results in a breakdown of communication and a lack of coordination between those who collect and grow seedlings and those who grow and sell more mature plant material. Urban foresters are generally looking for more mature plant material and would not typically contact a nursery which only collects seed and produces seedlings due to the time it would take to obtain this plant material in a mature form.

- SPECIES AVAILABILITY AND SUBSTITUTIONS: When an urban forester requests a species and it is not available, typically the nursery will substitute it with a different but comparable species or size of stock. The nursery will then record the sale of the substitute and not the original request and use that data to inform what is planted or sourced the following year, providing a skewed picture of the actual demand.

In response to these challenges, some Ontario conservation authorities (e.g., CVC, TRCA, GRCA) have developed their own plant nurseries where they can ensure that seed is sourced from within their seed zone(s). However, these nurseries tend to focus their resources on production of small container, bare root and seedling stock which is primarily suited for restoration/naturalization plantings and not for more formal municipal parks or street tree landscaping projects.

Discussions with some municipal staff and nursery growers in Ontario indicate that contract growing can and does work for some types of tree establishment programs. For example, the City of Toronto has an effective contract growing program in place for plant material used in the restoration of ecologically significant areas. However, City of Toronto staff note contract growing for larger caliper trees (i.e., street and park trees – 40 to 60 mm dbh) is more challenging because it takes seven years to grow a tree from seed to the required size and therefore requires a municipality to guarantee funding for a program many years into the future (R. Vendrig pes. comm., **Appendix B**).

Given this context, several suggested best practices are discussed below.

- REQUEST AND SUPPORT REQUIREMENTS FOR BETTER SOURCING: The FGCA administers a voluntary seed source certification program called "Ontario's Natural Selections", whereby the source of seed/stock is verified and buyers can have reasonable assurance of plant provenance. The FGCA also provides support to seed collectors and growers, including the use of climate models to identify seed collections areas having a climate similar (enough) to the planting area.
    - It is recommended that Peel support those (e.g., FGCA, Forests Ontario) providing local seed collector training and seed collection, as well as collaborating with others in the U.S. doing the same. The changing climate

requires collaboration with states to the south to obtain seed and/or stock that will help build local urban forest resilience.
    - It is also recommended that Peel and its partners request provenance information before purchasing stock, work with growers who provide source-certified stock (ideally in accordance with the FGCA's standards), and lobby local organizations (e.g., OALA) and the government to establish standards for tracking provenance.
    - Peel and its partners could also lobby the Nursery Trades Association to develop a mechanism to better track demand for different species that somehow accounts for species requests that are not filled to better gage the demand for native species.

- WORK WITH LOCAL PARTNERS TO TEST AND OBTAIN A GREATER DIVERSITY OF STOCK: Municipalities should engage with local conservation authorities who have nurseries (in Peel, that would be both CVC and TRCA) as well as other partners (e.g., Forests Ontario, FGCA) to explore opportunities for both testing and providing potentially suitable stock for a range of tree species from different provenances.

- ENGAGE IN CONTRACT GROWING: Contract growing requires the buyer to pay an up-front fee for the production and distribution of desired nursery stock, thereby limiting the financial risk to the producer and ensuring the desired plant material is available.
    - It is recommended that, in consultation with the industry, a plan be put together which allows for a mutually beneficial partnership between the Region, its municipal partners and growers. Key elements in this partnership could include:
        - Tools for proactive forecasting of stock species and size requirements;
        - Compensation up front to cover a portion of the seed collection, germination, and growing costs to compensate a nursery for its investments to grow less common species and larger stock;
        - Mechanisms for improved coordination between seed collectors and the municipalities to offer access to a broader range of potentially suitable native species and populations;
        - Consideration of mixing seed from different provenances within climatically similar ecodistricts to enhance genetic diversity and resilience within the same species; and
        - Providing municipalities with preferred access to stock as it becomes available.
    - This model can also potentially help ensure that properly sourced seed/stock is used and provide opportunities to procure less commonly available species that may be very successful in urban environments (e.g., *Crataegus* spp.).
    - It is recognized that contract growing may present some challenges for local municipal staff who may not be able to predict species requirements five years in advance or be able to provide an up-front retainer. The Region could provide support in this regard by facilitating contract growing through its Operational Efficiencies and Access Control Committee - Joint Contract Sub-Committee tasked with combining contracts for greater financial and logistical efficiencies.

Some wholesale nurseries known to provide native woody plants in the Peel area are listed in CVC's Guide to Native Plant Nurseries and Seed Suppliers (2011), available on their website. In addition, Landscape Ontario and the Canadian Nursery & Landscape Association (CNLA) may be among the organizations interested in working with the Region (and others) to help develop networks of local seed collectors, develop guidelines and recommendations for tree seed sourcing and develop guidelines for contract growing.

4.5 Use of "Native" Species

Like most of the topics covered in this guide, there is a lot that has been and could be said about native species. The focus of the discussion in this section is on their use in municipal streetscapes, rights-of-way, parks and open spaces in Peel's urban areas outside of natural areas.

"Native" plants are defined as species that occur naturally in an ecoregion and/or habitat where, over the course of evolutionary time, they have adapted to the physical conditions and co-evolved with other species in that system (adapted from University of Maryland Extension website). For the purposes of this guide, the term "native" is applied broadly to include plants known to occur naturally in eastern North America. However, just because a species is native to Peel does not necessarily mean it is suitable for a given site. As noted above, some species that occur in Peel have a range extending from central Ontario to southern Florida (e.g., red maple) while others have much narrower ranges that may shift outside the Region with climate change. In addition, conditions in an urban site typically will not support many species able to sustain themselves in Peel under conditions more akin to their natural setting. Therefore, woody species selected for urban plantings in Peel should be from seed sources adapted to the local range of existing - and anticipated - climatic conditions (as discussed in **Section 4.1**) and suited to the local site conditions (as discussed in **Section 3**).

The use of native species when planting within or close to natural areas is generally well-accepted in Peel and is even incorporated in municipal Official Plan direction. Conservation Authorities like CVC require native species to be planted for any planting/restoration work in their regulated areas (i.e., areas within or adjacent to natural features and natural hazards). It is also widely accepted that highly invasive species[15] should be avoided both within and outside of natural areas, and that within and adjacent to natural areas, non-native non-invasive species should also be avoided. However, there has been a long-standing controversy about the extent to which exclusive use of native tree and shrub species is appropriate in more built-up urban settings, especially in locations where only the hardiest trees are able to survive.

Native trees have two main advantages: (a) they are adapted to local conditions and therefore tend to require fewer inputs (e.g., water, fertilizer) to grow and thrive than non-natives, and (b)

[15] Terrestrial invasive plants are defined by the Ontario Invasive Plant Council as trees, shrubs or herbaceous plants that have been moved from their native habitat to an introduced area where they are able to reproduce quickly and crowd out native species. Some of the most widespread invasive trees and shrubs in Peel include common buckthorn and Norway maple.

they have evolved to co-exist with other native species and therefore provide critical food and shelter for native wildlife such as birds and insects. Examples of problems associated with some non-native plants that include: not being usable by native insects or wildlife as a food source, production of allelopathic chemicals which inhibit the growth of native plants and reduce biodiversity, greater water use and nutrient cycling, being more susceptible to damage during storms due to rapid growth (and weaker wood), and acting as hosts for invasive pests. If and where non-native species are being considered, those that display any of these characteristics should be avoided.

There seems to be some agreement among those engaged (e.g., see list of engaged municipalities who provided feedback in **Appendix B**) that readily available native species are preferable and can generally tolerate (and even thrive) in urban park settings and vegetated (not paved) rights-of-way with adequate shoulder space. But in more difficult built-up spaces where there is more human traffic and less permeable surfaces, many of the available and "proven" native species and cultivars tend not to fare as well as some of the readily available non-native species.

There have been decades of introduction of non-native (including some invasive) tree and shrub species in Peel's urban areas. Furthermore, conditions in urban areas are only going to become more challenging for tree establishment and growth as urban development intensifies and the environmental stressors associated with climate change increase in intensity. However, when considering introducing non-native species, it should be recognized that there is no "firewall" between the built environment and adjacent natural areas, and that on a landscape scale they are both part of a broader, connected ecosystem. Non-native species introductions that could alter or harm natural ecosystems and native species should be minimized.

Therefore, the suggested balanced but precautionary approach includes the following.

- Avoid all woody species considered highly (or "priority") invasive species.
- Preferentially select among suitable native species, including trial selection of some native species with provenances from more southerly ecodistricts (per MNRF 2020), to the greatest extent possible.
- Allow for inclusion of some non-invasive non-native species in difficult sites outside of areas regulated by CVC or TRCA where no or insufficient native alternatives exist.
- Work with local partners to expand the repertoire of suitable native species for planting in Peel's urban areas by undertaking trials for unproven but potentially suitable species in the region's urban streetscapes and parks.

Notably, CVC's policies require native species be planted in their regulated areas and TRCA's policies generally support the same practice. Therefore, the best practices for Peel have been refined to reflect this context.

4.6 Summary of Tree Selection and Procurement Best Practices

There are many factors to consider in the selection of tree species for planting in urban environments, and many aspects that are important for suitable nursery stock. The sections above highlight the key factors and considerations and provide resources where additional information can be obtained. It is important for urban forest managers and practitioners to understand these factors and, if required, seek input from local experts with knowledge of plants and planting practices. Best practices identified Section 4 are summarized in **Table 6**.

Table 6. Summary of best practices for tree stock selection and procurement

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Seed Source and Provenance (Section 4.1)	• Preferentially work with southern Ontario nurseries that purchase source-identified seed from certified collectors. • Support and participate in trials with different potentially suitable woody genera, species, cultivars and (if possible) provenances to expand the list of stock considered "proven" in Peel's urban areas in partnership with other agencies and organizations. • Consider woody species from the list of potentially suitable species for Peel developed for this project.

Species Selection (Section 4.2)	**SPECIES-SPECIFIC CONSIDERATIONS**
	• Species selection should be undertaken in conjunction with site assessment data (see Section 3). Select trees from nurseries which have similar soil to the site where they are being planted.
	• Species selection should prioritize eco-physiological factors over practical, service-based and aesthetic or cultural considerations, in the following order:
	  o PRIMARY SELECTION FACTORS
	    ▪ Hardiness and health
	    ▪ Successional niche
	    ▪ Tolerance of site conditions
	    ▪ Growth form and/or size
	    ▪ Contribution to diversity
	  o SECONDARY SELECTION FACTORS
	    ▪ Functional value
	    ▪ Maintenance requirements
	    ▪ Aesthetic and/or cultural attributes
	• Tools and other resources that provide species-specific information should be used by a person with knowledge of ecological, silvicultural and horticultural requirements and in conjunction with an understanding of site conditions.
	
	URBAN FOREST DIVERSITY CONSIDERATIONS
	• Implement species diversification at multiple scales (e.g., street level, site level, neighbourhood, ward level).
	• Enhance genetic diversity within a species where appropriate, by planting a range of suitable provenances of a species.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	• Strive to diversify species and genus level diversity among street and park trees while also incorporating species from genera other than those that are already widespread and those with pests/pathogens that are known to be problematic in eastern North America. • Work towards a target of having no more than 5% genus-level diversity by stem count for trees outside natural areas with the understanding that this can be a challenge as long as a limited number of suitable species are known and available, particularly for street trees.
Nursery Stock and Standards (Section 4.3)	• Use smaller stock for restoration or naturalization plantings and larger stock for plantings in rights-of-way. • Carefully select and inspect stock in the nursery prior to it being delivered to the project site, referring to standardized cue cards describing best practice criteria, and again upon delivery to the project site or municipal yard. This should include a random inspection of root structure and mechanical damage of delivered stock. • To facilitate inspections, it is recommended that procurement tenders specify that the municipality has the right to inspect and reject suspected problem or damaged stock at the provider's expense.

Sources of Nursery Stock (Section 4.4)	**REQUEST AND SUPPORT BETTER SOURCING**
	• Support those providing local seed collector training and seed collection (i.e., the Forest Gene Conservation Association) and collaborating with those in the U.S. doing the same.
	• Request provenance information before purchasing stock, work with growers who provide source-certified stock, and lobby local organizations (e.g., OALA) and government to establish standards for tracking provenance.
	• Lobby the Nursery Trades Association to develop a mechanism to better track demand for different species that accounts for species requests, even if such requests are not filled.
	• Work with nurseries to produce trees with better form.
	
	WORK WITH LOCAL PARTNERS TO TEST AND OBTAIN A GREATER DIVERSITY OF STOCK
	• Engage with local conservation authorities as well as other partners to explore opportunities for both testing and providing potentially suitable woody stock of a wider range of species from an increased number of provenances.
	
	ENGAGE IN CONTRACT GROWING
	• Develop a plan which allows for a mutually beneficial partnership between the Region/its municipal partners and the growers. Key elements in this partnership could include:
	    o Tools for forecasting stock requirements
	    o Compensation up front to cover a portion of seed collection and nursery costs
	    o Mechanisms for improved coordination between seed collectors and municipalities (to offer access to a broader range of native species)

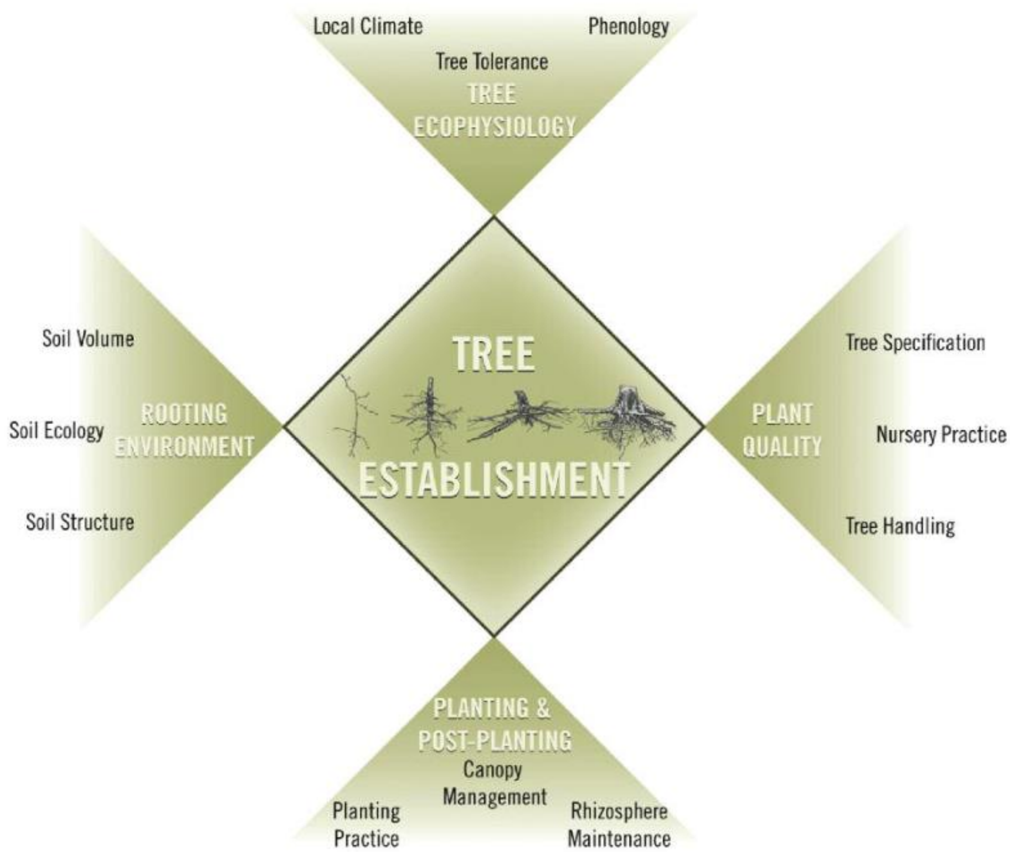
Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	◦ Consideration of mixing seed from different provenances within climatically similar ecodistricts, and ◦ Providing municipalities with preferred access to stock as it becomes available. • Facilitate setting up contract growing in Peel by having the Region coordinate contract growing for its local municipalities through its Operational Efficiencies and Access Control Committee - Joint Contract Sub-Committee tasked with combining contracts for greater financial and logistical efficiencies.
Use of Native Species (Section 4.5)	• Avoid all woody species considered potentially invasive. • Preferentially select among suitable native species, including trial selection of some native species with provenances from more southerly ecodistricts (per MNRF 2020), to the greatest extent possible. • Allow for inclusion of some non-invasive non-native species in difficult sites outside of areas regulated by CVC or TRCA where no or insufficient native alternatives exist. • Work with local partners to expand the repertoire of suitable native species for planting in Peel's urban areas by undertaking trials for unproven but potentially suitable species in Peel's urban streetscapes and parks.

5. Tree Establishment

This section focusses on tree and shrub establishment practices in the following planting situations: hardscapes (e.g., such as downtown boulevards), municipal streets/rights-of-way and municipal open spaces (including parks). Establishment of trees in naturalized or established wooded natural areas is not the focus of this report.

The aspects of establishment practices that are specifically addressed include site selection and preparation (**Section 5.2**), soil management (**Section 5.3**) and planting practices (**Section 5.4**). Watering, pruning, mulching/competition management and pest/disease management are addressed in **Section 6**.

Multiple factors affect the establishment of planted trees. As illustrated in **Figure 5-1**, these factors can be grouped into four categories: tree ecophysiology (addressed in **Section 4.1 and 4.2**), plant quality (addressed in **Section 4.3 and 4.4**), and planting/post planting care and rooting environment, addressed in this section.



Credit: Hirons and Percival (2011)

Figure 5-1. Illustration of key variables that influence tree establishment

The recommendations contained herein assume that site-appropriate, healthy tree species are matched to an adequately characterized site (see **Section 3**). Site characteristics related to establishment in Peel Region are provided in Report 3.

5.1 Defining the Establishment Period

The "establishment period" for trees is typically considered the first five years after planting. However, this can vary depending on the age and size of the stock when planted as well as the site conditions. The root establishment period is an alternate measure of the establishment period that is more refined. For shrubs, this is the time it takes for roots to spread in the ground to the edge of the canopy (Zuzek 2018). According to Zuzek (2018), the root establishment period for trees can be estimated using stem diameter at the time of planting. Tree establishment periods as identified by Zuzek (2018) for Minnesota using this method are provided in **Table** 7.

Table 7. Shrubs Establishment Period

Caliper of Tree Trunk*	Root Establishment Time
1 inch (2.54 cm)	1.5 years
2 inches (5.08 cm)	3 years
3 inches (7.62 cm)	4.5 years
4 inches (10.16 cm)	6 years
5 inches (12.70 cm)	7.5 years
6 inches (15.24 cm)	9 years

*Using method described in Zuzek (2018)

Given that Peel Region's climate is generally comparable to that of Minnesota, and based on the consulting team's applied experience, the establishment periods put forward by Zuzek (2018) are considered generally appropriate for shrubs and trees in Peel. This analysis suggests that establishment for woody species may take closer to ten than five years.

5.2 Site Selection and Preparation

This sub-section speaks to site selection considerations including: land use, planned construction, available planting space (width, depth, volume), utilities, drainage, maintenance considerations, soil testing, and (to a limited extent) other design considerations (e.g., street character/design, cultural perceptions, Crime Prevention Through Environmental Design (CPTED)). This sub-section also includes site preparation topics such as soil aeration, scarification and competition control.

The urban environment rarely presents optimal establishment conditions for trees. In addition to spatial constraints, the urban environment imposes a suite of abiotic stressors including and not limited to heat, drought, waterlogging, air pollutants, de-icing salt, intense winds, soil mineral deficiencies and compaction. The potential for these stressors to negatively impact tree establishment is compounded by climate change and potential damage sustained in relation to human traffic and/or development activities (e.g., road widening encroaching on rooting space). In some cases where a series of cumulative impacts are anticipated and no improvements to the site design or conditions can be made, it may not make sense to plant a tree in the first place. However, where a decision is made to plant, it is imperative that - following a thorough site assessment (**Section 3**) and proper tree selection (**Section 4**) - urban foresters consider approaches and tools to mitigate site constraints and support healthy tree establishment.

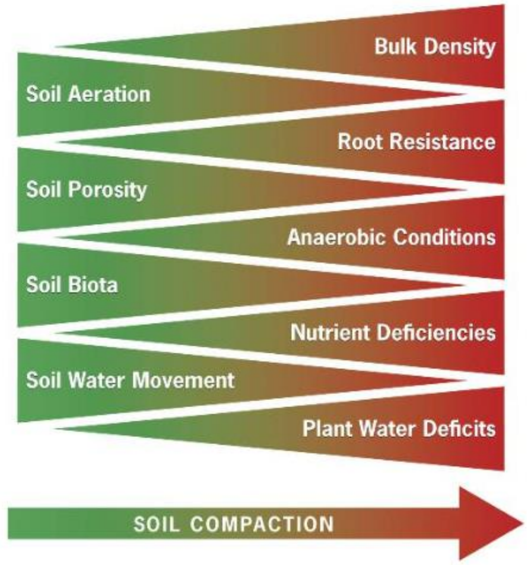
Table 8 presents common site constraints for trees in urban areas and suggested mitigation measures. Some site constraints, such as soil pH, are not easily mitigated and in such cases it would be prudent to select a species tolerant of site conditions, rather than attempt to ameliorate soil chemistry.

Table 8. Mitigation options for site constraints affecting tree establishment

Site Constraint	Impact on Tree Growth Potential	Potential Mitigation Options
Salt	• Decreases plant's ability to uptake water • Salt spray can cause death of foliage, meristems/buds; extent of spray is positively correlated with speed of traffic	• Salt is water soluble; well-drained soils allow salt to wash through soil column faster • Active flushing of soils after spring thaw (Urban *et al.*, 2019), assuming good drainage is in place • Plant a diversity of species thought to be salt-tolerant • Use of raised planter beds with soil cells beneath where possible rather than soil cell installations at grade (Ordonez *et al.*, 2018) • Implementation of a salt management program* including targeted use of alternative de-icers
Weed competition	• Increased competition for water, light and nutrients	• Remove competing vegetation • Plant larger nursery stock • Apply mulch to discourage weed establishment • Monitor problem areas
Soil compaction (see Figure 5-2)	• Decreases ability of plant to uptake water and nutrients • Decreases rooting potential • Decreases soil biota • Negatively effects drainage	• Prevention of compaction should be the first priority • Implement best practices when working around trees (including during planting), mulch, and consider installing physical barriers to foot and vehicular traffic (e.g., perennials and shrubs, fencing, pavement bridge, etc.) within the dripline + 1 m • Measure surface and subsurface soil compaction using a soil penetrometer to determine what part of the soil profile is compacted; bulk density can also be calculated • Aerate soil (see McGrath *et al.*, 2019)

Site Constraint	Impact on Tree Growth Potential	Potential Mitigation Options
		• Investigate feasibility of replacing soil within the planting area if aeration methods are not sufficient or feasible (see McGrath *et al.*, 2019, DTAH 2013) • See discussion in **Section 5.3**
Overhead utilities	• Can impose limitation on canopy growth • Frequent pruning required to avoid conflict with overhead wires may harm tree	• Plant shrubs or small or medium-sized tress that will not conflict with utilities once their full growth potential is reached • Move or install underground instead of overhead wires when the expense is warranted
Underground utilities	• Perceived conflict between root growth and utilities • Integrating utilities into root zones increases available soil volume for trees	• Plant trees a minimum of 2 m from utilities • Implement vertical zoning, allowing the root zone to be above or within the same space as utilities (see Chapter 2.3 of DTAH 2013) • Consider species tolerant of root pruning
Limited rooting space	• Poses limitation on tree growth potential	• Plant shrubs or small trees that can reach full growth potential within space available • Investigate ways to increase rooting depth/depth of planting space • Investigate potential to share soil volume of multiple planting spaces among planted trees
Inadequate drainage (excessive or insufficient)	• Insufficient drainage can lead to anoxic conditions and, eventually, root death, or shallow rooting that increases risk of leaning or toppling • Excessive drainage limits water available to plants	• Re-route water source(s) • Curb cuts could allow surface water to enter or exit planting areas • Install tile drainage in sites with insufficient drainage • Amend soil to reflect desired condition • Replace soil (for instructions on how to backfill soils, see Barcham 2019c)
Adjacent impermeable surface	• Restricts infiltration of water and nutrients • Impacts soil biota • May direct surface water to or away from planting area	• Investigate opportunities for permeable hardscaping (e.g., **Figure 5-3**) • Investigate opportunities to widen planting area (e.g. retrofit or new construction) • Investigate opportunities for subsurface soil volume
Metal tree grates	• Restricts tree growth and can lead to mortality if undersized for mature tree size	• Remove existing undersized grates and cease future use (DTAH 2013) • Use flexible plastic grates only when necessary
High winds	• Contributes to leaf desiccation • Potential to cause leaning or toppling of trees • Potential for rotation and/or stem breakage of newly-planted trees	• Increase irrigation frequency • Secure trees (e.g. stakes or root anchoring system) • Consider planting in sheltered locations • Preventative branch pruning • Select species more tolerant of high winds
Herbivory	• Direct damage to plants	• See **Section 6.3**

* It was noted by Regional staff that local municipalities already have salt management programs for roads and that current level of service on regional roads requires bare pavement because they support substantial movement of goods, and so mitigation of this nature would not be feasible at this time.



Credit: Hirons and Percival (2011)

Figure 5-2. Soil characteristics modified by soil compaction

Credit: Barcham (2019c)

Figure 5-3. Example of trees planted in about 30 m^3 of good quality soil per tree in built urban setting using soil cells beneath permeable pavers

5.3 Soil Management

I believe that the bigger issue is the below ground limitations. We continue to battle with soil volumes, soil quality, conflicts with existing infrastructure, etc. … If we plant better quality trees in more suitable locations, even if it means less trees planted, we will have higher success rates moving forward.

Ken Snowden, Assistant Manager, Parks Operations, Abbotsford, B.B., 2020

Work more on soil quality on urbanized sites. It does no good to plant a quality tree in a hole that is made of broken concrete and salty soil.

Stephen Smith, Urban Forest Associates (UFORE), 2020

Having the appropriate volume and quality of soil in planting areas is among the most critical factors in the viability of a planted tree. It is widely accepted and increasingly recognized that the volume and structure of soils directly impacts the health of trees (Coder 2000). This subsection touches on soil volume requirements (**Section 5.3.1**) and soil quality (including amendments such as compost, and mycorrhizae) (**Section 5.3.2**) to support tree establishment in municipal rights-of-way, parks and open spaces in Peels' urban areas.

5.3.1 Soil Volume and Depth

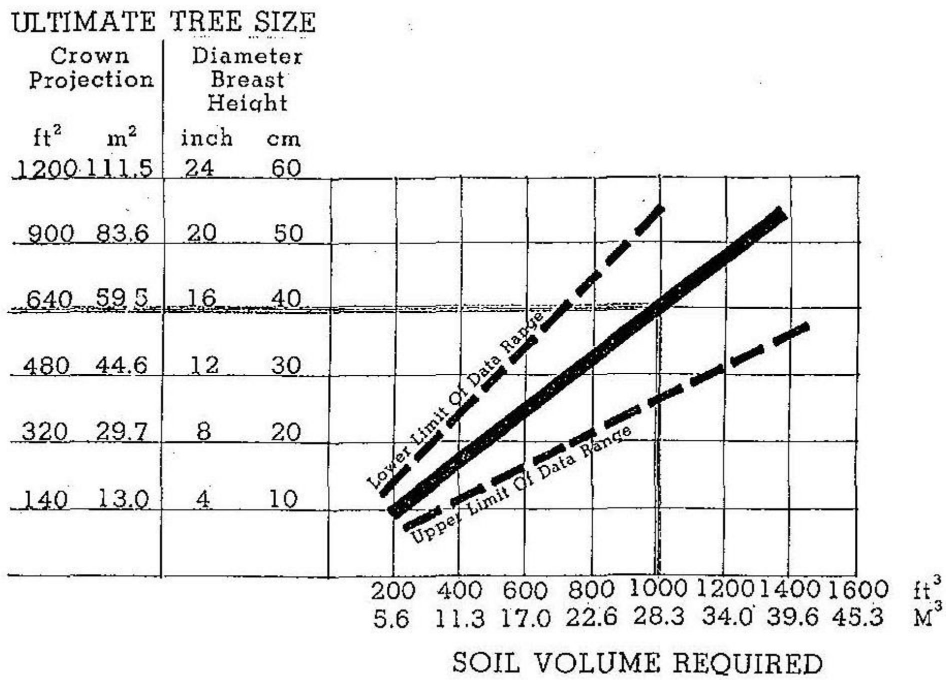
This section is specifically focused on urban trees in built up streetscapes, which tend to have the greatest constraints in terms of available soil volumes.

It is widely recognized that greater lateral soil volumes (where uncompacted) and pavement openings are positively correlated with urban tree health and growth (McGrath *et al.,* 2019, DTAH 2013, Grabowsky and Bassuk 1995, Kopinga 1991, Lindsey and Bassuk 1991). However, in an urban context where suitable rooting space must often be created and competes with other below-ground urban design elements, such as sewers and utilities, how much volume and depth of soil is enough?

Research by James Urban (1992) on soil volume published nearly three decades ago (see **Figure 5-4**) based on his applied experience, recommended 28.3 m^3 for a 40 cm dbh tree with a crown projection of about 60 m^2. Although there have been several different depictions of the original ranges recommended by Urban (e.g., Hirons and Percival 2011, DTAH 2013, City of Kitchener 2015), they continue to build on the approach and assumptions provided in Urban's original model. For example:

- Municipalities such as Toronto, Oakville, Richmond Hill, Vaughan and Markham specify a minimum of 30 m^3 of high-quality soil per tree, with up to 10 m^3 of allowable shared soil volume between two trees noted in some of the guidelines (e.g., DTAH 2013).
- York Region targets at least 16 m^3 for each street tree, with access to 30 m^3 as shared root space (Lane 2013).

- The City of Kitchener provides more nuanced guidance and specifies minimum soil volume requirements and allowable shared volumes per tree based on anticipated mature tree diameter (at breast height) (see **Figure 5-5**).



Credit: Urban (1992)

Figure 5-4. The original graph of recommended soil volumes published by James Urban in 1992, which remains best practice

Minimum Soil Volume (SV) Requirements by Tree Size			
	Large Stature Tree (LST) ≥60cm	Medium Stature Tree (MST) ≥40cm	Small Stature Tree (SST) 20 cm
Minimum SV for one tree	45 m^3	28 m^3	17 m^3
Minimum SV per tree where soils shared	30 m^3	18.5 m^3	11 m^3
Allowable shared soil volume	15 m^3	9.5 m^3	6 m^3

Credit: City of Kitchener Development Manual, Section M (2015)

Figure 5-5. City of Kitchener's minimum soil volume requirements

As tree roots primarily spread laterally, sufficient room for lateral rooting is needed. However, in reaching the desired total soil rooting volume, minimum soil depths need to be achieved. Recommendations for soil depth vary but are generally in the 1.0 m range.

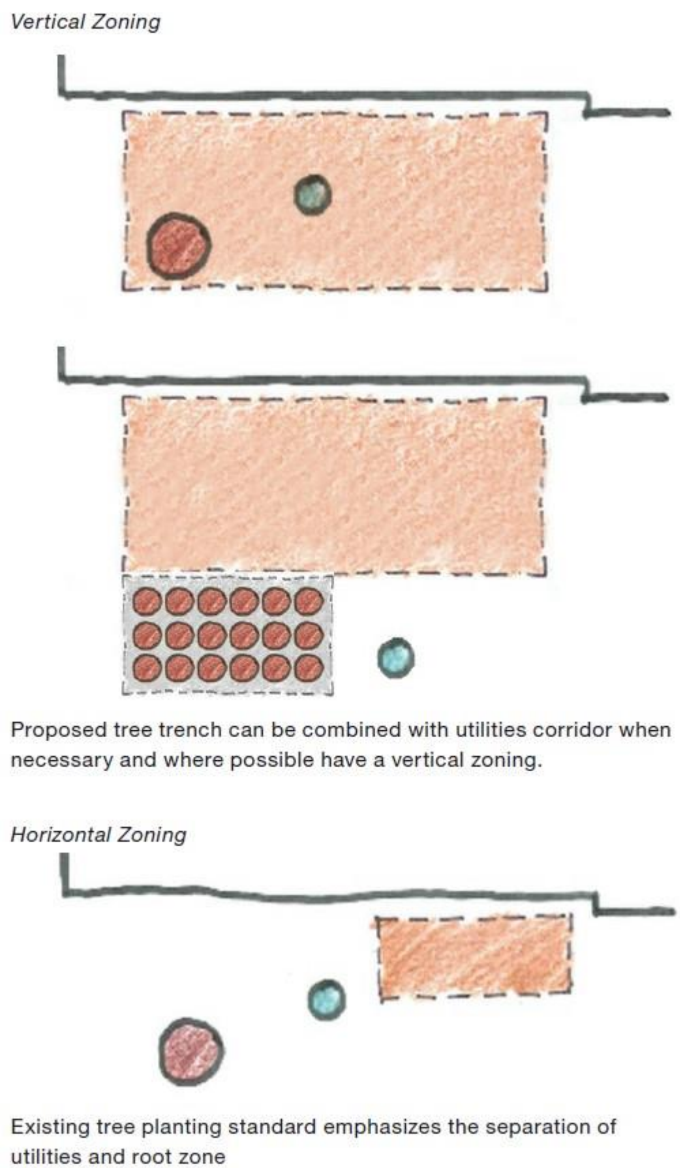
- The City of Toronto recommends a minimum soil depth equal to the height of the tree's root ball, with optimal minimum depth of 1 m (DTAH 2013).
- The City of Kitchener (2015) differentiates between minimum soil depths for residential plantings in boulevards with utilities (45 cm) and those for all other areas (90 cm), and further specifies that soil depths are not to exceed 1.0 m.

Although best practice volumes can be challenging to accommodate in built-up or urbanizing areas, effective strategies for obtaining such volumes include:

- Use of soil cells or comparable technology to provide rooting areas under supported impermeable surfaces
- Use of soil cells or comparable technology to connect the rooting area of a tree surrounded by impermeable surface (e.g., sidewalk) to an adjacent open area (e.g., yard or park), and
- Tree clustering or co-plantings to allow shared soil volume/space (see **Section 5.7.1**).

Given the need for balance between tree requirements for soil volume, depth and lateral rooting, the recommended best practices based on a synthesis of the recommendations above are:

- The soil volumes identified for the City of Kitchener (2015)
    - For small stature trees at maturity (20 – 39 cm dbh at maturity) minimum of 17 m^3/tree and 11 m^3 /two trees (up to 6 m^3 shared)
    - For large stature trees at maturity (40 – 59 cm dbh at maturity) minimum of 28 m^3/tree and 18.5 m^3 /two trees (up to 9.5 m^3 shared)
    - For large stature trees at maturity (≥ 60 cm dbh at maturity) minimum of 45 m^3/tree and 30 m^3 /two trees (up to 15 m^3 shared)
- Minimum soil depths of 90 cm and maximum soil depths of 1.0 m
- Where boulevards have underground utilities, tree planting soil volumes should be integrated with utility zones to the extent feasible using "vertical zoning" (see **Figure 5-6**), and
- Where soil volumes are shared among trees, planting distances of 6 to 10 m on center.



Credit: DTAH 2013

Figure 5-6. Vertical zoning utility placement allows for increased rooting space

5.3.2 Soil Quality

Soil quality is as important as soil volume to tree establishment and growth but continues to be overlooked and misunderstood.

Soil quality includes the physical, chemical and biological properties of soil. Physical quality refers to soil structure and texture and is most affected by compaction. The chemical properties of soil refer to pH, mineral content, available nutrients and presence of contaminants (e.g., hydrocarbons, metals, etc.). Lastly, the biological properties of soil include its capacity to support essential soil microbes, fungi and fauna, including but not limited to mycorrhizae and bacteria.

The depth and breadth of the subject of soil quality is expansive and cannot be covered in this guide. The subsections provided below focus on key aspects of soil quality that should be considered for plantings in municipal rights-of-way and parks or open spaces in Peels' urban areas. In all cases, available soils should be tested for these components to assess the substate suitability and determine if any amendments or soil replacement is required.

SOIL STRUCTURE

The interstitial spaces between soil particles and peds hold water, air and microbiota essential for plant growth and provide pathways for root growth. Soil compaction, especially in the upper 30 to 60 cm of soil where most tree roots are located, reduces these interstitial spaces, thereby inhibiting plant growth by limiting infiltration of water and air and decreasing the roots' ability to absorb air, water and nutrients (Morton Arboretum 2020, Bassuk 2019).

Sandy soils (such as those associated with the Iroquois shoreline) often have little or no ped development but excellent drainage, whereas soils dominated by clays (such as those associated with the Peel Plain and most of Peel's urban areas) or containing large amounts of organic matter are more likely to form strong peds. However, clay-dominated soils are also more prone to compaction.

Soil compaction can be assessed with a soil penetrometer or by measuring bulk density.

- A soil penetrometer is an inexpensive tool that measures resistance to a probe inserted into the soil measured in psi (pounds per square inch). Roots are unable to penetrate soil compacted to 300 psi or more (Schuler *et al.,* 2000). Soil assessed near or over this level should be aerated.
- Calculating soil bulk density (i.e., dry weight divided by volume) is another method used to assess compaction but requires soil samples to be sent to a laboratory. Ideal soil bulk densities vary with soil texture. Bulk density thresholds impacting root growth, according to the United States Department of Agriculture (USDA), are provided in **Figure 5-7**.

Soil Texture	Ideal Bulk densities	Bulk densities that may afffect root growth	Bulk densities that restrict root growth
	g/cm3	g/cm3	g/cm3
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Slilt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47
Source: Protecting Urban Soil Quality, USDA-NRCS			

Credit: USDA website

Figure 5-7. Table of soil bulk density thresholds impacting root growth for different soil textures

Most roots are unable to penetrate moist fine-textured soils having a bulk density greater than 1.4 to 1.6 g/cm^3, compared to more coarse textured soils in which root penetration is inhibited at bulk densities above 1.75 g/cm^3. Bulk densities inhibiting root penetration are lower when soils are drier (i.e., a moist soil allows easier root penetration), and root penetration strength varies across species (e.g., Kozlowski 1999, Brady and Weil 2008). As such, the values provided in **Figure 5-6** must be considered in the context of the hydrologic regime of the site and the species being planted.

Prevention of soil compaction is much more time and cost-effective than remedial measures and can be achieved using one or more the following methods:

- Prevention of uncontrolled foot and vehicular traffic within rooting zones of trees[16], especially when soils are wet, which can be achieved through use of tree protection measures
- Use of permanent physical barriers and/or underplantings
- Applying a thick layer of mulch (e.g., about 10 cm)
- Avoiding use of screened soil, and / or
- Adherence to proper soil preparation procedures.

If traffic within the rooting zone is unavoidable, compaction can be reduced by placing plywood over a minimum 10 cm layer of wood chip mulch on the ground. Compaction can also be at least partially mitigated through aeration and scarification to re-introduce interstitial spaces between soil particles.

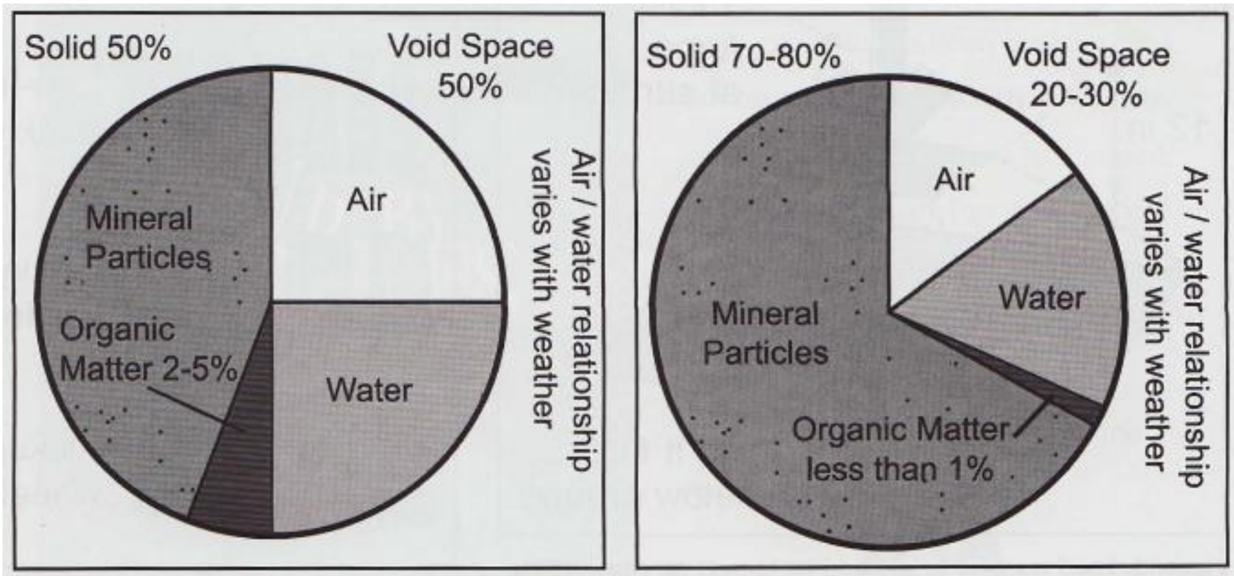
Where topsoil has been partially or completely removed and subsoil layers have been compacted, and there is no existing vegetation requiring protection, "soil profile rebuilding" is recommended (as per the International Society of Arboriculture's Soil Profile Rebuilding specifications, CSI Code 02910). This approach must be tailored to the specific site conditions and includes a combination of soil replacement, targeted tilling of the compacted soil, and introduction of compost.

SOIL COMPOSITION

In addition to having good structure, good quality topsoil should have a suitable ratio of sand:silt:clay:organics, contain adequate concentrations of macro and micro-nutrients, and should not contain too much vegetative debris or exceedances of contaminants, particularly those likely to harm plant health. All three local municipalities in Peel have standards and specifications for soil testing that include target ranges of soil texture, organic matter, debris, pH and nutrients that should be tested for prior to tree establishment.

Urban soils are often impacted by or a by-product of construction practices combined with years of human interference and use, and as a result typically have higher mineral content and less air, water and organic matter than soils typical of forest environments (**Figure 5-8**).

[16] Rooting zones can extend up to three times the diameter of the tree crown and are opportunistic in nature (Perry 1989).



Credit: Urban (2008)

Figure 5-8. Comparison of soil composition - ideal forest soils (left) versus urban soils (right)

Although it is always a best practice to try and use available native soils, all soils should be tested before use to confirm they fall within the established ranges set for good quality soils. Testing may reveal that soil amendment or even replacement is required to ensure the tree(s) being established have a rooting environment with adequate structure and quality.

In general, soils appropriate for Peel's urban areas are free of coarse vegetation, debris and large stones and consist of 40 – 60% sand, 30 – 40% silt, 10 – 25% clay, a minimum of 4% to 5% organic matter and a pH of 6.0 to 7.5.

SOIL AMENDMENTS

Potential soil amendments include organic materials, fertilizer, mycorrhizae, bio-stimulants, sugars and hydrogels. The list of products available on the market is vast, but evidence supporting the use of some of these amendments is limited.

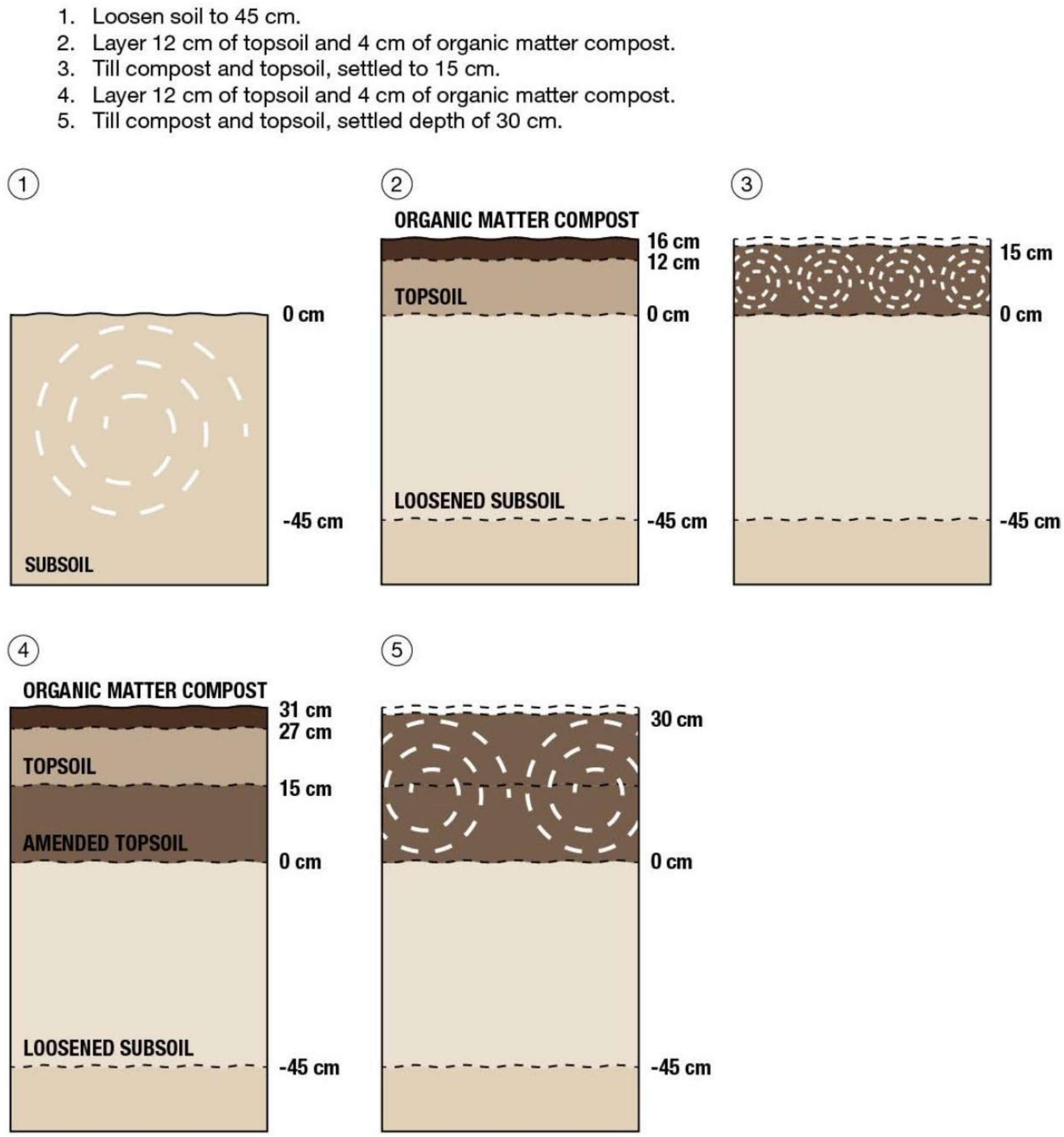
While amendments such as organic matter and fertilizer are generally well-documented as improving sub-optimal planting sites, factors such as soil compaction and rooting volume, tree quality, species choice, planting method and post-planting maintenance have greater effects on the success of planted trees (Barcham 2019c). A high-level overview of the state of research on selected soil amendment types is provided **Table 9**.

Table 9. Overview of soil amendment types

Amendment	Benefits and Drawbacks	Overview of Recommended Use
Compost	• Increases organic, microbial and nutrient content of soil • Results in greater tree growth [(1)]	• Include a layer of compost as the top layer or mix with backfill on sites having soil with little organic matter • If used as a top-dressing, approx. 5 cm of compost under mulch is recommended
Mulch	• Top-dressing increases soil structure; prevents compaction, erosion and water loss • Working mulch into the soil is not recommended, as it will tie up available nitrogen in the soil	Highly recommended for use as a top-dressing only for all plantings (see **Section 6.3**)
Fertilizer	• Limited root volume of newly-planted trees may limit nutrient uptake • Soil pH may limit nutrient availability	Slow-release useful only after establishment period [(3)]; organic material (e.g., compost) added to backfill and top-dressing of mulch likely sufficient for newly planted trees [(2)]
Mycorrhizae	• The net benefit to the tree is influenced by the interactions between the fungi, the species of tree and the microbial communities present in the rhizosphere which, in combination, influence nutrient availability [(3)] • Mixed evidence of benefit to newly-planted trees; benefit may be increased as products containing more diverse arrays of fungi come to market [(2, 3, 4, 5)]	• Additions of mycorrhizae are not known to cause any negative impacts and some of the research done has shown positive impacts [(3, 5)] • Further study is required to determine and refine appropriate uses and benefits • Inoculation of inorganic planting media used in nursery may be beneficial [(4)]
Bio-stimulants [(2)]	• Little evidence of benefit of humates, plant extracts • Evidence of benefit of sugars is mixed • Biochar can increase soil water holding capacity, increasing refugia for micro-organisms	Use of biochar may be beneficial in some situations, particularly if amendment to well-drained soil is needed and/or if drought is a concern [(6)]
Anti-transpirants	• Reduces water loss through leaf surface • Usually only recommended during certain situations of planting stock transport	• May be useful in limited situations where summer transplanting is unavoidable. However, it is not needed for spring or fall planting and with irrigation. • May aid in reducing winter desiccation of evergreen trees [(2)]

Sources: [(1)] Scharenbroch and Watson 2014; [(2)] Barcham 2019c; [(3)] McGrath *et al.*, 2019; [(4)] Sean Fox, pers. comm., March 2020; Dixon *et al.*, 2015 [(5)], https://www.bartlett.com/news/biochar-effective-urban-trees [(6)]

Where existing substrates are inadequate or long-term compaction impacts are anticipated (e.g., in a popular urban open space with high foot traffic) the soils can be "buffered" from compaction through the addition of coarse sand and/or compost, which can be critical to achieving the required drainage in urban soils. An overview of different types of soil amendments and recommendations for their use in the context of Peel's urban areas is provided in **Table 9**. An illustration of how to integrate organic matter into urban soils is provided in **Figure 5-9**.



Credit: CVC (2017)

Figure 5-9. Illustration of how to rebuild the soils profile when stockpiled soils are deficient in organics

Mycorrhizal fungi, which are beneficial for supporting the uptake of water and nutrients by tree roots and tend to occur naturally in native soils, are commercially available as inoculants in soils mixes. Although different types of mycorrhizae are associated with different woody species, and the applied science is still developing[17], there is evidence that an appropriate mycorrhizal inoculum can help mitigate against drought stress in newly established trees (e.g., Dixon *et al.,* 2015). Additional peer-reviewed research is required to refine appropriate uses and benefits.

Salt, which is commonly used as a de-icing agent on sidewalks and roads in Ontario, can be harmful to plants when it accumulates in snow and then seeps into rooting areas, limiting water uptake by roots,[18] with impacts on trees that are notoriously difficult to mitigate. However, as salt is water soluble, spring rains and irrigation can dilute and wash salt out of the upper layers of the soil profile, reducing the effect of salt during the growing season provided there is adequate drainage. In addition, flushing has had some success in managing salt impacts to trees in built up urban areas in the GTA (Hill 2018; R. Lucey, pers. comm. 2020, **Appendix B**). Hill (2018) found that Freeman maples and American elms planted in soil cell systems grew well despite receiving street salt run-off, presumably because fresh water flushed through the cells for the remainder of the year.

IMPORTING OR REPLACING SOILS

As shown in **Figure 5-8**, soils consist of air, water, mineral particles and organic matter. Healthy growing media achieves a balance between these elements, as well as providing appropriate soil density, texture, chemistry, nutrients and structure (see **Figure 5-10**). Soil testing is an integral part of the site assessment process (see **Section 3**). If *in-situ*/native soils are not adequate to support optimal tree growth and cannot be remediated, soil replacement may be necessary.

The following recommended best practices for Peel's urban areas were adopted from the City of Toronto's *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* (DTAH 2013). They have been refined based on input from local municipal foresters (see **Appendix B**) and with consideration of guidance from local agencies (TRCA 2012, CVC 2017).

Where soils need to be imported for use in planting areas (with or without structural cells), manufactured soil can be purchased from soil suppliers. Topsoil, often sourced from suburban developments, is harvested and sold to soil suppliers who mix the topsoil with coarse sand and compost. Organic matter may or may not be included in this mix. Generally appropriate ratios of these four elements vary according to the intended use. Provided a planting bed is being used for trees and receives a minimal amount of stormwater inputs, the suggested mix by volume is: 45 to 50% coarse sand and 40 to 45% topsoil, with 12 to 15% compost. It is further recommended that 10 cm of yard waste compost be tilled into the upper 10 cm of soil.

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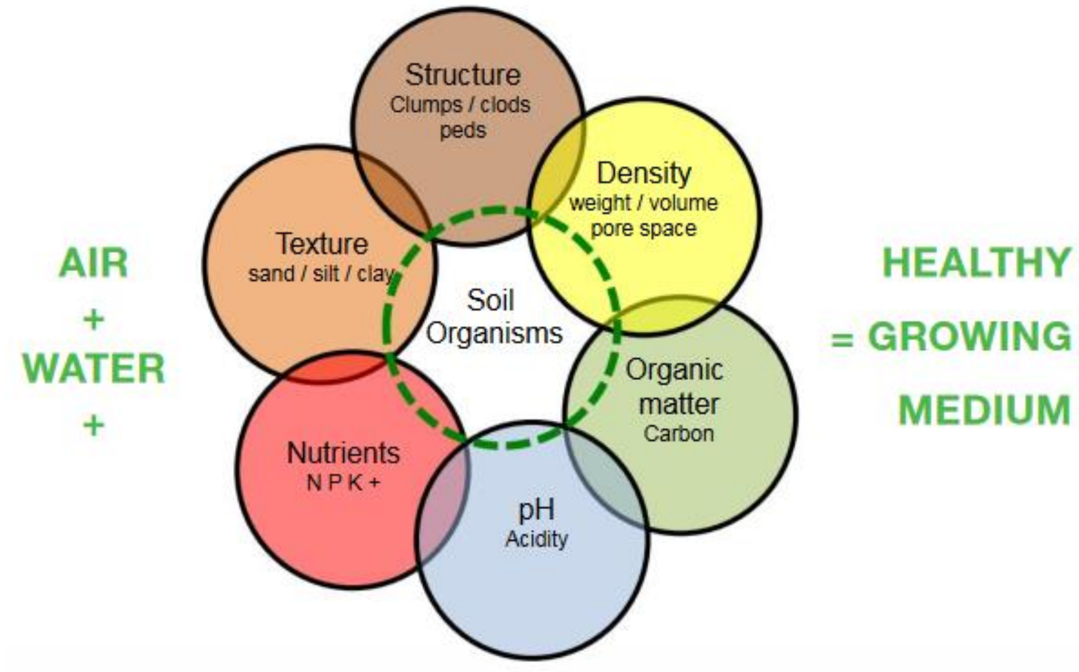
[17] Research of commercially available mycorrhizal inoculum at the University of Guelph is ongoing, see: https://www.rootrescue.com/site/university-of-guelph-data and the City of Toronto is undertaking some trials starting in 2020 (R. Vendrig, pers. comm. 2020, **Appendix B**).

[18] In addition to water-borne salt that can leach into soils, plants can be impacted by aerial salt spray which can cause bud die off, leading to a "witch's broom" appearance and shoot growth deformity. In general, the amount of salt spray is commensurate with the speed of vehicle travel and is an additional impact to which rights-of-way trees are often subjected.



Credit: DTAH (2013)

Figure 5-10. Components of healthy growing media

Soils having between 15 to 25% clay content aid in water retention, nutrient availability and result in stronger peds and as such these should be generally favored when selecting imported soils.

"Structural soils" are typically a mixture of gravel (mostly crushed stone) mixed with some soil, with the gravel providing a stable base and allowing plant and tree root penetration. Structural soils were once considered a good solution for protecting tree roots from compaction and desiccation in urban environments. However, following about a decade of use of in various urban applications, structural soils are no longer considered a best practice and some municipalities (e.g., City of Toronto) no longer permit their use. Some studies have found that owing to their high inorganic matter content, structural soils do not have adequate water holding capacity or nutrient composition for tree growth and trees in natural uncompacted soils outperform those in structural soils (e.g., Hirons and Pervical 2011). Based on the available science and feedback from practitioners, structural soils are not recommended for use in urban areas.

5.3.3 Soil Installation and Profile Rebuilding

The following guidance is for situations where there is no soil to start with or the existing soil is contaminated or of such poor quality that it needs to be removed and replaced. The guidance has been adopted from the City of Toronto's *Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual* (DTAH 2013) and refined based on input from local municipal foresters (see **Appendix B**) and with guidance from local agencies (TRCA 2012, CVC 2017).

Subsoil considerations in urban settings are as follows.

- SUBSOIL-TOPSOIL INTERFACE
    - Prior to placement of imported soil, the subgrade should be roughened up using a rototiller or the teeth of a backhoe bucket to aid in drainage between the subgrade and the planting soil.
    - In cases where planting soil is to be installed adjacent to compacted subsoil that is supporting a structure (e.g., a sidewalk, road, or building), the excavation along the structure must be at an angle away from the structure and at an angle appropriate for the type of subgrade material and expected loading. Consultation with an Engineer will be required.

- DRAINAGE: The layer below the planting soil must drain adequately lest ponding result in anoxic conditions and root death. If the subgrade cannot be mechanically loosened, then other options for drainage need to be explored (e.g., drainage lines can be connected to sewer outlets).

Recommended topsoil placement to manage compaction and settling is as follows.

- COMPACTION: Planting soil should be placed in layers, or "lifts", to allow for sufficient compaction to reduce settlement, but not too much so as to limit tree growth.
    - In softscape (i.e., open, permeable planting areas) settings or when filling a larger planting area with future growing medium, it is recommended that lifts between 30 cm and 45 cm thick be compacted to approximately 75% - 80% proctor density (this density is usually achieved by a single pass of a plate vibrator or skid steer), although lifts of 15 to 20 cm can also be used successfully.
    - When backfilling around root balls, foot tamping in lifts of 15 to 20 cm is suggested.

- SETTLING
    - The initial placement of unconsolidated soil, if done properly, leaves fairly large pores which results in settling over time. Decomposition of the organics in the soil cause further settling. As such, it is recommended that final soil depths be above final design grade (i.e., 10%) where feasible to allow for settling, although it is recognized this may not be possible in cases where the soil area is directly adjacent to a walkway and where grade continuity is required.
    - For sub-surface continuous soil trenches below suspended paving, lifts of 15 to 20 cm compacted to a cone penetrometer reading of 200 to 250 PSI has been suggested by the City of Toronto to compensate for the inability to easily return to add more soil or address settlement issues after the surface paving is installed.

5.4 Tree Planting Practices

Planting techniques vary according to planting site, stock type and tree size, however many principles remain the same irrespective of context. The following subsections outline temporal considerations and planting methods for multiple stock types in both softscape and hardscape environments. Although these practices are described for individual trees, they can be applied equally to shared planting spaces, which are recommended where they can be accommodated.

5.4.1 Temporal Considerations

Timing of planting can minimize post-planting stress and increase the likelihood of tree survival (McGrath *et al.,* 2019). To allow for root growth, it is recommended that trees only be planted when soils are moist and free from frost. In general, deciduous and coniferous trees should be planted in early spring or fall, avoiding periods of active shoot elongation (Barcham 2020a, Koeser and Northrup 2017, DTAH 2013, Barcham 2000a).

Should planting schedules not allow for spring or fall planting, use of smaller planting stock or larger root ball to stem caliper ratios may increase the chances of survival (DTAH 2013), in conjunction with summer maintenance (e.g., increased irrigation) as needed.

5.4.2 Handling Tree Stock

To reduce physical and drought-induced stress, care should be taken when transporting trees from the nursery or holding site to the planting site, as follows:

- Trees should be transported in a covered vehicle. If necessary, a flatbed or pickup truck can be used, provided all tree parts are covered in shade cloth and protected from drying winds.
- The utmost care should be given not to disrupt the soil within the root ball during transport and planting, particularly during hot and dry weather.
- In all cases, trees should be well-watered prior to transport and root balls inspected for signs of drying during all stages of transport (Hirons and Pervical 2011).
- In no case should a tree with soil intact around the root ball be moved or lifted by the trunk or branches. Balled and burlapped and wire basket trees should be moved using straps or by using power equipment. As per McGrath *et al.,* (2019):
    - Balled and burlapped stock should be supported from below or lifted by the basket at three or four points.
    - Containerized stock, if large, can also be transported by straps or by using power equipment, while smaller containerized stock can be moved by hand.
    - Bare root stock should only be transported while dormant and only handled at the base of the stem. Due to the propensity of this type of stock to drying, extra care should be taken to ensure that roots remain adequately moist and are protected from drying and physical damage (wrapping roots in plastic or a tarp is essential).

5.4.3 Holding Tree Stock

Ideally, the delivery of plant material will be timed to minimize on-site holding times. On site, plants should be placed under shade and irrigated twice daily when temperatures are ≥24°C (Hirons and Percival 2011). McGrath *et al*. (2019) recommend that plants not be kept on site longer than 36 hours.

If bare root plants cannot be planted within 24 hours of receipt, McGrath *et al*. (2019) recommend using hydrogel on roots if planting will occur soon after 24 hours. If bare root plants must be held for longer periods, McGrath *et al*. (2019) recommend heeling in plants in a bed of irrigated pea gravel, wood chip mulch or soil; heeled-in plants should be protected from temperature extremes and shielded from direct sun.

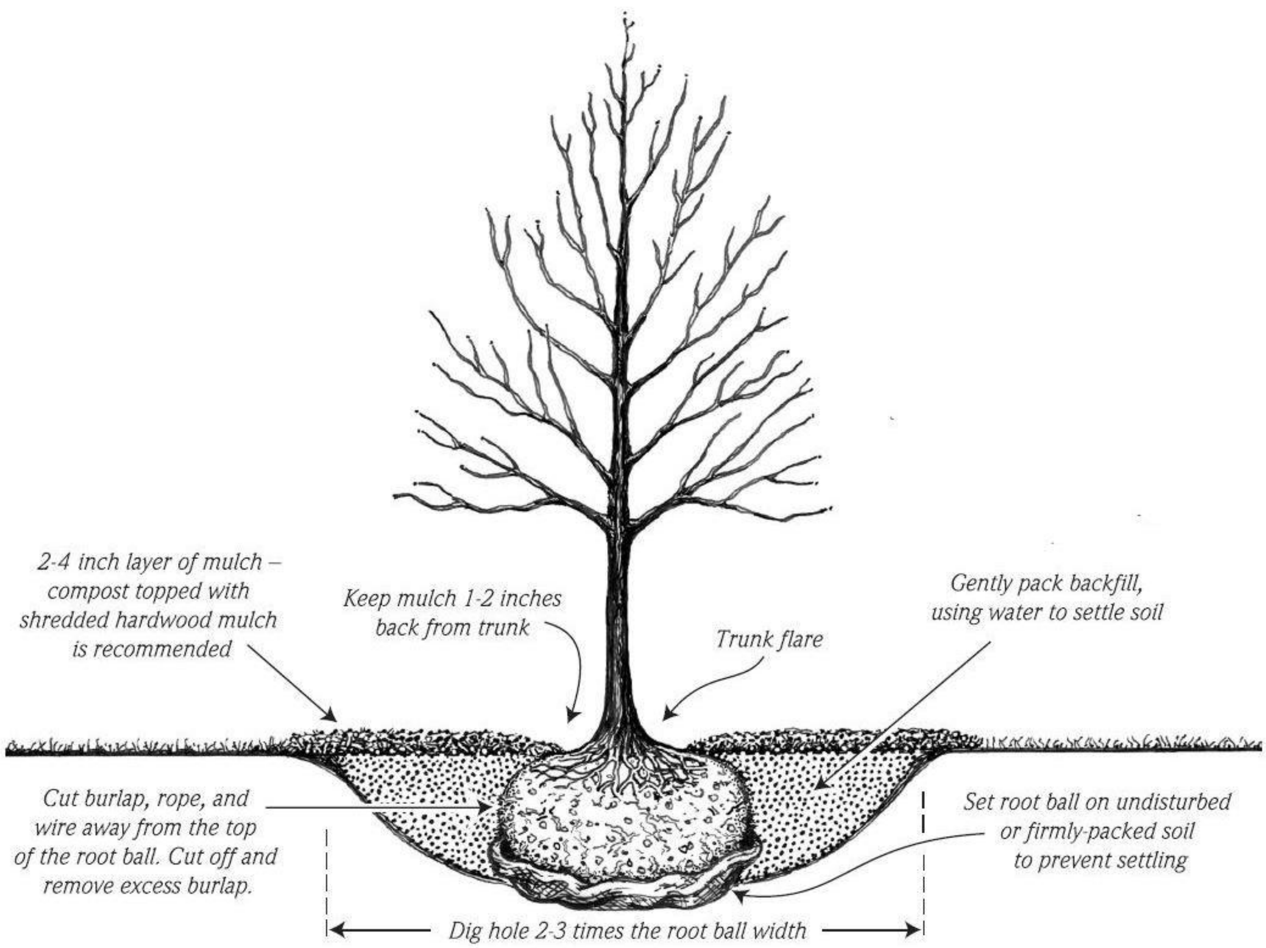
If large quantities of planting material are to be held for an extended period, municipalities should consider having a dedicated holding yard. The holding yard should have an adequate supply of water and irrigation equipment, a shade structure, windbreak and a combination of softscape and hardscape areas (if softscape areas are unavailable, a thick layer of mulch over hardscape material will likely suffice). Trees should be held in protected softscape areas, while hardscape areas should be used for vehicle access. An added benefit of having a dedicated holding yard is that staff can inspect and maintain trees prior to planting. The yard could also be used for mulch and tree planting equipment storage.

5.4.4 Tree Planting Pit Preparation

Correct planting depth is very important for tree survival, as planting a tree too high will result in root desiccation and plant instability; planting too deep may lead to root girdling, oxygen deprivation, limitation of gas exchange and water restriction (McGrath *et al.,* 2019, DTAH 2013). The following recommendations apply to all stock types in both softscape and hardscape environments.

- The planting hole width should be two to three times the diameter of the root ball (Barcham, 2019c, McGrath *et al.,* 2019, DTAH 2013; Hirons and Percival 2011; Barcham 2020b).
- The planting hole should be wider at the top and narrower at the bottom (see **Figure 5-11**).
- Manual scarification and loosening of the planting hole side walls is necessary to allow for root penetration, especially if machinery is used to dig the planting hole and the sides of the hole become glazed (Barcham, 2019c, Koeser and Northrup 2017, DTAH 2013).
- Loosened backfill material should be added in the planting hole to promote rapid root growth.
    - In well-drained soils, the planting hole should be dug at a depth at or slightly shallower than the height of the root ball; the trunk flare should sit slightly above grade (DTAH 2013).

- In poorly drained soils (as are typical in many parts of Peel south of the Niagara Escarpment), it is recommended that the planting hole be dug shallower than the height of the root ball (Watson and Himelick 2013).
  - In cases where poorly-drained soil cannot be amended or managed to improve drainage, planting a flood-tolerant species with its root flare 7.5 cm to 10 cm above grade may be helpful (Koeser and Northrup 2017, CLS 2016).
- To avoid shifting and/or settling, the base of the planting hole should be undisturbed, or if disturbed, tamped down (McGrath *et al.,* 2019, DTAH 2013).



Credit: Inside Auburn Hills (Anon 2020)

Figure 5-11. Illustration of tree planting pit showing several best practices

5.4.5 Tree Installation

The following recommendations apply to all types of woody planting stock irrespective of their planting location. Recommendations specific to types of planting stock are contained under the respective headings below.

- To avoid structural problems in the future, trees and shrubs should be planted upright, with their root balls placed flat against the base of the planting pit.

- In all cases, girdling roots should be pruned.
- Backfill soil can consist of the soil dug out of the planting hole (provided the soil was assessed as suitable prior to planting) or imported soil (see discussion in **Section 5.3**).
    - Backfill soil should be loose and friable, with large clods of soil (most prevalent in soils with high clay content) broken up and peds retained.
    - Once the planting hole is backfilled to half the height of the root ball, backfill soil should be gently tamped by foot and then irrigated to remove air pockets (DTAH 2013). The remainder of the planting hole can then be filled.
    - After backfilling is completed, if the ground surface is level, construct a 10 cm high round-topped soil berm with walls 15 to 20 cm wide around the periphery of the root ball (McGrath *et al.,* 2019). Tamp the berm. When planting on a 5-50% slope, the berm should be constructed in a semi-circular shape and located at the periphery of the root ball at the downhill side of the slope (Urban Tree Foundation 2014). Upon completion of the berm, water the area within the berm, or "tree well", in accordance with proper arboricultural practices (see **Section 6.1**).

WIRE BASKET AND BALLED AND BURLAPPED STOCK

Synthetic rope and burlap have been shown to decompose slowly, and some natural burlap is treated to reduce decomposition (Khuns 1997). Given the slow decomposition rate of these materials and wire baskets, it seems plausible that in the medium to long term, these materials will restrict root growth and may even result in root girdling. Surprisingly, commonly referenced studies have shown there to be little ill effect on tree growth when containment materials (e.g., wire basket, rope and burlap) were left intact when transplanting (Klein *et al.,* 2019, Koeser *et al.,* 2015, Lumis, 1990, Lumis and Struger 1988), with some evidence showing that trees will engulf wire baskets (**Figure 5-12**).

Credit: Gilman (2015)

Figure 5-12. Tree planted with wire basket intact has engulfed basket

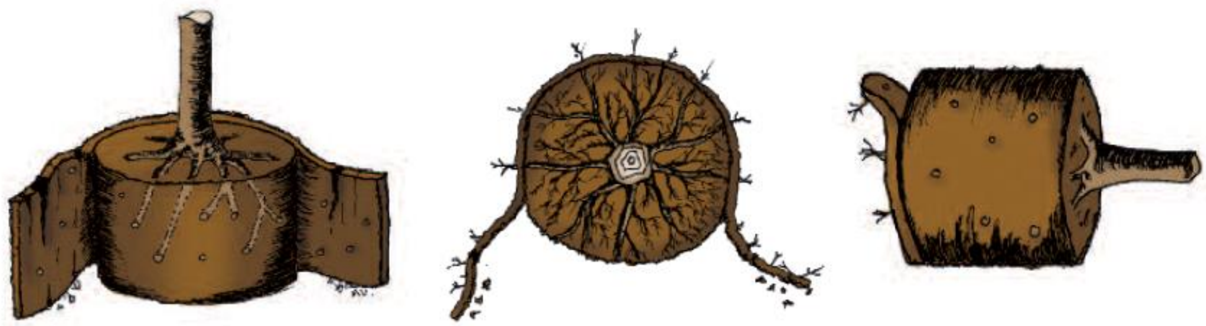
Koeser *et al.,* (2015) recommends removing no more than the upper third of containment materials prior to positioning, as removing more than that could lead to tree instability after planting. However, consideration should be given to site context. In the consulting team's experience, wetted wire basket and balled and burlapped stock grown in soils with high clay content experience minimal root ball soil loss upon removal of containment material. Conversely, stock grown in sandy soils is expected to lose substantially more soil, even when wet, and thus containment materials should not be removed completely. Furthermore, if the soil texture within the root ball is coarser than the backfill material, in some instances where burlap is not removed, roots may begin to circle within the root ball (Sean Fox., pers. comm. April 2020), which could eventually lead to girdling. University of Florida Professor Ed Gilman (2015) notes that if synthetic strapping materials are left on when planting, they should be removed one year afterwards.

Given the risks and benefits to removing containment materials versus leaving them intact, it is recommended that once the tree has been properly positioned within the planting hole, the top third of the tying and containment materials be removed without causing the root ball to shift or a substantial amount of soil to fall from the root ball. Using a utility knife, cut strips into the sides of the burlap to allow for outward root penetration from the root ball. In recognition of proper handling techniques and the risk of instability and soil loss, removal of containment materials prior to positioning within the planting hole is not recommended.

In cases where removal of containment materials causes soil to crumble and the position or angle of the tree to shift, using the root ball, carefully readjust the tree to an upright position (with root flare at or slightly above grade) and place approximately 10 to 15 cm of backfill into the planting hole and tamp by foot to help secure root ball position. Afterwards, ensure that backfill is applied in 15 to 20 cm lifts that are irrigated upon placement, with empty spaces within the root ball filled with soil and compacted by hand. The tree will require staking.

CONTAINER STOCK

Containerized stock will need to be removed from their containers prior to planting. Depending on the container type, roots may need to be pruned to promote growth or proper structural development. Rootbound plants should have their outer roots (up to 2 cm around the entire circumference) shaved off using a sharp arboricultural saw to encourage lateral root growth (Barcham 2019c, McGrath *et al.,* 2019) (**Figure 5-14**). Any material at the bottom of the planting container that does not contain roots should be removed so that the root ball sits flat on the base of the planting hole.



Credit: Barcham (2019c))

Figure 5-13. Shaving outer circumference of container stock root ball

If pot-bound stock cannot be easily removed from its container, to prevent damage to the plant it is recommended that the container be cut away rather than the root ball compressed and the plant pulled from the pot by its stem (Barcham, 2019c, Koeser and Northrop 2017).

BARE ROOT STOCK

Bare root stock is not large and should ideally be installed using the standard forestry method. This involves using a c-slit (i.e., two spade entries in the soil, lifting the flap of soil, inserting the tree with the roots spread, and allowing the soil to come back down). This is a time efficient approach that also minimizes the introduction of air pockets.

5.4.6 Stabilization

Tree stabilization may or may not be required depending on the size of the tree planted, nursery production method employed and planting site conditions (Koeser and Northrop 2017).

As trees grow and taper in response to wind-induced movement, it is recommended that rigid stabilization techniques be avoided and the technique employed allow for some non-excessive movement of the tree crown, while stabilising the roots (McGrath *et al.,* 2019, Koeser and Northrop 2017, Hirons and Percival 2011). Except for underground guying systems, which cannot be removed, stabilization materials should be removed as soon as the tree is able to support itself – neglecting to do so may result in girdling. Most often, this is after one year of growth, unless the growing media is sub-optimal for root formation (e.g., very sandy or poorly-drained soils), in which case removal after two years is more typical.

Detailed instructions for the installation of staking, guying and root ball anchoring systems are available in the Landscape Ontario *Tree Planting Guide* (McGrath *et al.,* 2019). Key points are summarized below:

STAKING: Staking can be used for all stock types, though is typically not used for deciduous trees less than 1.0 m in height or coniferous trees less than 3 m tall. This method typically uses two or three wood stakes driven into the soil and attached to the tree using pliable and biodegradable ties. The first stake should be placed upwind from the prevailing wind direction.

GUYING: Guying stabilization systems can be above- or below-ground. Above-ground systems function much the same as staking, with flexible, biodegradable ties being attached to the tree trunk well below the first set of branches and attached to three in-ground anchors by guy wires. This system is typically used for deciduous trees having a caliper size over 10 cm and coniferous trees over 3 m in height. Below-ground systems function like the root ball anchoring summarized below and are used in similar applications, with guy wires attached to a triangular or square above-ground frame placed above the root ball and attached to three anchors located below the root ball. Barcham (2019c) cautions that tensioning of underground guying systems can cause or exacerbate deep planting, which will have a negative impact on the tree.

ROOT BALL ANCHORING: Root ball anchors are essentially oversized wood staples installed over the root ball (**Figure 5-14**). This method of stabilization is typically used for wire basket, balled and burlapped and large container stock; it is unsuitable for smaller container and bare root stock.

Credit: McGrath *et al.*, (2019)

Figure 5-14. Illustration of root ball anchors

5.4.7 Shared and Multi-use Planting Beds

Although most of the text and guidance in the previous sections focusses on individual trees, one of the most strongly recommended best practices in terms of planting design for trees along municipal urban streetscapes, rights-of-way and parks is to establish trees in planting beds in urban areas (whether in hardscape or softscape conditions) in a way that mimics their natural growing conditions, wherever possible.

This is an important shift away from the more traditional approach to urban municipal plantings, which have typically been constrained by an aesthetic vision of a street with a monoculture of medium to large-statured trees planted in single file along each side of the street with mown lawn or a paved/concrete surface over their root zones (see top left image in **Figure 5-15**). This shift to a more ecologically-based approach (see top right in **Figure 5-15** and **Figure 5-16**) provides a shared planting space that includes relatively large caliper stock (e.g., 40 to 60 mm dbh) installed with conventionally accepted spacing (e.g., 6 to 10 m on center) combined with smaller shrubs and/or perennial herbaceous species in the understory. This approach (albeit on a very small scale) is more aligned with a tree's natural growing conditions, supports the health and resilience of the tree and also contributes to urban forest diversity by:

- Providing a diversity of vegetation species and some structural diversity
- Providing natural protection to the rooting area from trampling and other disturbances, while also helping stabilize and maintain the structure and quality of the rooting area, and
- In some cases, providing opportunities for integrating other services, such as stormwater management.

Credits: Top left - Region of Peel 2017, top right – M. Ursic, City of Toronto

Figure 5-15. A traditional street tree planting (top left) and shared and diversified planting bed (top right)

Credit: City of Brampton 2013

Figure 5-16. Shared and diversified planting beds in urban Brampton

5.5 Summary of Tree Establishment Best Practices

Once a site has been assessed and appropriate species selected, choosing appropriate establishment practices are the next step towards successful tree planting. Key establishment best practices considered suitable for hardscapes, streets/rights-of-way and parks/open spaces in Peel's urban areas are provided in **Table 10**.

Table 10. Summary of best practices for tree establishment in urban hardscapes, rights-of-way and parks

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Site Selection and Preparation (Section 5.2)	Site assessment and soil testing should always be undertaken to inform tree establishment. (More details are provided in Table 8).
Soil Management (Section 5.3)	**MINIMUM SOIL VOLUMES AND DEPTH** • Small trees at maturity (20 – 39 cm dbh) 17 m^3/tree, 11 m^3/2 trees • Large trees at maturity (40 – 59 cm dbh) 28 m^3/tree, 18.5 m^3 /2 trees • Very large trees at maturity (≥ 60 cm dbh) 45 m^3/tree, 30 m^3/2 trees • Min. soil depths of 90 cm and max. 1 m • Tree planting soil volumes should be integrated with utility zones to the extent feasible using "vertical zoning" • Where soil is shared, trees should be spaced 6 to 10 m on center

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	ACCEPTABLE SOIL COMPOSITION FOR *IN SITU* SOILS • Generally free of coarse vegetation, debris and large stones and characterized by: 40 – 60% sand, 30 – 40% silt, 10 – 25% clay; min. 4% to 5% organics; and a pH of 6.0 to 7.5. **COMPACTION MANAGEMENT** • Prevention of soil compaction is much more time and cost-effective than remedial measures and can be achieved by: excluding foot and vehicular traffic from root zones of trees, especially when soils are wet, avoiding use of screened soil and adherence to proper soil installation procedures. • If traffic within rooting zone unavoidable, use of plywood over a min. 10 cm layer of wood chip mulch over root zone. • Mulching can also be effective for mitigating post-construction compaction, and more so in conjunction with co-plantings, a raised bed and/or some type of barrier around the rooting area. **AMENDMENTS:** A range of amendments can be considered (see Table 9) where needed based on testing. In some cases, the soil will be too degraded to amend and replacement will be required. **IMPORTED SOILS** • Imported soils, where required, should be 45-50% coarse sand, 40-45% topsoil and 12-15% compost (tilled up to 5 cm in to the upper 10 cm soil) • Favour soils with 15-25% clay content. • Structural soils are not recommended. **INSTALLATION** • Roughen the subgrade, ensure adequate drainage where planting soil is to be installed adjacent to compacted subsoil, and consult with an Engineer to ensure the excavation is at an angle appropriate for the subgrade and expected loading where appropriate. • In larger planting areas topsoil should be placed in layers or "lifts" 30 to 45 cm thick and compacted to approx. 75 - 80% proctor density; in smaller planting areas lifts of 15 to 20 cm are recommended. • Final soil height should consider settling and decomposition of organic matter over time.
Tree Planting Practices (Section 5.4)	**TEMPORAL:** Deciduous and coniferous trees should be planted in early spring or fall. **HANDLING** • Trees should be transported in a covered vehicle and protected from drying winds. In all cases, trees should be well-watered prior to transport. • Trees with soil intact should never be moved by the trunk or branches. **HOLDING** • Time delivery of plant material to minimize on-site holding times. • Bare-root plants should be installed within 24 hours and no plant should be left on site longer than 36 hours. • If large quantities of planting material are to be held for an extended period, municipalities should consider a dedicated holding yard.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	PLANTING PIT • The planting hole width should be 2 – 3x the diameter of the root ball. • Undertake manual scarification and loosening of the planting hole side walls. **INSTALLATION** • Root balls to be placed flat against the base of the planting pit; girdling roots should be pruned. • Backfill with soil dug from the planting pit or imported soil. • Plant so that the final settled grade will be about 7.5 to 0 cm below the root flare and with the root collar at or slightly above the final grade, regardless of where the root collar is in the container or basket when received. • WIRE BASKET AND BALLED AND BURLAPPED STOCK: There are risks and benefits to removing containment materials versus leaving them intact; at minimum the top third of the tying and containment materials should be removed after positioning within the planting hole, but preferably as much of the wrapping material should be removed as possible. • CONTAINER STOCK: Remove from containers prior to planting; roots may need to be pruned; rootbound plants should have their outer roots shaved. • In all cases, the final settled soil grade (i.e., ground level) should be just below (e.g., 7.5 – 10 cm) the root flare. **STABILIZATION AND PROTECTION** • In general, rigid stabilization should be avoided but temporary protection for newly established trees is often required (from both wildlife and/or humans). • Where needed, stabilization materials should be removed as soon as the tree is able to support itself (i.e., usually within a year). • Temporary tree protection measures – both for the stem and roots - should be flexible in that they can readily accommodate or be adjusted to accommodate tree growth. • Although it can be “messy” one of the simplest and best protections for newly established trees is mulch and, if space permits, small shrub and perennial herbaceous co-plantings. • In built-up urban settings, trees protected with mulch and co-plantings can be effective in conjunction with a clearly defined planting area either raised or bounded by some type of barrier such as a concrete curb or very low fence. **SHARED PLANTING BEDS** • Shift, wherever possible, to a more ecologically-based approach that provides a shared planting space for large caliper stock combined with smaller shrubs and/or perennial herbaceous species in the understory. • Consider opportunities for integrating other services, such as stormwater management, into shared planting beds.

6. Tree Maintenance and Management

This section provides rationale for suggested Standard Operating Procedures (SOPs) for common tree maintenance activities in hardscapes (e.g., such as downtown boulevards), municipal streets/rights-of-way and municipal open spaces (including parks). Maintenance and management of trees in naturalized or established wooded natural areas is not the focus of this report.

While many programs and initiatives tout the importance of planting trees, it is equally important that municipalities have the staff and financial resources to maintain and manage existing trees.

As discussed above, tree maintenance requirements can be minimized by: appropriately assessing the site-specific conditions (as per **Section 3**), matching the species selected to the existing and anticipated planting site conditions and selecting healthy stock (as per **Section 4**), and ensuring the stock is properly installed (including adequate rooting space and soil quality) (see **Section 5**).

Tree maintenance activities are typically undertaken by municipal staff, though they may be outsourced to independent contractors or even citizens through an "adopt a tree" program. As previously mentioned, tree maintenance requirements are highest during the establishment period, which ranges from two to five years after planting, depending on species and site context. It is during this time that trees are most susceptible to mortality (Hilbert et al., 2019). Accordingly, investing in tree maintenance during the establishment period and beyond results in long term cost savings and contribute significantly to urban forest resiliency[19].

6.1 Watering

Lack of watering and/or inadequate access to moisture is one of the primary causes of dieback and mortality among newly established trees in urban settings outside of natural areas. This risk is exacerbated by poor establishment practices and by climate change, which will increasingly cause longer periods of heat and drought. Research has shown that tree establishment is positively correlated with regular irrigation applied to the root ball or immediate rooting area within the dripline of the tree, especially when dealing with larger stock (Gilman *et al.,* 1994, Gilman *et al.,* 1996, Gilman 2001). Therefore, it is essential that new plantings be provided with adequate moisture after transplanting and throughout their establishment phase (see **Section 5**).

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[19] For example, the York Region Street Tree Program saw up to 40% replacement rates prior to initiating program enhancements such as improved species selection, planting specifications and implementation; enhanced watering schedules; and ongoing monitoring and continuous improvement, among other practices.

Well-established trees and shrubs, although generally more tolerant to periods of drought than newly planted stock, can also be subject to drought stress and – if it is long and/or frequent enough – mortality. Therefore, moisture requirements of established and mature trees also need to be considered.

6.1.1 Watering Frequency and Quantity

There is no "one size fits all" for tree and shrub watering. The frequency and quantity of irrigation required for newly established plants depends primarily on the species' requirements and tolerances, type of nursery stock planted, site conditions and condition of the plant's roots and rooting environment. Trees and shrubs planted without fully intact roots (e.g., bare root stock, machine dug, balled and burlapped) typically require more frequent irrigation immediately following planting than those with intact roots (e.g., potted). While nursery stock type can influence the short-term watering requirements of planted specimens, these factors can continue to play an important role as the tree or shrub matures. In all cases, it is recommended that young, mid-aged and mature trees be monitored during periods of drought, especially if species are known to be drought sensitive.

According to the *Ontario Landscape Tree Planting Guide* (McGrath *et al.,* 2019), trees will experience greater water stress under any of the following scenarios:

- Limited soil volume (i.e., limited water storage volume and limited catchment);
- Poor quality soils, especially soils with less than 5 % organic matter)'
- Sites with high heat loads (e.g., reflected heat);
- Rainfall failing to reach the rooting zone due to impermeable surfaces; or
- Tree roots are in competition with turf for water.

To mitigate water stress for woody species, trees and shrubs should be planted in:

- Adequate volumes of good quality soils including 5% organic matter (see **Section 5.3**);
- Sites that provide permeability, at least to the tree's dripline; and
- Sites where the covering to the rooting area, at least within the dripline, supports the retention of moisture (e.g., mulching and/or co-plantings as noted in **Section 6.3**).

Although there is no "one size fits all" for tree and shrub watering, there is guidance from the academic literature and applied sources to consider.

Based on research out of the University of Minnesota, Zuzek (2018) recommends that, ideally newly planted trees should be watered immediately upon planting, daily one to two weeks after planting, every two to three days three to 12 weeks after planting, and after 12 weeks weekly until roots are established. Newly planted shrubs are considered established when their root spread equals the spread of the above-ground canopy, which in Minnesota takes up to two years. However, while this kind of regimen may be manageable for someone planting a tree or two in their yard, it is not practical for municipal staff or contractors tasked with overseeing the establishment of hundreds or thousands of trees across a given jurisdiction.

Similarly, recommended watering volumes for nursery or more intensively managed settings (e.g., Zuzek (2018) recommends applying approximately 4 L/2.5 cm of stem caliper (1 to 1.5 gal/in) per watering every 1 to 2 days) cannot be readily applied to municipalities responsible for watering hundreds or thousands of trees without irrigation systems. An increasing number of municipalities in the GTA and elsewhere have tried watering bags (e.g., Treegator™) or other comparable systems that can be filled with water that is released slowly to the soil. For example, water bags can hold 64 to 68 L (14 to 15 gal) and release this water over a 5 to 9 hour period (Zuzek 2018).

Practices from two neighbouring jurisdictions adjacent to Peel Region reported as being effective and considered suitable for Peel's urban areas are as follows.

- In Toronto, urban foresters found that watering (typically using a water bag) once every two weeks from May to September with around 40 L, with weekly watering over July and August, was to be a generally effective practice for most municipal street trees (A. Rudolfs pers. comm. 2020, **Appendix B**).
- York Region found that street tree establishment and survival rates were vastly improved after they adopted the use of 75 L watering bags and increased the frequency of watering to 14 times each year from May to September for the first three years after planting (Lane 2013).

It has also been noted by some municipal staff that while watering bags or comparable tools are both a pragmatic and effective solution to help meet the watering requirements of individual trees on municipal lands, such tools should be removed in the winter to avoid damaging the tree. From this perspective, the newer (and perhaps unfortunately named) Tree Diaper™ may be preferable. However, these tools are relatively new and more research and documentation are needed in terms of their respective pros and cons in northern climates.

Notably, these recommendations are generalized and the volume of required water may need adjustment based on factors such as: tree species, plant size, amount of natural precipitation, wind conditions and air temperature, slope, moisture holding capacity and drainage of existing soils (Barcham 2019c). Overwatering can also be problematic, as conditions caused by soil saturated for more than 24 hours can starve roots of needed oxygen and is difficult to correct (USDA 2008).

6.1.2 Watering Methods

Water should be applied slowly and directly to the root ball after planting using a low-pressure stream from a hose. For newly planted trees and shrubs, the effectiveness of watering is increased when a water reservoir, or "tree well", is built around the root ball (see **Figure 6-1**). Water can also be delivered slowly via above or below ground drip irrigation systems, including watering bags (**Figure 6-2**), which are particularly useful for newly planted trees.

As roots grow and spread the watering area needs to be increased to cover the root crown - roughly 45.72 cm (18 in) of growth annually (Zuzek 2018) - which generally coincides with the area within the dripline of the tree (McGrath *et al.,* 2019). Surficial watering generally encourages the development of surficial roots, which are important but do not serve the tree as well as somewhat deeper roots during periods of drought. Therefore, it is recommended that plants be watered to a soil depth of 300 mm, which is equivalent to 40 L/m^2 of soil surface for soils with good water holding capacity (Barcham 2019c).

Credit: Zuzek (2018)

Figure 6-1. Water reservoir around a newly planted shrub

Credit: Zuzek (2018)

Figure 6-2. Watering bag on a newly planted tree

Established trees and shrubs need little to no water during periods of consistent rainfall (assuming they are in a location with adequate rooting conditions). However, good indications of the need for supplemental watering include temporary wilting and when the first 15 to 23 cm (6 to 9 in) of the topsoil is dry (Zuzek 2018). Watering regimes will vary with the soil composition as well as the site conditions, but potential water stress can generally be managed by implementing the best practices described in **Section 6.1.1** above.

Although mulch is not always the preferred cover for the rooting area in urban environments subject to high levels of human traffic, its value to trees and shrubs cannot be overstated. Mulch is one of the most cost-effective and easiest ways to help decrease water evaporation from soil. It also acts like a sponge and prevents runoff around plants growing in heavy clay soils (as are common in Peel) or on sloped sites (not uncommon in rights-of-way), while also buffering the soils from extreme summer and winter soil temperatures and helping to mitigate soil compaction and damage to stems and trunks from human activities (Zuzek 2018, Smith pers. comm. 2020 – see **Appendix B**).

6.2 Pruning

Tree pruning is another topic on which an abundance of technical work has been published. This sub-section will touch on the following topics highlighting information of relevance to Peel's urban areas:

- Young tree pruning (**Section 6.2.1**)
- Mature tree pruning (**Section 6.2.2**)
- Municipal pruning cycles (**Section 6.2.3**)
- Qualifications (**Section 6.2.4**), and
- Pruning around utilities (**Section 6.2.5**).

The ANSI A300 (Part 1) standards are the generally accepted industry standards for tree pruning. The companion document is the International Society of Arboriculture (ISA) *Best Management Practices - Tree Pruning, 3rd Edition*, 2019.

Trees are pruned for a variety of reasons including:

- Managing risk
- Improving tree health and/or form
- Developing tree structure
- Providing clearance (e.g., for traffic, site access, line of site, etc.), and
- Improving aesthetics.

A structural pruning program is recommended to develop and maintain a structurally sound trunk and branch architecture from the time a tree is planted. It is also recommended, as noted in **Section 2**, that any staff, contractors and volunteers undertaking pruning should be trained in pruning best practices.

6.2.1 Young Tree Pruning

Pruning of young trees should focus on developing good structure. Young tree structural pruning involves:

- Favouring a single leader by reducing or removing competing branches
- Removing dead/broken branches
- Removing low limbs
- Removing branches to create more even spacing between lateral branches
- Removing branches that are rubbing
- Removing or reducing branches with narrow angles of attachment or included bark, and
- Removing or reducing branches similar in diameter to the trunk or branch limb to which they are attached.

It is widely recognized that trees should be pruned on a regular basis when they are young to medium-aged to foster good structural development, including correcting issues or defects that could create problems as the tree gets larger (see **Figure 6-3**).

Trees with good structure have a single dominant leader, strong branch unions, well spaced branches, and a balanced crown. When trees are not pruned frequently enough or at all when they are young, they can develop defects such as codominant stems, week branch attachments, and low limbs, which can lead to failures when the tree matures.

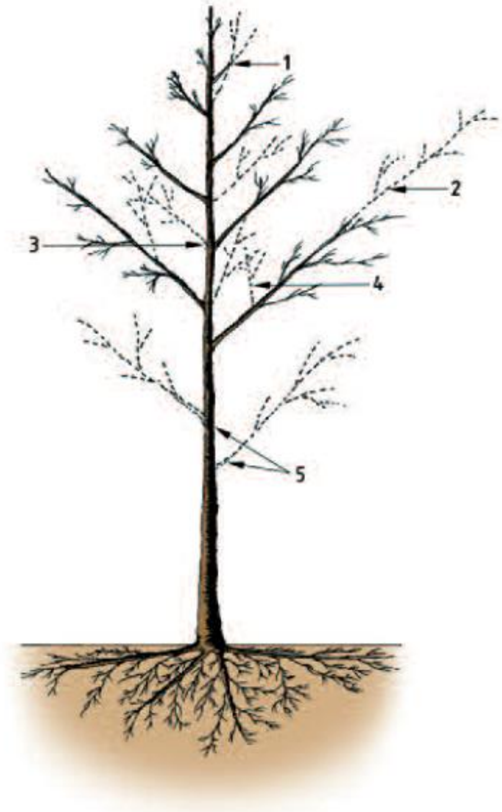
One of the most common defects in planted trees is formation of large, low branches as the tree matures, which tend to overextend, sag, and break, and create clearance problems (Gilman and Bisson 2007b). Removing these large branches creates large pruning wounds, which are prone to decay; however, if these problematic branches are removed or reduced when small, future issues can be avoided. Ideally, removal of lower branches for clearance (crown raising) should be done before branches exceed 5 cm in diameter (Whiting *et al.,* 2006).

Most of the branches that cause clearance issues or structural problems (low branches, codominant leaders) are branches that came with the tree from the nursery; therefore, pruning should start when the tree is planted or within the first year or two after planting (Gilman 2019). ISA (2011) recommends pruning only dead or broken branches when the tree is planted and postponing other pruning until the tree is established two or three years after planting. If the tree has more than one leader, the City of Portland (n.d.) recommends selecting the best leader for retention and removing the other(s) at the time of planting. A lower pruning rate that removes <20% of the crown is recommended for recently planted trees, whereas a higher pruning rate (>20%) may be appropriate for young established trees (Gilman and Bisson 2007a). In general, no more than 25% of live growth should be removed at one time (ISA 2011).

In terms of municipal levels of service, the City of Toronto has a "Newly Planted Tree Maintenance Program," whereby all street treees are revisited two or three years after the two year warranty period to prune, water, fertilize, refresh mulch and remove stakes, as needed.

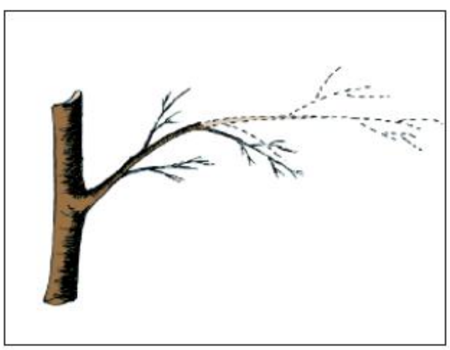
Suggested resources for young tree pruning include:

- *Developing a Preventive Pruning Program: Young Trees* (Gilman and Bisson 2007a)
- *Pruning Young Trees* (ISA 2011)
- *Tree Care and Pruning* (City of Portland n.d.), and
- *Sample Pruning Specifications for Young Trees* (Hoyt and Gilman n.d.).



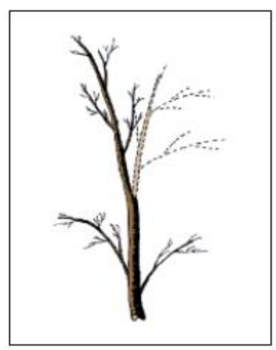
1. Co dominant leader to be removed
2. Over vigorous laterals to be subordinated to the main trunk.
3. Opposite branches to be removed
4. Upright growth into the crown to be removed
5. Lower branches from the nursery to be kept subordinated as they will not form part of the final scaffold branching system

Note: The above can only be a guide as species morphological habit vary and does not take account of feathered, multi-stems or other trained forms.



Lateral branches subordinated to be no more than 50% of the main trunk at the point of attachment

Included branch unions or weak forks to be pruned out



Co-dominant leaders to be pruned out or subordinated to the main leader

Credit: Barcham (2019c)

Figure 6-3. Typical formative pruning cuts

6.2.2 Mature Tree Pruning

Maintaining and pruning mature trees is easier and more cost-effective if good structure was established through preventive pruning early on. For example, Ryder and Moore (2013) found that young tree structural pruning is less costly than waiting to correct defects at 20 years.

Pruning of mature trees is typically required to remove dead and broken limbs (crown cleaning) and reduce risk of branch failure. Crown thinning, involving judicious removal of smaller branches from the outer/upper canopy, may also be beneficial in mature trees. Crown raising for clearance may also be required for mature trees; however, this is best done when trees are young. Mature trees are typically less tolerant of pruning than younger trees; therefore, removal of live branches from mature trees should only be done when there will be a demonstrable benefit (e.g., to improve tree form/health, correct defects to mitigate risk). In general, no more than 10% of the live growth should be removed from mature trees at one time, unless required to correct severe defects (Gilman and Bisson 2007a).

Selected resources for mature tree pruning are provided in **Appendix A**.

6.2.3 Pruning Cycles

A pruning cycle is the frequency at which pruning is conducted for a particular tree or block of trees.

If the pruning cycle is too long:

- Defects can become more severe
- Larger cuts may be required to correct structural issues (which take longer to heal and invite decay), and
- A large proportion of the live crown may have to be removed at one time (which can be stressful on trees, particularly older trees).

However, a shorter pruning cycle does not necessarily imply better management. For example, a longer cycle combined with young tree structural pruning, high quality nursery stock, and good growing conditions can allow for longer cycles (UFI and Beacon 2018).

Although some older studies have identified 4 to 5 years as an 'optimal' pruning cycle for temperate climates to balance costs and benefits, based on experience with different municipalities in southern Ontario and elsewhere, a general best practice (as cited in UFI and Beacon 2018) is that good form and structure can be developed with six to seven proper pruning events in the first 25 to 30 years after planting (Gillam and Bisson 2007a). Many municipalities cite between 5 to 8 years as pruning cycle target (see **Table 11**), and a common best practice in Canadian municipalities is three pruning interventions (or at least inspections) in the first 10 years after planting/establishment.

Table 11. Block/grid pruning cycles from selected urban municipalities*

Municipality	Target Pruning Cycle	Comments
York Region, ON	3 years - juvenile trees 7 years - intermediate trees Mature trees - pruned as-needed	Juvenile: 1 cm to 12 cm dbh Intermediate: 13 cm to 50 cm dbh Mature: (>50 cm); 4-year inspection cycles
Mississauga, ON	8 years	Street trees
Toronto, ON	7 years	Target in 2014 UFMP, to be achieved by 2023
Vaughan, ON	7 years	
Brampton, ON	5 to 7 years	For trees under 9 m ht.; trees >9 m pruned on as-needed basis
Ottawa, ON	7 years	Annual inspection for elm trees
London, ON	10 years	Transitioning to 5-year cycle
Oakville, ON	9 years	Planning starts in 2019, operation starts in 2020

* Based on information collected over 2019 and 2020

6.2.4 Pruning Specifications

ANSI A300 (Part 1) is the generally accepted industry standard for pruning, but these are not specifications or prescriptions. Municipalities should develop their own prescriptions or specifications for tree pruning based on ANSI 300 standards and ISA Best Management Practices.

As per Gilman (2019), the key components of a pruning prescription/specification are:

- Identify the objective (e.g., clearance, structural improvement, cleaning);
- Identify the pruning system (this will typically be the "natural system");
- Identify the target branches (which branches to prune); and
- Specify the amount of tissue to be removed (size, number, and types of cuts).

Resources for writing pruning specifications are provided in **Appendix A**.

6.2.5 Utility Pruning

In Ontario, the Electrical Safety Authority (ESA) requires a minimum three-metre clearance between trees and overhead utilities.

It is recommended that pruning around utilities be conducted in accordance with ANSI 300 standards for pruning; however, pruning for utility line clearance does not always follow proper pruning methods where the needs of the utility right-of-way take priority.

When a tree under a power line requires frequent crown reductions, the tree should be considered for removal and replacement with a more suitable species (e.g., trees that remain small at maturity) or with a tree in an alternative location (Whiting *et al.* 2006).

Municipal and utility tree-related standards, including pruning and planting, should be reviewed and coordinated on a regular basis. Coordination with local utility providers can help to reduce tree pruning frequency and expense, reduce impact on trees, and improve pruning practices. For example, the Town of Oakville's urban forestry staff and local utility are members of the Public Utility Coordinating Committee (PUCC), which enables information exchange regarding current and best practices. Oakville Hydro contracts the Town's Urban Forestry Services and its contractors to conduct tree maintenance, including in proximity to overhead utilities, on a 3-year pruning cycle.

6.3 Competition and Herbivory Management

Even in urban areas, young trees can be subject to competition from other plants (e.g., weeds) and herbivory from rodents and deer, which can impact their health and growth potential. This sub-section touches on methods for managing these threats, including mulching, vegetation and herbivory management methods.

6.3.1 Mulching

The importance of proper mulching as an easy and cost-effective tool to help mitigate some of the stressors associated with urban settings and climate change, and help manage competition from other vegetation, cannot be stressed enough. The benefits of proper mulching (Chalker-Scott 2007, Jackson 2018, Zuzek 2018) include:

- Conserved soil moisture by increasing water infiltration and slowing evaporation
- Improved soil structure, fertility, and aeration as mulch decomposes
- Moderated soil temperature, protecting roots from extreme summer and winter temperatures
- Reduced risk of tree damage from mowers and trimmers
- Prevented soil compaction by reducing foot and vehicle traffic, allowing roots to "breathe", and
- Impeded growth of weeds and grass that compete with tree roots for water and nutrients.

Turf can be an especially problematic competitor, as its dense root system outcompetes woody plants for water and nutrients in the top few centimetres of soil (Zuzek 2018). Therefore, mulching around trees and shrubs in parks and open spaces where they are surrounded by grass is especially important.

Mulches may be organic (e.g., wood chips, pine needles, hardwood and softwood bark, cocoa hulls, leaves, and compost mixes) or inorganic. However, when organic mulches decompose they improve soil structure and increase soil fertility, and are therefore recommended exclusively.

General best practices for use of organic mulch around a tree or shrub installed at the right soil level are as follows (adapted from Jackson 2018, Barcham 2019c and USDA 2008);

- Apply in a 1 m circle around the tree base or to the drip line of the established tree, whichever is greater
- Apply as a "top dressing" on the surface – do not incorporate mulch into the soil
- Apply mulch 5 to 10 cm (2 to 4 in.) thick (i.e., no mulch "volcanoes") but closer to 7.5 cm (3 in.) if soils are poorly drained (see **Figure 6-4**)
- Keep mulch at least 7.5 to 15 cm (3 to 6 in.) away from the trunk of young trees and 20 – 30 cm (8 to 12 in.) from mature trees
- Fine-textured mulches (e.g., double-shredded bark) should be applied more thinly than coarser mulch (e.g., wood chips), and
- Freshen or replace the mulch every two years, making sure the total depth remains at 5 to 10 cm (2 to 4 in).

There are various types of mulch that can be used, and sometimes it is most efficient and cost-effective to chip and use vegetation being taken down on site. However, some recommend the use of hardwood bark mulch (especially when it contains a blend of bark, wood, and leaves) (Jackson 2018).

Credit: adapted from USDA (2008)

Figure 6-4. Mulch application: correct (left), incorrect (middle) and correct (right)

Applying too much mulch can result in root oxygen starvation and inner bark death at the base of the tree, which in the case of younger trees, can increase susceptibility to damage from insects, disease and small rodents using the mulch for shelter. Layers of wet mulch that are too thick can also create excessive heat. This can be readily corrected (as shown in **Figure 6-5**) by e, clearing away excessive mulch to expose the root flare (where the trunk meets the soil line), distributing the mulch in a broader circle that is no deeper than 10 cm in any given location.

1) Excessively mulched tree with mulch piled against trunk.
2) Hand trowel used to pull mulch back and redistribute.
3) Tape marking the original depth of the mulch.
4) Excess mulch spread evenly, 2–4 inches deep, out to tree's drip line.
5) Mulch pulled back from trunk, exposing the root flare.
6) Tree properly mulched using the same amount of mulch.

Credit: Jackson (2018)

Figure 6-5. Illustration of steps in correcting application of too much mulch

6.3.2 (Unwanted) Vegetation Management

The topic of vegetation control as it relates to tree and shrub establishment in urban areas focusses on any plants (i.e., native, non-native and/or invasive) other than those intentionally established that are competing for space and resources with the planted specimen.

Competition from invasive plant species and other weeds is a well-established problem in wooded natural areas and can also be a problem in rights-of-way and municipal open spaces, and even in hardscape planter boxes or cells.

Proper and regular mulching (**Section 6.3.1**) is a preferential and proactive solution to unwanted vegetation around newly established trees. However, where this approach has not been implemented proactively or for some reason was not effective (e.g., mulch applied was removed by human disturbance, high winds or water), intervention may be required. Options include manual and chemical control methods.

- MANUAL CONTROL METHODS: Manual control methods for undesirable competitive plants consist of hand pulling, mowing and trimming/cutting.
    - It is crucial that managers are cautious when mowing or trimming, as power tools have the potential to damage roots and stems of woody plants, especially when string trimmers are used.
    - The optimal time to manually control undesirable vegetation is in the spring, as plants will be more affected because they have less stored energy, are actively transporting sugars and nutrients through their vascular systems and, usually, have not yet flowered and produced seed.

- CHEMICAL CONTROL METHODS: Most chemical herbicides are best applied in the spring or autumn. Application methodology varies by product, and as such this topic is not discussed here. It is recommended that herbicides be applied by a licensed pesticide applicator in accordance with the *Pesticides Act* (1990) and its attendant Ontario Regulation 63/09[20].

6.3.3 Herbivory Management

Woody vegetation in urban areas can be subject to damage from herbivory, particularly when the vegetation is located near a natural area or corridor (e.g., creek, rail line) used by urban wildlife for movement through built spaces. Most herbivory in urban settings is related to activities from small mammals and sometimes deer.

Mammals can feed on woody plant material at any time of year, although the risk is most pronounced during winter when sources of herbaceous plant material are scarce. Young plants are most susceptible to herbivory by mammals, especially rodents.

[20] Note that tree care specialists are exempt from some of the prohibitions of the cosmetic pesticides ban. See https://www.ontario.ca/page/technical-guidance-pesticides-act-and-ontario-regulation-6309-tree-care-specialists?_ga=2.115843398.1704375648.1585522312-476922656.1585522312 for more information.

Several methods can be employed to deter mammals from feeding on woody plants, including installation of physical barriers such as fencing or tree guards, or application of repellents. The method of management is dependent on the plant being protected and the pest being deterred. **Table 12** identifies some specific best practices for protecting newly established woody plants from common herbivores such as mice, voles, groundhogs, rabbits and deer.

Table 12. Herbivory management options

Deterrent Type	Material(s)	Method(s)
Fencing	• To deter rodents, use ¼-inch mesh hardware cloth attached to supporting stakes. • To deter deer, use durable and flexible woven wire or wire-mesh fencing supported by metal t-bar stakes (Loegering and Witt, 2019).	• Fencing should enclose the entire plant or planting bed. • Fencing can be installed around each tree (and lower branches) or around the planting bed. • Fencing should be buried 5 – 10 cm below the ground to deter burrowing mammals from breaching the fence. • To deter rodents, fencing should extend 40 – 60 cm above the ground or, in winter, the anticipated snow line (Loegering and Witt 2019). • To deter deer, fencing should extend a minimum of 2.5 m above the ground surface or, in winter, the anticipated snow line.
Individual Plant Barriers	Wire mesh, drain tile and plastic spiral tree guards are commonly used. Paper products are also commercially available.	• Barriers should enclose the entire plant stem. • Some barrier systems require staking for support. • Requires annual maintenance to ensure performance and avoid girdling.
Repellents	Commercially available chemical repellant includes Skoot™. Repellants using natural ingredients include Plantskydd™ and Bobbex™, with the former being favored by the University of Guelph Arboretum (S. Fox, pers. comm, 2020).	• Contact repellents are preferred over area repellents. • Repellent is typically applied in autumn in accordance with the manufacturer's instructions, usually by using a backpack sprayer. However, where herbivory is a known or suspected problem, repellant can be applied at any time of year. • It is recommended that products that require only one application per season be used instead of those which require multiple applications. • See the Minnesota *Wildlife Damage Management Program's Nuisance Wildlife Repellent Handbook*, available online, for further information on products and methodologies for deterring deer.

6.4 Pest and Disease Management

Tree pest and disease management as it relates to the urban forest is an extensive topic that cannot be comprehensively covered in this guide. The information in this guide provides high-level best practices related to municipal approaches for managing tree pests and diseases.

Greater incidence of extreme events and drought resulting from climate change has already begun to increase tree stress and thus susceptibility to insect pests and pathogens. Climate change is also allowing some insects and pests already found in southern Ontario to be active for longer periods, and other insects and pests that have not previously occurred in southern Ontario are shifting their ranges north. When trees are already impacted by climate change stressors (such as extended periods of heat and drought) and then subject to pests and/or disease, this further increases the risk of mortality, which is why it is critical for urban forest managers to take proactive and integrated approaches to manage existing and potential threats.

In Peel, the three pests currently posing the greatest threats to trees and the urban forest are Asian-long Horned Beetle (ALB), Emerald Ash Borer (EAB) and Gypsy Moth. Municipalities' recent experiences with Emerald Ash Borer (EAB) have shown that when a serious pest or disease becomes widespread, the costs and impacts are substantial[21]. Other tree pests and diseases currently present in Peel include: spring and fall cankerworm, fall webworm, two-lines chestnut-borer, bronze birch borer, pine shoot beetle, and forest tent caterpillar. Tree pests and diseases considered potential future threats to Peel include: Hemlock woolly adelgid, white pine weevil, oak skeletonizer, willow leaf beetle, elm leaf beetle, Japanese beetle (on *Tilia americana* and *T. cordata*), beech bark disease and Asian gypsy moth.

Integrated Pest Management (IPM) is a best practice used by some municipalities (e.g., City of Mississauga) to help manage and monitor tree pests and diseases. This approach requires an understanding of the problem (including past and present impacts and risks) to develop and implement a proactive risk management strategy that considers the available information in conjunction with communication needs, as illustrated in **Figure 6-6**.

[21] Between 2012 and 2017 the costs borne to remove and replace ash trees impacted by EAB are estimated at $37 million by the City of Toronto, with another $30 million spent by the Canadian Food Inspection Agency prior to 2012 to try and slow the spread pf the pest.

Credit: E-Journal of Entomology and Biologicals
https://ucanr.edu/blogs/strawberries-vegetables/index.cfm, 2020

Figure 6-6. Illustration of components of an Integrated Pest Management (IPM) approach

Key components of an IPM strategy for forest pests and diseases are presented in **Table 13**.

Table 13. Key components of an Integrated Pest Management (IPM) approach for forest pests

IPM Components	Information to be Considered
Knowledge and Resources	• Status: Canadian Food Inspection Agency (CFIA) Regulated Species Status • Target(s): host tree species including preferred host(s) • Range: North American distribution • How it works: Mechanism of infection/attack and infestation cycles • How it is detected: signs and symptoms of infestation • Impact: How it impacts its host • Local data: Last documented in the jurisdiction and in nearby jurisdictions
Pest Management	• Existing management that may be increasing or decreasing the species threat • Identification of management options • Evaluation of management options using decision criteria, such as: o Likelihood of Success o Protection of Values o Nuisance level o Public Concern o Adverse Impacts o Tree Health and Condition o Tree Susceptibility and Vulnerability o Tree Size o Tree Value • Recommended management approach, including triggers for one or more types of management activities
Planning and Organization	• Coordination of data sharing • Monitoring changes in CFIA Regulated Species Status • Monitoring changes in spatial distribution, tracking of zones of impact • Monitoring effectiveness of management undertaken
Communication	• Communications with key agencies (e.g., CFIA) • Assessment of public understanding of the key issues and potential impacts to the community • Strategies for outreach and key messages to Council, the public • Outreach to key partners within the jurisdiction and in adjacent jurisdictions to share information and coordinate efforts

The first approach in managing an invasive insect pest or disease is trying to prevent their arrival into an area. If this fails, then containment and eradication are the next approaches to prevent the pest/disease from becoming established. If this fails and the invasive species has arrived and is established, the only remaining tactic is to slow its spread within the area.

The methods used to eradicate or manage pest species vary depending on the species, degree of infestation, available resources and land use context. However, several proactive approaches that can be used to manage tree pests are also measures generally supportive of urban forest health and building resilience. These include:

- Planting a diversity of native tree species (see **Section 4.5**)
- Planting a range of clones or provenances of the same species (see **Section 4.1**)
- Managing the urban forest for structural/age diversity
- Selective cutting or thinning to remove trees from plantations, particularly in dense stands where moisture deficits may occur and have little species or structural diversity (e.g., Red Pine plantations), and
- Pruning for tree health (see **Section 6.2**).

Additional methods include trying to establish barriers to movement and exploring potential biological or chemical controls.

Based on the considerations above, a high-level recommended best practice is to develop a regional IPM program for the urban forest that:

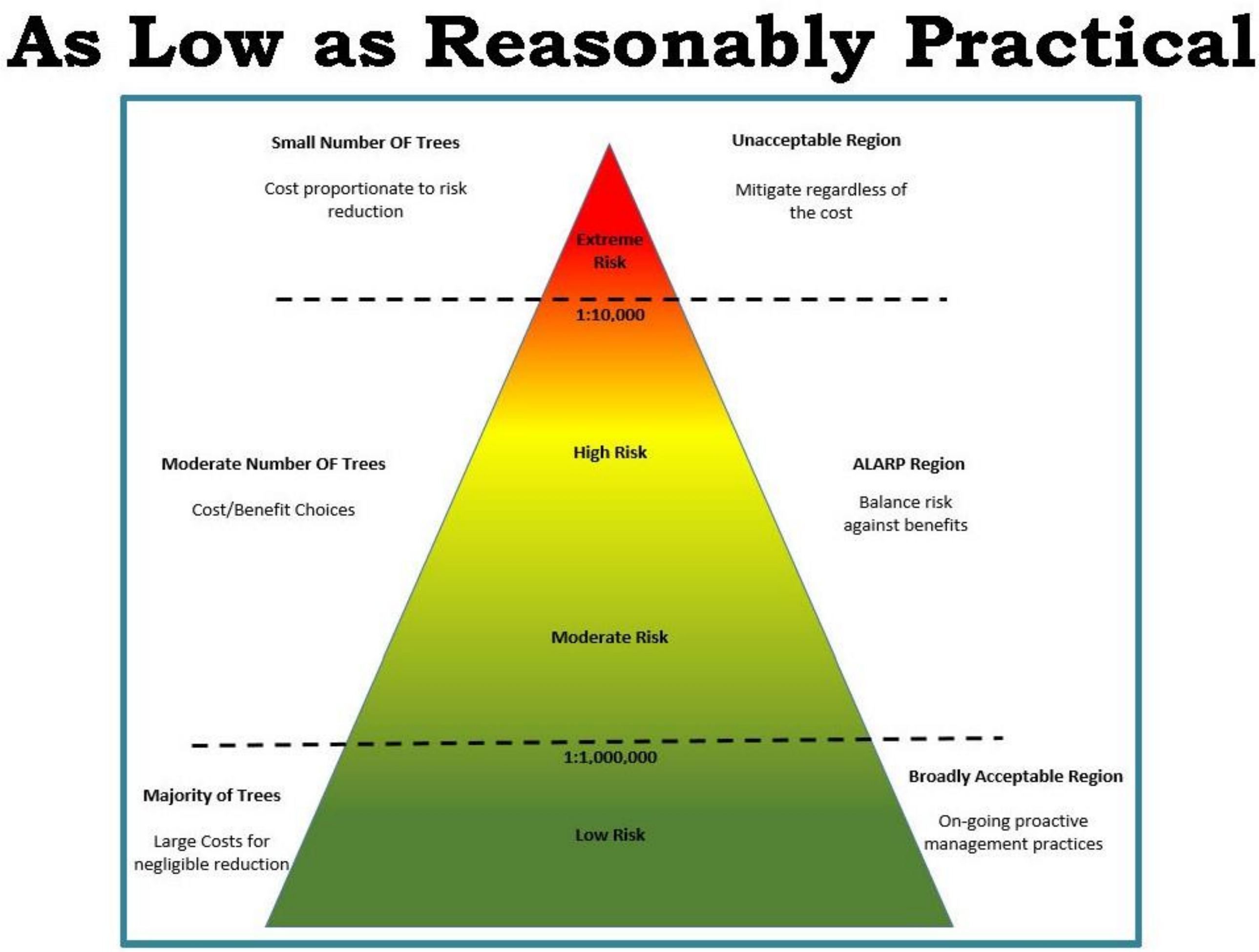
- Is developed and implemented with local agency and municipal partners, as well as neighbouring municipalities
- Speaks to tree pests and diseases already extant in the Region as well as those reasonably suspected to occur in the near future, and
- Uses a risk management approach to prioritize species.

6.5 Tree Risk Management

> ***If you don't invest in risk management, it doesn't matter what business you're in, it's a risky business.***
>
> **Gary Cohn**
>
> ***Risk management is a more realistic term than safety. It implies that hazards are ever-present, that they must be identified, analyzed, evaluated and controlled or rationally accepted.***
>
> **Jerome F. Lederer**

Many factors can independently and cumulatively impact tree health including: inadequate above or below-ground area, poor soil/substrate conditions, poor or lack of adequate pruning, storm events, too much or not enough water, trunk or root damage, and pests or disease. When the health of the tree is compromised, the risk of parts or of the entire tree failing, increases. When trees are proximal to people and property (as they often are in an urban setting) evaluating the risk of the tree becoming a hazard to nearby people or property must be considered (Pokorny 2003), particularly on lands owned and/or managed by the municipality.

Risk associated with an individual tree depends on: (1) the likelihood of a mechanical failure within a given timeframe, (2) if a part fails, the likelihood of it striking a target, and (3) if the part fails and if a target is struck, the potential consequences. Targets can include people as well as property, including buildings, infrastructure and utilities, vehicles, etc. The risk associated with a tree is complex, as every tree part has some potential to fail and the tolerance for risk can be heavily influenced by variables that have nothing to do with the tree itself (e.g., perceived or actual value of the target). A tree is generally not considered a "hazard" until it has been confirmed as structurally unsound or having a significant structural defect, in which case it can pose an imminent risk to a target, which can be described as an extreme risk. In general, a best practice objective would be to manage municipal urban forest assets so that most, or ideally all, municipal trees do not become "extreme" risks (see **Figure 6-7**).



Credit: USDA Forest Research Webinar Series 2017
https://www.fs.fed.us/research/urban-webinars/tree-risk-assessment-science-and-practical-application.php
Figure 6-7. A graphical representation of the four risk categories assigned to trees

Tree risk assessment should not be confused with tree risk management:

- TREE RISK ASSESSMENT (TRA) is the technical process focussed on an individual tree for: (a) evaluating what could happen based on the existing conditions, (b) estimating how likely they are to occur, and (c) examining the potential consequences if they were to occur. A TRA should result in (1) an overall risk rating for the tree and (2) recommended mitigation options to address the identified risk, if confirmed as needed.
- RISK MANAGEMENT is the process by which the municipality assesses and monitors its risks jurisdiction-wide and selects and implements measures to address those risks as part of jurisdiction-wide management.

The current industry standard for tree risk management is ANSI A300 (Part 9) and the companion document published by the International Society of Arboriculture (ISA): *Best Management Practices, Tree Risk Assessment*, Second Edition (2017). Together these two documents constitute a Standard of Care (see **Section 6.5.1**) that should be implemented by qualified arborists. The ISA Tree Risk Assessment Qualification (TRAQ) is a credential available to arborists that demonstrates professional knowledge in tree risk assessment through participation in a training course and passing an exam. This qualification is for municipal staff and/or contractors conducting tree risk assessments and is also recommended for managers making decisions regarding tree risk management.

Tree risk can be managed with a combination of reactive and proactive measures. As with tree pest management, many of the proactive measures intended to reduce the likelihood of tree failure or impact on a target are also consistent with good urban forest management. They include:

- The maintenance of an up-to-date tree inventory (see **Section 7.1**) that includes tree attributes related to risk such as health, structure and risk rating and can be used to identify risk and prioritize inspections and maintenance
- Adherence to proper establishment techniques (see **Section 5**)
- Pruning in accordance with proper arboricultural techniques
- Prevention of structural issues through structural pruning of young trees (see **Section 6.2.1**)
- Routine pruning trees as part of a planned pruning cycle (see **Section 6.2.3**), and
- Improving tree health and structure through proper maintenance of trees.

Additional proactive urban forest management practices that are specific to risk management include:

- Routine and periodic inspection of designated areas such as road rights-of-way, municipal buildings, trails and other municipal property
- Annual inspections of high use and high target value areas (e.g., well-used trails in woodlands, well-used parks with many mature trees)
- Inspections every two to four years or annual windshield surveys of moderate use and moderate target value areas

- Inspections to low use and low target value areas on a request basis
- The ability to use Level 3 (per ANSI standard/ISA BMP) advanced tree risk assessment methods[22] where appropriate and needed to inform risk assessment and management
- An effective work order management system that enables identification, prioritization, assignment, tracking and monitoring of required mitigation work, including resident requests
- Having a tree risk management plan and policies concerning effective responses to issues that arise, such as: restricting public access to areas where the risk of tree failure is high but there is a desire or decision to retain the trees for their ecological services. and
- The dispatch of tree maintenance crews when needed (see **Figure 6-8**).

Credit: Pokorny (2003)

Figure 6-8. Planting trees too deep is a primary cause of lower stem decay and subsequent tree failure

Based on the considerations above, best practices for municipal tree risk assessment staff and contractors include:

- Being familiar and use the ANSI A300 (Part 9) and the companion *Best Management Practices, Tree Risk Assessment*, Second Edition (ISA 2017)
- Having training in Tree Risk Assessment Qualification (TRAQ)
- Practicing proactive urban forest management practices that are specific to risk management and are also consistent with generally good urban forest management (see above), including routine inspections of the health and condition of municipal trees in accordance with industry standards, and

22 Level 3 (per ANSI standard/ISA BMP) advanced tree risk assessment methods include: aerial inspection, sonic tomography, stability assessments and drilling (where appropriate).

- Assessing and managing trees using an appropriate balance between the valued ecosystem services that a tree provides and the potential costs/consequences of it failing in whole or in part (Purcell 2012).

6.5.1 Tree Risk Management Plan or Policy

Having a tree risk management plan or policy is another recognized best practice and can be an effective tool for documenting and consolidating risk assessment practices, and for helping to implement them consistently. Many municipalities in the United Kingdom maintain tree risk management plans and policies, as do several Canadian municipalities (e.g., Saskatoon, SK; Red Deer, AB; Oakville, ON; Surrey, BC). A formal tree risk management plan or policy helps mitigate risks and protect municipal assets. Such a plan or policy should (adapted from UFI and Beacon 2018):

- Be developed with a concrete understanding of duty and standard of care[23] and liability
- Frame the plan/policy scope
- Outline responsibilities, goals and acceptable standards of care
- Set thresholds for acceptable and unacceptable levels of risk and uncertainty
- Establish minimum training and qualifications of tree risk assessors and managers
- Outline the frequency of inspections/assessments for trees of different categories
- Review management options to mitigate risk
- Establish record-keeping protocols for risk assessments and management activities
- Identify strategic funding and/or partnerships
- Set program assessment, monitoring and adaptation protocols (including tree failure/risk profiles for different species, areas, age classes, etc. if and as they become available)
- Be developed in collaboration with municipal legal and risk management staff, insurers, urban forestry, etc.
- Support advanced tree risk assessment methods and include resources to support their undertaking when appropriate, and
- Favor conservation-based approaches where possible.

Selected resources for developing a municipal tree risk plan are provided in **Appendix A**.

[23] "Duty of care" is a legal obligation to apply reasonable actions when performing tasks that may potentially harm others (Dunster *et al.,* 2017).

- For tree owners, duty of care means "the owner has some level of responsibility to ensure a reasonable degree of safety for people or property near the tree under their care" (Dunster *et al.,* 2017).
- For tree risk assessors, duty of care means "using the generally accepted standard of care (as defined in applicable standards, best management practices, qualifications, and training courses) when performing work" (Dunster *et al.,* 2017).
- Breach of duty is the failure to act in a reasonable manner, as defined by the concept of Standard of Care. Breach of duty may constitute negligence, and liability requires that the tree manager or assessor has failed to follow a Standard of Care.

6.6 Summary of Maintenance and Management Best Practices

One a tree has been established, the final phase of active management involves maintenance and management of the established tree. An overview of the best practices identified in this guide are provided in **Table 14**. Although the focus of these best practices is on relatively young or immature trees, some guidance related to mature trees is also included. More details are provided throughout **Section 6** and in selected resources included in **Appendix A.**

Table 14. Summary of best practices for tree maintenance and management in urban hardscapes, rights-of-way and parks

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Watering (Section 6.1)	Young, mid-aged and mature trees should be monitored during periods of drought, especially if species are known to be drought sensitive. To mitigate water stress for woody species they should be planted in: • Adequate volumes of good quality soils including 5% organic matter • Sites that provide permeability, at least to the tree's dripline, and • Sites where the soil covering the rooting area, at least within the dripline, supports the retention of moisture (e.g., mulching and/or co-plantings). Watering requirements vary with the species and site, but in all cases: • New plantings need to be irrigated after transplanting and regularly during the establishment phase • All trees need to be monitored during periods of drought, and • Water should be applied slowly and directly to the root ball after planting and should extend past the tree's dripline. Based on applied results from Toronto and York Region it is recommended that in Peel: • Watering bags or comparable tools able to hold 40 to 75 L be used • Watering occur once every two weeks May to September with an increase to weekly over July and August (i.e., about 14 times per year), and • This approach and frequency be maintained for the first three years after planting.
Pruning (Section 6.2)	**YOUNG TREE PRUNING** • Prune only dead or broken branches when the tree is planted and postpone other pruning until the tree is established, two or three years after planting (ISA 2011). • In general, no more than 25% of live growth should be removed at one time. • Generally, it is a good practice to reduce multiple leaders to allow dominance of one main upright leader to prevent crown breakage. **MATURE TREE PRUNING:** In general, no more than 10% live growth should be removed from mature trees at one time, unless required to correct severe defects.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
	GENERAL PRUNING AND RISK MANAGEMENT • A municipal structural pruning program is recommended. General best practices include between 5 to 7 years as a pruning cycle, with three pruning interventions (or at least inspections) in the first 10 years after planting. • Municipalities should develop prescriptions or specifications for tree pruning based on the ANSI 300 standards and ISA Best Management Practices. • Municipal and utility tree-related standards, including pruning and planting, should be reviewed and coordinated.
Competition and Herbivory Management (Section 6.3)	**MULCHING:** General best practices around use of organic mulch around a tree or shrub which is presumed to have been installed at the right soil level are as follows: • Apply in a 1 m circle around the tree base or to the drip line of the established tree, whichever is greater. • Apply as a "top dressing" on the surface – do not incorporate into the soil matrix. • Apply mulch 5 to 10 cm (2 to 4 in) thick (i.e., no mulch "volcanoes") but closer to 7.5 cm (3 in.) if the soils are poorly drained. • Keep mulch at least 7.5 to 15 cm (3 to 6 in) away from the trunk of young trees and 20 to 30 cm (8 to 12 in) from mature trees. • Fine-textured mulches (e.g., double-shredded bark) should be applied more thinly than coarser mulch (e.g., wood chips) but coarse woodchip mulch is preferred to fine textured mulches, as it takes longer to break down and provides greater aeration and moisture permeability. • Freshen or replace the mulch every two years, making sure the total depth remains at 5 to 10 cm (2 to 4 in). **VEGETATION CONTROL:** Manual controls are best undertaken in early spring and caution should be taken when mowing or trimming not to damage the tree/shrub being protected. **HERBIVORY:** Methods that can be employed to deter urban mammals from feeding on newly established woody plants include: installation of physical barriers such as fencing or tree guards, or application of repellents (see Table 13 for details).
Pest and Disease Management (Section 6.4)	Develop a Regional Integrated Pest Management (IPM) program for the urban forest that: • Is developed and implemented with local agencies and municipal partners, as well as neighbouring municipalities • Speaks to tree pests and diseases already extent in the Region as well as those reasonably suspected to occur in the near future, and • Uses a risk management approach to prioritize species.

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Tree Risk Management (Section 6.5)	Based on the considerations above, best practices for municipal tree risk assessment staff and contractors include: • Being familiar and use the ANSI A300 (Part 9) and the companion Best Management Practices, Tree Risk Assessment, Second Edition (ISA 2017) • Having the Tree Risk Assessment Qualification (TRAQ) • Practicing proactive urban forest management practices that are specific to risk management • Seeking an appropriate balance between the valued ecosystem services and the potential costs/consequences of it failing in whole or in part, and • Having a tree risk management plan or policy.

7. Urban Forest Inventory and Monitoring

> *You can't manage what you don't understand.*
>
> Unknown

Ongoing inventory (or assessment) and monitoring[24] of the urban forest in a jurisdiction is broadly recognized as a key aspect of management and a fundamental best practice (e.g., Kenney *et al.,* 2011, Bardekjian 2018, USDA 2019). Both inventory and monitoring of an urban forest can be undertaken at various scales and at varying levels of detail, but in all cases the type and level of effort should optimize use of the available resources to fill priority information gaps that will help inform strategic management directions.

There are many types of inventory and monitoring that can be undertaken in relation to the urban forest. These can range from site-specific inventories of street trees and monitoring their success through updates to the inventory, to inventory of natural wooded areas and monitoring of their condition, to jurisdiction-wide assessments and monitoring of tree cover and condition using remote sensing. For municipalities like those in Peel, having information at both the individual tree scale and the jurisdiction-wide scale has value. Therefore, this section focusses on three broad types of urban forest inventory and monitoring considered, with an emphasis on approaches and tools most relevant for informing municipal management of Peel's individual street trees and park trees.

1. INDIVIDUAL TREE INVENTORY AND MONITORING: Point-based inventories of individual trees (e.g., typically street and park trees on municipal lands), often geo-referenced and tied to a database, with regular updates to and assessment of the data to assess changes in these trees over time and inform arboriculturally-based management of each tree to maintain its health (**Section 7.1**).

2. URBAN TREE CANOPY (UTC) COVER ASSESSMENT, MONITORING AND RELATED TOOLS: Analyses of jurisdiction-wide canopy cover on all types of lands over time, sometimes supplemented with field-based data collection (e.g., using the i-Tree Eco model) and/or other desktop tools used to estimate the value of certain services provided by UTC cover (**Section 7.2**).

[24] In the context of this guide, the term "inventory" is used to refer to data collection at a single point in time to inform assessment or characterization of a feature or area whereas the term "monitoring" is used to describe the repeated collection of data using comparable methods and at a comparable scale to detect trends over time. Both inventory and monitoring can be done at various scales from site-specific to jurisdiction-wide, but monitoring is specifically intended to document and assess change to identified metrics over time.

3. CRITERIA AND INDICATORS (C&I) MONITORING: The use of a range of set criteria and indicators to evaluate change over time and inform sustainable urban forest management (**Section 7.3**).

Although wooded natural areas inventory and monitoring is also considered important for characterizing and managing the urban forest in Peel, it is not examined in this guide whose focus is on municipal trees outside of Peel's natural areas.

The concept of adaptive management is central to progressive and effective urban forest planning and management. In part, this is because the urban forest is comprised of living biological organisms that are constantly changing and responding to different environmental variables, sometimes in ways that cannot be anticipated. In addition, the urban forest includes organisms and ecosystems that can be very long-lived, and adaptive management allows for changes in approaches as new information and new technologies emerge. The concept of adaptive management is directly related to inventory and monitoring, as these activities are needed to inform adaptive responses.

The concept of adaptive management generally encompasses four phases that continually cycle, as follows:

1. PLAN: This includes collection of baseline data about key aspects of the urban forest through inventory and establishing management objectives and/or targets.
2. DO: This includes undertaking management of urban forest assets.
3. EVALUATE AND LEARN (a.k.a. INVENTORY AND MONITOR): This includes assessment and review of data collected in relation to established management objectives and/or targets.
4. ADJUST: This involves adjusting management approaches in response to new information, circumstances, tools and/or technologies, and potentially refining management objectives and/or targets as well and if needed.

Adaptive management is not possible without a good understanding of existing conditions that are accounted for in developing management strategies. It requires the strategic and systematic monitoring of the effectiveness of these strategies and allows for adjustments to be made based on experience gained and new information or changing circumstances. The cycle allows for new findings or circumstances to inform management approaches in a continuous feedback loop.

In the 21st century, urban forest managers are having to review and re-consider their approaches and practices through the lens of climate change. Continued strategic data collection and monitoring, and sharing this information, will be critical to informing shifts in urban forest management going forward.

The Peel Urban Forest Best Practice Guide 5 *Working with Trees: Best Practices for a Resilient Future* includes a framework for urban forest planning that embeds the principal of adaptive management and is provided as an additional resource.

7.1 Municipal Tree Inventory and Monitoring

A cornerstone of a proactive municipal urban forest program and a recognized urban forest management best practice is having a comprehensive and current municipal tree inventory[25].

A comprehensive tree inventory should include all trees on municipally-owned and managed lands, including those in wooded natural areas. Individual trees (e.g., street trees and park trees) should be assessed and monitored individually from an arboricultural perspective whereas trees in natural areas should be assessed and monitored as a community from an ecological and/or forestry perspective.

For inventories of individual trees, there is no single best practice for data collection tools. However, the selected tool should be: easy to use, readily integrated with existing municipal information technology and work order/asset management systems, and allow for corporate-wide access. Ideally, basic tree data from the inventory tool should also have the potential to be made accessible to those external to the municipality (such as local conservation authorities, volunteer tree establishment groups and even the community-at-large).

Attributes that should be captured for individual trees include:

- Basic information related to location, species and size (both trunk and crown diameter)
- Year planted, supply contractor and warranty period
- Key metrics and notes about health and structural condition
- Attributes related to risk (such as health, structure and risk rating), and
- Notes on competition or damage from weeds, invasive species or herbivory.

A summary of attributes included in municipal tree inventories that distinguish between a "basic" and an "optimal" / best practice inventory is provided in **Table 15**.

A comprehensive and current municipal tree inventory can enable a municipality to:

- Schedule and prioritize regular tree inspections and basic maintenance (e.g., mulching, watering, pruning)
- Accommodate reactive management in response to resident inquiries/requests or emergencies (e.g., ice storms damage, trees hit by vehicles)
- Inform development application review (e.g., with the number, size and condition of trees on nearby municipal lands that may be impacted)
- Guide and track block pruning
- Inform genetic diversity planning, including information about species and, if available, provenance and seed source
- Plan and implement proactive and reactive tree risk management, and
- Inform forecasting as part of an Integrated Pest Management (IPM) Program (**Section 6.4**).

[25] The best practice guidance in this section has been adapted from the Richmond Hill Urban Forest Management Plan full technical report courtesy of Urban Forest Innovations (http://urbanforestinnovations.com/).

Table 15. Characteristics/attributes of "basic", "good" and "optimal" tree inventories*

ATTRIBUTE	BASIC	GOOD	OPTIMAL
Location	Municipal Address or Block	Municipal Address or Block	GIS integration
Location Type Description	-	√	√
Species	√	√	√- may include cultivar
Diameter (dbh)	√	√	√
Crown Diameter (approx.)	-	-	√
Crown Height (approx.)	-	-	√
Tree Height (approx.)	-	-	√
Tree Age Class	-	√	√
Condition	-	Basic	By tree component part
Pest/Pathogen ID	-	-	√
Work Recommendations	-	√	√
Work Priority	-	√	√
Risk Assessment	-	√	Using formal tree risk rating system
Infrastructure Conflict	Yes/No	Descriptive	Code-based
Plantable Spaces	-	√	√
Comments	√	√	√
Database Management	Computerized	GIS integrated	GIS and work order/asset management system integration
Data Collection Method	Paper or handheld device	Handheld device	Handheld device with GIS/GPS capability
Availability	Forestry department only	Corporate-wide	Corporate wide and (limited) public online access

* Provided courtesy of Urban Forest Innovations (http://urbanforestinnovations.com/)

Current best practices related to municipal tree inventories include:

- Having an ESRI-compatible GIS-based inventory
- Having "pick-lists" or drop-down menus to minimize typing and typos
- Data collection cycles that ensure none of the data is more than five years old
- Quality control mechanisms (e.g., correct species identifications)
- The ability to share the inventory data internally with other municipal staff, and
- The ability to share components of the inventory externally (e.g., City of Ottawa, City of London, City of Toronto, Town of Oakville – see **Figures 7-2 and 7-3**) and potentially the ability of the public to contribute basic information and updates to the inventory.

A few municipalities are also starting to explore ways of integrating their urban forest (and other natural) assets into established municipal asset management plan processes as a current and evolving best practice in Ontario (e.g., York Region, Richmond Hill, London, Mississauga and Guelph – see **Section 2.1**). Therefore, municipal tree inventories should include information that can inform and be readily aligned with asset management planning. Although the format and terminology used to organize this data will vary by municipality, generally applicable categories of information to be considered are as follows.

- STATE OF THE INFRASTRUCTURE: For street and park trees, this should be addressed through an inventory (see **Table 15**), including a condition assessment.

- REMAINING USEFUL LIFE ASSUMPTIONS: Assumptions need to be made about the anticipated life expectancy of the treed assets (e.g., York Region assumes lifespans 35 years for urban trees, 44 years for suburban trees and 53 years for rural trees).

- LEVELS OF SERVICE: Determining desired and appropriate levels of service to be provided by and for assets can be very challenging, and different approaches for Peel are still being explored (e.g., CVC 2020).

- ASSET MANAGEMENT COSTING: Undertaking defensible cost:benefit analyses of different scenarios, including comparisons of investments required in natural assets versus "grey" infrastructure assets to provide comparable services, remains challenging as there are currently no standards for costing natural asset life cycles. However, different approaches for Peel are being explored and developed by agencies like CVC and TRCA (e.g., CVC 2020, Beacon 2020).

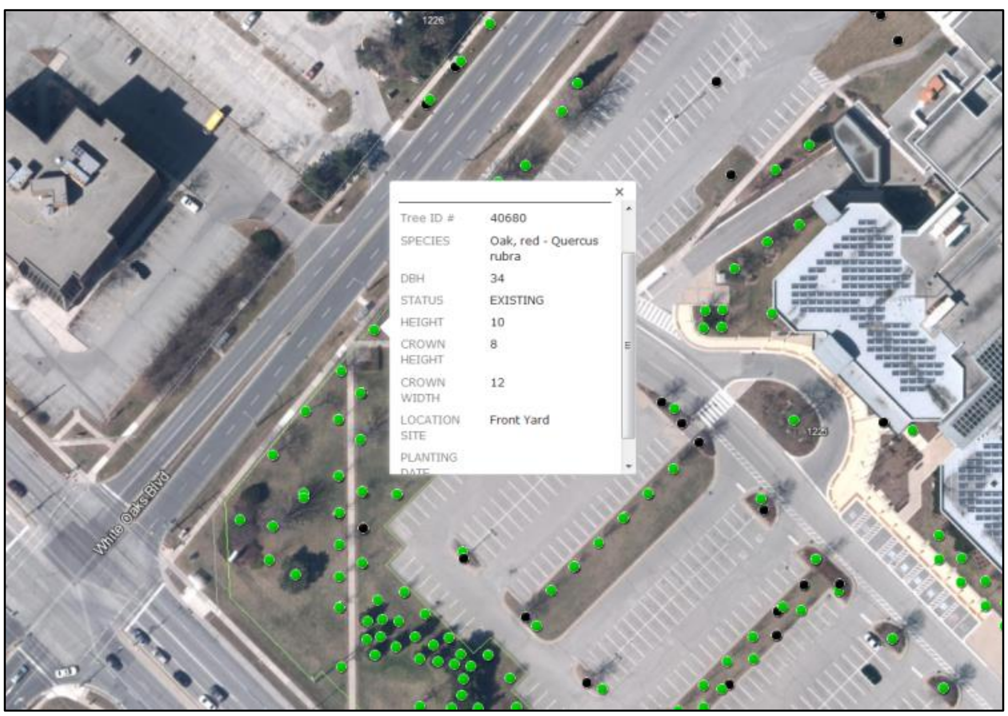
- FINANCIAL STRATEGY: This task considers resource requirements for procurement, establishment, maintenance and monitoring over the anticipated life cycle of the asset once a commitment is made to the investment.

- CONTINUOUS IMPROVEMENT: This concept is based on the principle that making small, incremental improvements to ongoing practices on a proactive basis can help ensure that desired levels of service are provided cost-effectively. For trees, a good example is investing in regular tree pruning within the first 10 years of a tree's life to reduce more costly pruning and risk management needs when the tree matures.

Inventory data can be collected by in-house staff or contractors. Contractor collection can be faster and less costly overall but requires project funding rather than being incorporated into a regular staff work plan. Examples of municipalities with high quality inventories in southern Ontario include: Richmond Hill, Bradford-West Gwillimbury, Cambridge, Kitchener and New Tecumseth.

Credit: Town of Oakville website, 2019

Figure 7-1. Example of woodlot restoration mapping publicly available on the Town of Oakville's website



Credit: Town of Oakville website, 2019

Figure 7-2. Example of street and park tree inventory data publicly available on the Town of Oakville's website

7.2 Urban Tree Canopy (UTC) Assessments and Related Tools

Urban Tree Canopy (UTC), as defined by the USDA Forest Service, refers to the layer of tree leaves, branches, and stems that provide tree coverage of the ground when viewed from above. UTC assessments have emerged as one of the most widely used tools for assessing the urban forest at a high-level across a jurisdiction.

UTC is used to assess changes in the extent and location of this cover over time, and to inform the identification of UTC targets. UTC assessments have also been leveraged to inform climate change strategies (e.g., Region of Peel 2019), prioritize general locations for tree planting efforts (Region of Peel 2015), understand issues of equity related to access to tree cover, and justify budget increases for urban forestry programs (Nowak *et al.,* 2010; Chuang *et al.,* 2017; USDA 2019). UTC assessments can also be used to inform other aspects of urban forest management, depending on the amount and types of data collected.

The approaches and analyses conducted to undertake UTC assessments can be broadly divided into two categories: those based exclusively on remote sensing and those based on remote sensing supplemented with field data collection. There are also several tools that have been developed by the USDA Forest Service (and others) that generate valuations of certain services provided by the urban forest based on UTC data. These are each discussed in further detail below.

In Peel, the Region and its partners completed their first UTC assessments in collaboration with the USDA Forest Service in 2009 based on remote sensing supplemented with field data collection undertaken by TRCA (e.g., Region of Peel 2011). These assessments were updated using exclusively remote-sensing based on 2015 aerial imagery and data (B.A. Blackwell & Associates Ltd. 2017) (see **Table 1**), and included valuations of the ability of Peel's urban forest to filter air pollution and sequester carbon dioxide. The City of Mississauga (in Peel) also undertook its own, more detailed, UTC assessment update based on 2014 imagery (Plan It Geo 2015).

URBAN TREE CANOPY (UTC) ASSESSMENTS BASED EXCLUSIVELY ON REMOTE SENSING

Data collection and analyses used to inform UTC assessments always rely on remote sensing for jurisdiction-wide assessments of tree canopy cover, although the specifics of the platform and analytical tools used can vary. UTC analyses based exclusively on remote sensing are one of the easiest and most cost-effective ways to obtain jurisdiction-wide metrics related to the urban forest that can be readily monitored over time. In fact, because in Peel (as in most jurisdictions), the bulk of the tree canopy cover is on lands under private ownership, remote sensing is one of the only ways to get comprehensive coverage.

UTC analyses based exclusively on remote sensing have traditionally been limited in that they: (a) have included several sources of error (e.g., trees in shadows of buildings being overlooked) and (b) could only provide metrics based on a two-dimensional "bird's eye" view of the urban forest with little to no data about the diversity, condition or structure of that forest.

However, over the past decade, the nature and types of imagery and remote sensing tools have become more refined[26] and the accuracy of the UTC analyses has improved significantly. In addition, the availability of imagery through Google Street View™ and more widespread use of drones has further enhanced the potential to collect site-specific information remotely. Nonetheless, these tools are not able (at least not yet) to provide all of the site-specific tree-related data that can be collected with in-person field visits by a qualified arborist.

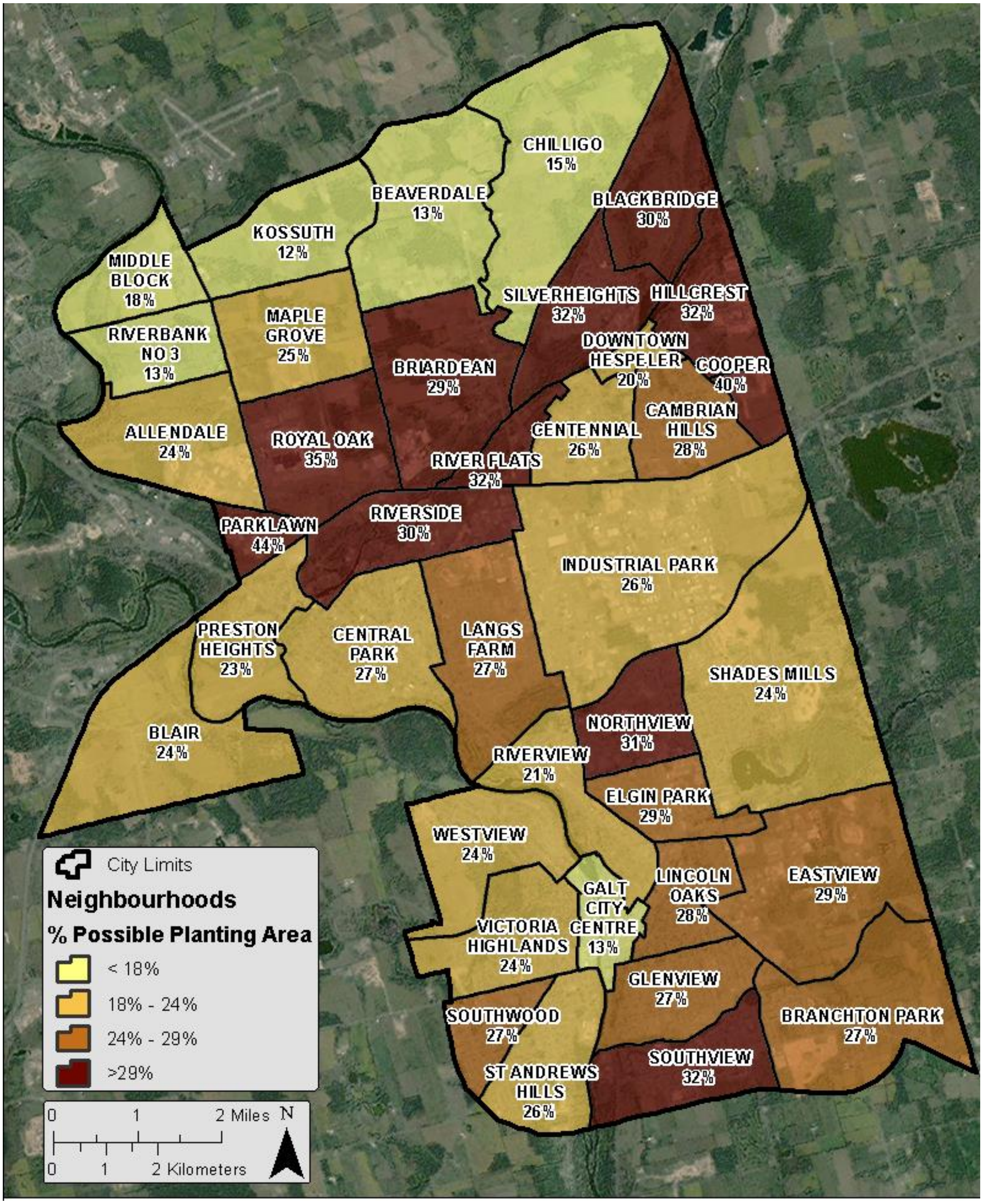
The approaches and tools available to undertake UTC assessments have evolved over the past decade in response to the types of imagery that are available and to the growing interest among municipalities in using UTC to inform strategic urban forest management at various scales. Remote UTC assessments are typically undertaken using GIS at the municipal-wide scale, but with the evolving technical tools and technologies, can be leveraged to undertake analyses at much smaller scales (such as wards, neighbourhoods and even local schools and parks).

The evolution of UTC technology has made results from older baseline assessments difficult to compare with more current analyses, which tend to be more accurate. Although there is currently no single "best practice" for mapping or analyzing UTC, current best practice directions intended to optimize accuracy, maximize usefulness to municipalities and help ensure results can be compared over time are as follows.

- Use high-resolution aerial imagery, where possible combined with LiDAR[27] for a high-quality, accurate and precise assessment.
- Use UTC analyses to assess existing UTC and to inform planting priorities (see example in **Figure 7-4**) to assess potential UTC in the given land use context.
- Collect data in formats and using methods that are well-documented and can be readily compared with previous data, even if the newer methods are more accurate or otherwise improved.

[26] For example, current analyses are typically supplemented by analysis of LiDAR and/or hyperspectral imaging where available (see web-based resources in **Appendix A**).

[27] LiDAR has the advantage, particularly in urban areas, of being able to "see through" shadows created by buildings to elucidate any trees that might otherwise be overlooked (O'Neil-Dunne 2010). Its use is also recommended for Peel by Blackwell & Associates Ltd. (2017).



Credit: City of Cambridge *Urban Forest Management Plan* (UFI *et al.,* 2015)

Figure 7-3. Potential plantable areas by neighbourhood across the City of Cambridge, Ontario

Specific recommendations for helping to ensure "apples to apples" comparisons between monitoring years as the technology evolves include the following (adapted from Plan-It Geo 2018 and B.A. Blackwell & Associates 2017).

- Do not undertake the work until current and high-quality imagery can be obtained.
- Clearly document the approach taken and methodology, including defining key terms to facilitate replication of the methodology.
    - For example, ensure the same geographic area is being assessed from year to year, and that the same inclusions and exclusions are applied (e.g., do the overall canopy cover percentages include or exclude areas of open water?).
- Avoid re-assessing UTC too frequently (e.g., generally once every five to 10 years is recommended, erring towards five years in rapidly urbanizing jurisdictions).
- Identify validation points that can be replicated such as built-in checks or approaches to screen for human error in digitizing (such as the use of tested algorithms which provide a "first cut" computer-based analysis that can then be subject to observation-based refinements as needed).

Where possible, when comparing UTC between years, undertake a scoped sensitivity analysis comparing current levels of accuracy with previous levels of accuracy to confirm if differences being detected between monitoring years are more strongly correlated to actual changes in the UTC or to the analysis methods.

URBAN TREE CANOPY (UTC) ASSESSMENTS ENHANCED WITH FIELD DATA

The value of UTC analyses completed with remote sensing can be enhanced with targeted field data collection that provides metrics related to the composition, structure and condition of the trees that comprise the urban forest.

There are different frameworks and approaches that can be used for data collection to supplement UTC assessments, but the most common framework used in North America is the i-Tree Eco™ assessment framework. This was what was used in Peel as part of the original UTC work done between 2009 and 2011[28], and what remains a best practice today.

In the i-Tree Eco™ method, selected tree metrics are collected from a number of stratified and randomly located land-based plots[29], and the results are extrapolated to apply to the entire jurisdiction. The main limitations of this value-added component are: (a) the time and resources required to plan, implement and summarize the analyses (including liaison with landowners to secure access for field data collection), and (b) the degree of error associated with the results due to the extrapolation. However, as with the UTC remote sensing, the methodology for i-Tree Eco™ have been refined over the past decade, and this margin of error has been reduced significantly.

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[28] For example, i-Tree Eco™ was undertaken in the City of Brampton by TRCA to enhance the information collected through the UTC remote sensing analyses (TRCA *et al.,* 2011).

[29] i-Tree Canopy™ is a tool that supports the identification and randomization of sample plot locations for collection of field data to inform urban forest management in a jurisdiction.

Where resources permit, i-Tree Eco™ (or comparable ground-based data collection) is recommended, as it enhances the understanding of the community's urban forest. Analyses of field collected data can provide information about the species composition, sizes and condition of the trees that comprise the canopy. Comparative analyses of differences in species composition, sizes and condition between different land uses and between different parts of a municipality can also be undertaken. These types of analyses can inform decisions about prioritizing certain areas for risk management, tree establishment, tree species diversification targets, etc.

Where resources for an i-Tree Eco™ are not available, other sources of available data can be used to help inform the UTC analyses. These could include street and/or park tree inventory data as well as natural areas survey data.

URBAN TREE CANOPY (UTC) ASSESSMENTS TO INFORM URBAN FOREST VALUATIONS

To help communicate the importance and value of the urban forest, a suite of tools have been developed that leverage the data collected through UTC and/or i-Tree Eco™ assessments to generate estimates of the financial value of certain services provided by trees to the broader community. The most well-established tools which are readily available to urban forestry professionals and municipalities are those developed by i-Tree™ sponsored by the USDA Forest service and its partners.

One of the first tools or modules released by the USDA in 2006 was i-Tree Eco™ (described above). Since that time, additional tools have been developed and existing tools have been enhanced through use, research and development and peer-review. The full suite of i-Tree tools is available from the i-Tree website (www.itreetools.org/) at no charge to individuals, groups and organizations. These tools have had such broad appeal that they have been translated into several languages (e.g., Spanish, Italian and Korean) and adapted for use in cities and countries around the world.

The primary purpose of these tools is to quantify ecosystem services and benefit values (e.g., pollution mitigation, storm water run-off reduction, carbon sequestration and storage, tree compensatory value) of community trees and forests at multiple scales. These tools leverage UTC data and can be run with remote data but may also be informed by site-specific field data.

In addition to i-Tree Eco™, available tools include the following.

- i-Tree MyLandscape™ which supports the exploration of tree canopy in relation to land cover and basic demographic information within a given area to assist in the prioritization of tree planting efforts in terms of which parts of a jurisdiction might benefit most from the ecosystem services provided by trees.
- i-Tree Design™ which allows anyone to estimate the value of some of the services (i.e., carbon dioxide removal, air pollution removal and stormwater retention potential) provided by individual trees based on inputs of location, species, tree size and condition.

Valuation estimates can be incorporated into outreach and engagement and can also be used to inform some aspects of urban forest planning and management (e.g., municipal asset management, tree planting prioritization).

7.3 Criteria and Indicators Monitoring

The third and most comprehensive type of monitoring discussed in this guide is the "Criteria and Indicators" framework to inform sustainable urban forest management.

The criteria and indicators (C&I) framework was initially developed by Clark *et al.,* (1997), who provided a list of criteria and indicators for urban forest sustainability that considered the vegetation itself, the community in which the urban forest occurs and how the urban forest is managed. Each criterion included indicators of low, moderate, good and optimal levels of performance, as well as key objectives which described the desired outcome.

The original C&I framework was then expanded and revised by Kenney *et al.,* (2011) to make it more applicable to municipal urban forest planning and management by providing more quantifiable performance measures. Most recently, the C&I framework was further revised by a USDA-led working group (Leff 2016) (see example provided in **Figure 7-5**) based on peer review and input from a range of experienced professionals including Dr. Kenney.

The C&I framework provides a comprehensive approach to monitoring for a municipality insofar as it requires consideration of: (1) the vegetation resource (i.e., the urban forest itself), (2) the community framework (i.e., the level to which various partners and stakeholders are engaged), and (3) the resource management (i.e., the level to which a range of management approaches are commensurate with either established best practices or measures/targets established by the municipality itself). The framework can be tailored in response to local conditions and objectives/targets and provides a comprehensive reference against which to assess a community's urban forest resources, community engagement and management programs, and can be used to identify areas where improvement and/or more information are required.

The performance indicators are to be reviewed periodically to track whether the urban forest and its management are improving (or not), and to identify if and in what areas management approaches need to be adjusted. Examples of communities in southern Ontario that have adopted the C&I framework include the Cities of Ottawa, Mississauga, Burlington, Guelph and Cambridge.

It is recommended that C&I be reviewed and updated every four or five years and be informed by data and information collected through ongoing inventory, management and monitoring, as well as by input from a cross-section of urban forest stakeholders. It may also be appropriate to tailor the criteria or attributes being monitored to the local context.

As a best practice, the C&I is intended to be used as a framework for overall urban forest monitoring with UTC assessments (Section 7.2) and tree inventories and monitoring (Section 7.1) to be undertaken to inform components of that overall framework.

		TBD	Low	Moderate	Good	Optimal
	Vegetation Resource					
V1	Relative Canopy Cover	○	○	●	○	○
V2	Age distribution	○	●	○	○	○
V3	Species suitability	●	○	○	○	○
V4	Species diversity	○	●	○	○	○
V5	Publicly-owned Trees	○	○	●	○	○
V6	Publicly-owned natural areas	○	○	○	●	○
V7	Trees on private property	○	○	○	○	●
	Community Resource					
C1	Municipal agency cooperation	○	○	○	○	●
C2	Large land holders	○	●	○	○	○
C3	Utilities cooperation	○	●	○	○	○
C4	Green industry cooperation	●	○	○	○	○
C5	Citizen involvement and neighbourhood action	○	○	○	●	○
C6	Trees as a community resource	○	○	○	●	○
C7	Regional collaboration	○	○	○	○	●
	Resource Management Approach					
M1	Tree Inventory	○	○	○	○	●
M2	Canopy cover assessment and goals	○	○	○	●	○
M3	Environmental justice and equity	○	○	●	○	○
M4	Municipality-wide urban forest plan	○	●	○	○	○
M5	Municipality-wide urban forestry funding	○	○	○	●	○
M6	Municipal urban forestry program capacity	○	○	○	●	○
M7	Tree establishment planning/implementation	○	○	○	●	○
M8	Growing site suitability	○	○	○	●	○
M9	Maintenance of publicly-owned trees	○	○	○	●	○
M10	Tree Risk Management	○	○	○	●	○
M11	Tree protection policy	○	○	○	●	○
M12	Publicly-owned natural areas mgmt.	○	○	●	○	○
M13	Native vegetation	○	○	○	●	○
M14	Urban forest product utilization	○	○	○	●	○

Credit: Provided courtesy of Urban Forest Innovations (http://urbanforestinnovations.com/)

Figure 7-4. Illustration of a Criteria and Indicators urban forest assessment

7.4 Summary of Inventory and Monitoring Best Practices

Both inventory and monitoring of trees on municipal lands and high-level assessment of the urban forest as a whole are recognized as part of an ongoing process of targeted data collection and assessment to inform management of this asset. An overview of the best practices identified in this guide related to tree and urban forest inventory and monitoring are provided in **Table 16**.

Table 16. Summary of best practices for inventory and monitoring of Peel's urban forest

Topic (Report Section)	Selected Best Practices and Opportunities for Peel
Municipal Tree Inventory and Monitoring (Section 7.1)	• Develop and maintain a comprehensive and current inventory of trees on municipal lands. • Integrate an adaptive management approach to urban forest monitoring and management.
Urban Tree Canopy (UTC) Assessments and Related Tools (Section 7.2)	**UTC ASSESSMENTS** • Undertake jurisdiction-wide UTC analyses every 5 to 10 years. • Where resources permit, supplement the remote UTC assessments with scoped field-collected data, ideally collected in accordance with the i-Tree Eco™ model. • Use high-resolution aerial imagery and, where possible, combine with LiDAR and/or hyperspectral imagery to maximize accuracy. • Use UTC analyses to inform current and potential canopy cover. • Collect data in formats and using methods that are well-documented and can be readily compared with previous data, even if the newer methods are more accurate or otherwise improved. **URBAN FOREST SERVICE VALUATIONS** • Leverage the UTC data collected to estimate the value of key municipal ecosystem services provided by trees in the urban forest using the i-Tree™ suite of tools.
Criteria & Indicators Assessment (Section 7.3)	• Municipalities should develop a C&I assessment as a framework for high-level monitoring of (a) the urban forest itself, (b) the level to which partners and stakeholders are engaged, and (c) the degree to which urban forest management is aligned with established best practices and/or local objectives/targets. • The C&I assessment should be updated every four to five years and informed by data and information collected through ongoing inventory, management and monitoring, as well as input from a cross-section of urban forest stakeholders.

8. Concluding Remarks

This report provides high level guidance on best practices for selecting, procuring, establishing, maintaining and monitoring trees in a context of urbanization and climate change, particularly as it relates to Peel Region in Ontario, Canada. The best practices provided in this report provide a compendium of pragmatic and progressive guidance for municipalities seeking to maximize the benefits and services provided by their tree assets outside of natural areas. Although trees in municipal natural areas are not the focus of this report, some of the best practices included in this report are applicable to wooded natural areas as well.

This best practice guide provides high level guidance for Peel as it relates to:

- Municipal forestry program administration (**Section 2**)
- Site-level considerations (**Section 3**)
- Tree selection and procurement (**Section 4**)
- Tree establishment (**Section 5**)
- Tree maintenance and management (**Section 6**), and
- Tree and urban forest inventory and monitoring (**Section 7**).

This guidance has been informed by a targeted review of a range of technical sources (see **Appendix A** and the report references), an understanding of Peel's local context, input from a range of local municipal and conservation authority professionals with expertise in municipal urban forestry (see **Appendix B**), and the consulting team's experience. Special thanks are extended to the project team members and forestry staff from various municipalities who took the time to share their expertise and provide input.

As noted in the introduction, entire manuals could be (and in some cases have been) written for each of the topics covered in this guide. This guide seeks to provide a concise overview and high-level guidance, while pointing to resources for more in-depth reading. Furthermore, this guide presents a cross-section of best practices based on current research and findings. It is expected that as the understanding of climate science and urban forestry progress, updates to the best practices in this guide will be warranted.

The best practices provided in this guide have been selected based on their relevance and suitability for trees in Peel's built and urbanizing areas but may be applicable in comparable contexts outside Peel.

While it is not anticipated that it will be feasible for the City of Mississauga, City of Brampton, Town of Caledon and Region of Peel to adopt all the best practices identified in this guide, it is hoped that each municipality will consider and adopt the appropriate guidance where feasible and as resources permit.

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Appendices

Urban Forest Best Management Practices Guide for Peel

Appendix A

Key Urban Forest Management On-line Resources

Appendix A
Key Urban Forest Management On-line Resources

The following on-line resources have been selected based on their specific and direct relevance to urban forest management best practices in Peel. The links listed below were accessed between January and December 2020. Links to additional resources cited in the report are provided in the references (**Section 7**).

Municipal Forestry Program Administration

The Clark-Matheny Model for Assessing Urban Forestry Programs
https://www.vibrantcitieslab.com/resources/the-clark-matheny-model-for-assessing-urban-forestry-programs/

Tree Canada – Compendium of Best Urban Forest Management Practices
https://treecanada.ca/resources/canadian-urban-forest-compendium/

Also see Best Practices Guide to Urban Forest Planning in Peel (2020) Appendix A for links to comprehensive municipal Urban Forest Management Plans and examples of Ontario-based asset management plans that incorporate the urban forest.

Site Assessment

Site Assessment and Tree Selection for Stress Tolerance (N. Bassuk et al., Cornell University)
http://www.hort.cornell.edu/uhi/outreach/recurbtree/pdfs/~recurbtrees.pdf

A rapid urban site index for assessing the quality of street tree planting sites (Scharenbroch and others including N. Bassuk)

- Journal article: https://www.sciencedirect.com/science/article/abs/pii/S1618866717301620
- Presentation: https://cdn.ymaws.com/www.asca-consultants.org/resource/resmgr/ac2017/handouts/Scharenbroch_etal_2017_ASCA_.pdf

USDA (United States Department of Agriculture). Natural Resources Conservation Service. 1996. Soil Quality – Urban Technical Note No. 2: Urban Soil Compaction. 4 pp. Accessed at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053278.pdf

USDA - Flow diagram for teaching soil texture by feel analysis
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311

Vineland Research & Innovation Center - Assessment and Planning for Urban Tree Establishment
https://www.greeningcanadianlandscape.ca/services

Tree Seed Selection

Forest Gene Conservation Association. 2018. Ontario Seed Zones. Accessed at https://fgca.net/what-you-can-do/seed-collection/ontario-seed-zones/

Ministry of Natural Resources and Forestry (MNRF). 2020. Ontario Tree Seed Transfer Policy. Accessed at: https://files.ontario.ca/mnrf-ontario-tree-seed-transfer-policy-en-2021-01-11-v2.pdf

Tree Species and Stock Selection – Local Resources

Credit Valley Conservation (CVC) Plant Selection Guideline (2018)
https://cvc.ca/wp-content/uploads/2018/04/Plant-Selection-Guideline-FINAL-APRIL-24th-2018.pdf

The City of Richmond Hill's Tree Species Selection Tool
https://www.richmondhill.ca/en/find-or-learn-about/Trees-and-Yards-Native-Species.aspx

Vineland Research & Innovation Center – Greening the Canadian Landscape – Tree Species Selector for Eastern Canada
https://www.greeningcanadianlandscape.ca/tree-species-selector/eastern-canada-tree-species

Tree Species and Stock Selection – International Resources

Street tree species selection tools from multiple jurisdictions in the U.S.
http://urbanforestry.frec.vt.edu/STREETS/treeselection.html

The Rutgers / University of Florida Northern Tree Selector (includes over 976 species for 50 categories)
http://lyra.ifas.ufl.edu/NorthernTrees/

The Tree Selection Guide (Barcham, UK) provides comprehensive information on species' tolerances, natural range, ecosystem services and disservices, and aesthetics
https://www.barchampro.co.uk/wp-content/uploads/2019/05/Species-Selection-FINAL.pdf

Trees and Design Action Group - Tree Species Selection for Green Infrastructure: A Guide for Specifiers https://www.csla-aapc.ca/sites/csla-aapc.ca/files/hirons-and-sjoman-2019-tree-species-selection-for-green-infrastructure-v13.pdf

Tree Establishment – Local Resources

DTAH. 2013. Tree Planting Solutions in Hard Boulevard Surfaces: Best Practices Manual. Viewed at: https://issuu.com/dtah/docs/iii-iv_best-practices-manual_append

Landscape Ontario Horticultural Trades Association. 2019. Ontario Landscape Tree Planting Guide https://landscapeontario.com/assets/1570803523.Ontario_Landscape_Tree_Planting_Guide-2019_updated.pdf

Preserving and Restoring Healthy Soil: Best Practices for Urban Construction https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/healthy-soils/preserving-and-restoring-healthy-soil-best-practices-for-urban-construction/

Toronto, City of. 2014. Construction Specification for Growing Medium https://www.toronto.ca/wp-content/uploads/2017/11/89e9-ecs-specs-roadspecs-TS_5.10_Apr2014.pdf

TRCA (Toronto and Region Conservation Authority). 2014. Preserving and Restoring Healthy Soil: Best Practices for Urban Construction. June 2012, Version 1.0 https://trca.ca/planning-permits/procedural-manual-and-technical-guidelines/

York Region. York Region Designed Soil Mix Specification. https://www.york.ca/wps/wcm/connect/yorkpublic/8521d7ba-5b7f-42e4-954e-ecece8e65220/19131_yrDesignedSoilMix.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE.Z18_29D41BG0PGOC70QQGGJK4I0004-8521d7ba-5b7f-42e4-954e-ecece8e65220-mXh2cEs

Vineland Research & Innovation Center – Greening the Canadian Landscape

- Urban Soil Toolkit https://www.greeningcanadianlandscape.ca/urban-soil-toolkit
- Urban Soil Sampling Protocol https://www.greeningcanadianlandscape.ca/soil_sampling_protocol.pdf

Tree Establishment – International Resources

Hirons, A. and Percival, G. 2011. Fundamentals of tree establishment: a review. Proceedings of the Urban Trees Research Conference, in Trees, People and the Built Environment. Forest Commission, Edinburgh, UK, pp. 51-62. Accessed at: https://www.researchgate.net/publication/269631711_Urban_Trees_Chapter_20

Urban Tree Foundation – Open-source tree planting details and specifications, template soil specification, tree quality/grading cue cards, tree selection, etc.
http://www.urbantree.org/

Nina Bassuk (Professor and Program Leader at the Urban Horticulture Institute at Cornell University)

- Cornell University Woody Plants Database – ornamental and environmental characteristics
  http://woodyplants.cals.cornell.edu/home
- Urban Habitats - Moving Beyond the Natives/Exotics Debate, N. Bassuk and M. Sutton
  http://www.urbanhabitats.org/v07n01/nativesdebate_full.html
- Video on how to remediate compacted soils compromised by urban construction
  https://www.youtube.com/watch?v=MQnI21l48yo

Ed Gilman (Professor, Environmental Horticulture Department, University of Florida)

- Planting resources from species selection and nursery growing practices to planting details https://hort.ifas.ufl.edu/woody/index.shtml
- Pruning webinar http://www.urbanforestrytoday.org/videos.html
- Adaptions from Illustrated guide to pruning, second edition (E.F. Gilman, Delmar Publishers, Albany, NY, 330 pgs.) and Horticopia: Illustrated pruning and planting (E. F. Gilman CD-ROM):
  https://www.sactree.com/assets/files/greenprint/toolkit/a/pruningComplete.pdf

Keith Sacre (Nursery Manger, Educator - Barcham Trees / University of Exeter)

- Barcham Trees – nursery guides for growing, planting and selecting trees
  https://www.barcham.co.uk/guides-advice/
- Trees & Design Action Group – guides for trees in hard spaces, valuing trees and green infrastructure and links to other resources for urban trees
  http://www.tdag.org.uk/guides--resources.html

James Urban (Landscape Architect and Horticulturalist, retired 2019)

- Planting in hardscape resources
  https://www.jamesurban.net/
- Up By Roots (book avalable for purchase)
  http://www.jamesurban.net/up-by-roots

Preserving and Restoring Healthy Soil: Best Practices for Urban Construction
https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/healthy-soils/preserving-and-restoring-healthy-soil-best-practices-for-urban-construction/

DeepRoot – Albert Key – Presentation on Urban Trees, Stormwater and Urban Design
http://www.ohioplanning.org/aws/APAOH/pt/sp/planning-webcast-series

Tree Maintenance and Management: Pruning

An approach to pruning you won't forget by Dr. Ed Gilman
https://www.youtube.com/watch?v=cHt3ym3F7Kc

Pruning shade trees in landscapes (University of Florida)
https://hort.ifas.ufl.edu/woody/pruning.shtml

Pruning - TCIA A300 Specification Writing Guideline
https://www.tcia.org/TCIAPdfs/Resources/Arboriculture/A300TreeCareStandards/A300Pruning-SpecificationWritingGuide-20170413.pdf

Pruning Specifications (Airhart & Zimmerman)
https://www2.tntech.edu/tlcfortrees/pruning_specifications.htm

Developing a Preventive Pruning Program in Your Community: Mature Trees
http://edis.ifas.ufl.edu/pdffiles/EP/EP31600.pdf

ISA Pruning Mature Trees (2011)
https://wwv.isa-arbor.com/store/product/28/

Pruning Mature Shade Trees (Whiting 2006)
https://static.colostate.edu/client-files/csfs/pdfs/616.pdf

Sample Pruning Specifications for Medium-aged and Mature Trees on a Condominium Complex http://www.floridaisa.org/mature

Tree Maintenance and Management: Risk Management

USDA Forest Service – Guide for developing and implementing tree risk management program:
https://parks.ny.gov/publications/documents/UrbanTreeRiskMgmnt.pdf

USDA Forest Service - Tree Risk Assessments: Cutting edge science meets practical applications
https://www.fs.fed.us/research/urban-webinars/tree-risk-assessment-science-and-practical-application.php

Tree and Urban Forest Inventory and Monitoring

Also see Best Practices Guide to Urban Forest Planning in Peel (2020) Appendix A

USDA Forest Service

- Urban Tree Canopy Research & Development
https://www.nrs.fs.fed.us/urban/utc/
- Urban Tree Canopy Assessment: A Community's Path to Understanding the Urban Forest, 2019
https://www.fs.fed.us/sites/default/files/fs_media/fs_document/Urban%20Tree%20Canopy%20paper.pdf

University of Vermont – SAL (Spatial Analysis Laboratory)

- LiDAR 101 Webinar (J. Neil-O'Dunne 2010)
http://letters-sal.blogspot.com/2010/08/lidar-101-nyc-lidar-workshop.html

i-Tree: Free and peer-reviewed tools from the USDA for assessing and managing the urban forest based on both GIS-based and plot data
https://www.itreetools.org/about

New York City Tree Map
https://tree-map.nycgovparks.org/

London, ON – Trees City Map
https://www.london.ca/residents/Environment/Trees-Forests/Pages/Tree-Inventory.aspx

Appendix B

Outreach Summary Table

Appendix B
Outreach Summary Table

The following table provides an overview of the input received through the outreach undertaken in support of the development of the *Urban Forest Management Best Practices Guide for Peel* between September 2019 and December 2020. Information was gathered through a combination of phone interviews, video calls, and email correspondences as well as verbal comments provided during and surveys responses provided following a webinar-workshop for urban forest practitioners in Peel and the GTA held in June 2020. This overview summarizes key pieces of information provided through this targeted engagement.

These summaries have not been reviewed by the participants. Beacon has tried to capture the information shared accurately but takes responsibility for any errors or misrepresentation.

Comments have been organized according to the source municipalities, agencies and firms, however the names of the individuals consulted have been excluded from this summary to respect their privacy.

Efforts were made to contact several international experts, however the key experts identified were retired or semi-retired and those who responded pointed us to the resources posted on their affiliated organizations' websites. Therefore, research efforts focussed on reviewing the various documents, videos and presentations posted on their on-line, as listed in **Appendix A**.

Conservation Halton (CH)
Fall 2019 • Shared CH's Draft Guidelines for Landscaping and Rehabilitation Plans, and Tree Preservation Plans via email
York Region

September 2019 and June 2020
• Shared information about York Region's planting and maintenance practices along regional roads
• Provided verbal feedback on tree establishment best practices at the June 16, 2020 workshop and also submitted feedback form
• Key feedback was as follows:
    o in ROWs the best tree is the one that will survive – irrespective of native/non-native, target diversity, etc.
    o Diversity targets are ok for parks / municipal ROWs and yards, but not regional ROWs.
    o Contract growing is challenging with public procurement. Who holds the risk if there are large failures?
    o Soil quality – more sand (50-60%), less clay (10 – 15%)
    o Roughening subgrade and soil scarification often not possible in hardpan
    o Watering – gator bags eliminate need to measure and return frequently for monitoring
    o Some success increasing pressure to accept storm water runoff into planting pits

City of Toronto

June 2020 (Provided verbal feedback at the June 16, 2020 workshop and feedback form)

- Need to distinguish between smaller potted / bare toot stock and larger 50-60 mm caliper trees for sourcing. Most of the stock used in restoration planting is species specific and grown from seed or cuttings so I support using plant material grown from locally collected species. In the case of large wire basket field grown caliper trees used in street and park tree planting – much of what we buy are cultivars. These are grown in southern Ont. But are purchased as "whips" from nurseries in the USA or on the west coast where growing seasons are much longer.
- Diversity targets are too rigid in urban centres.
- Nursery stock - inspection of stock using standardized cue cards should be the minimum requirement that a municipality should rely on. I would recommend that municipalities try to hire at least one person who has experience in the nursery industry and understands best practices.
- Contract growing - contract growing can and does work for specific programs.
- Our preference in Toronto is always to use native species whenever possible. However, given climate change and growing conditions along streets in the urban environment – staff have to find the best tree for the site; non-native trees should be considered
- Soil amendments have their place
- Recommend using native soil when possible but there is a place for amendments. For example, mycorrhizae appear to provide some benefits
    - City of Toronto plans to do a study on the benefits of mycorrhizae in autumn 2020.
- Critical to track seed/stock provenance but challenging to convince Council to invest in sole source contract growing.
- Would be better if Province regulated / required provenance tracking; but at this time Province has moved away from valuing tree seeds or their tracking.
- Tree plates or grates are only bad if the opening is not large enough to accommodate root plate growth. In general, too much energy/resources allocated to plates, tree protection, etc. and not enough to providing basic needs for tree – space and drainage. Examples of successful approaches:
    - plastic tree guards perform the same as metal but were cheaper and easier to maintain and helped prevent movement of gator bags which sometimes damage trees;
    - tree “diapers” also very effective and did not move around in the wind and so did not damage trees;
    - using planting guards on all newly-planted trees.
- Species selection also key for hardscapes.
- Consider adding more detail on amount, frequency and time of year of watering since watering is such a key factor in post-planting establishment. I think the rule of thumb of watering 4L for every 2.5cm of caliper applies more to automated irrigation systems that water every 1-2 days. In Toronto we specify watering once every 2 weeks May to September with around 40L (typically in a gator bag), with an increase to 1 trip per week in July and August.
- Regarding topsoil placement and compaction, I have seen specifications very depending on whether soil is being installed to backfill around root balls, or to fill a larger planting area with future growing medium.
- Around root balls I believe Toronto specs foot tamping in lifts of 15 cm, and adding water once planting hole is half-filled with soil. In open planting areas, the typical specs. are to install in lifts of 30-40 cm and compact lightly by foot.
- Support leaving soil 10% higher than desired grade to allow for settlement, but not always possible if the soil area directly adjacent to a walkway where grade continuity is required.
- When it comes to sub-surface continuous soil trenches below suspended paving, I have been pushing for a slightly more thorough foot compaction done in lifts of 20 cm to a cone penetrometer reading of 200-250 PSI, to address the fact that we can't return to add more soil or otherwise address settlement issues after paving is installed.

City of Hamilton

September 2019 and June 2020
• Shared information about City of Hamilton's planting and maintenance practices for street trees, including successes with some aspects of management and challenges with hardscape plantings
• Attended June 16, 2020 workshop and also submitted feedback form
• Key feedback was as follows:
    o Tree species selection should take into account cultivars (e.g., fruitless etc.), salt and heat tolerance, mature tree size, public visibility and daylight triangles, as well as potential pest concerns.
    o Spacing for trees should be 8 - 10m on centre for larger species and 6 - 7 metres on centre for smaller species.
    o Guidelines for species diversity should ensure no single species shall make up more than 20% of the total street tree population.
    o No coniferous trees permitted on City of Hamilton road allowance (due to visibility).
    o Trees planted on the road allowance have a minimum approximate caliper of 50 mm.

City of Guelph

September 2019 and June 2020
• Shared information about City of Guelph's planting and maintenance practices for street trees, including successes with some aspects of management and challenges with hardscape plantings.
• Provided verbal feedback on tree establishment best practices at the June 16, 2020 workshop and in a follow-up call on June 17, 2020, and a subsequent email with input on the feedback form June 26, 2020.
• Key feedback was as follows:
    o General support for the suggested BMPs in the feedback form with the following specific suggestions:
        ▪ 12a – 10 m on center seems large. I would use 6 m for smaller trees. The on center distance should be min 6 but determined by species size.
        ▪ 13b – include the word 'temporary' somehow. People tend to leave this protection on for much longer than required.
        ▪ 15 – compost level seems high
        ▪ 18a – says both 3m minimum and 1.5m minimum. Either I'm not understanding this or you are saying two contradictory diameters
        ▪ 21 – gator bags to be removed for winter
    o See City of Guelph's Tree Technical Manual: https://guelph.ca/wp-content/uploads/Tree-Technical-Manual.pdf
    o Typically, City of Guelph maintains (i.e., inspects, prunes) at 5 and 10 year marks after warranty period, and waters / mulches for two years. However, City currently transitioning into an assumption model whereby proponent undertakes maintenance and monitoring for a set period of time.
    o Have had some success in prolonging life of ash trees with treatments – not so much with saving them from EAB.
    o Previously had some challenges with soil cell installations where drainage was not considered and number of trees appeared to have drowned. This has been corrected.
• In some geographic areas (like Guelph where pH tends to be high) amendments are required

City of Mississauga
September 2019 and June 2020 • In Sept. 2019, shared City's street tree inventory is done; park trees about 30% done. • Attended workshops for partners on May 1 and May 8, 2020 on Draft Urban Forest Management Best Practices Guide for Peel. • Attended and provided some verbal feedback on tree establishment best practices at the June 16, 2020 workshop. • In June 2020, shared some information about the City's woodland naturalization practices in City parks. • In October – November 2020 shared additional feedback related to the City's urban forest planning procedures, standards, specifications and levels of service.
City of Brampton

October 2019 and June 2020
• Shared information about City of Brampton's planting and maintenance practices for street trees, and about both successful practices / approaches and gaps in knowledge.
• Provided verbal feedback on tree establishment best practices at the June 16, 2020 workshop.
• Key feedback included:
  o Newly completed development guidelines include specifications tree spacing, species selection, tree arrangement, texture, min. tree size, soil volume and depth – so far these specs appear to be resulting in well-established trees that will contribute to the City's canopy cover as they mature.
  o Planners can develop policy for easement agreements with private property owners for access to planting (volume); sidewalk breakouts are also an option to increase soil planting volumes.
  o In general, well-installed breakouts do not result in sidewalk heave because (a) roots given adequate space to expand below-ground and tree also given adequate space to accumulate mass above-ground. Also – avoid tree grates; tree plates are better for protecting planting area but easier to remove as tree grows (note - tree plates are solid plates that act as an extension of the sidewalk).

Town of Caledon
October 2019 and May - June 2020 • Shared some information about the Town of Caledon's planting and maintenance practices for street trees, but noted due to the Town's limited resources this work is largely contracted and specific activities and results are not tracked. • Attended workshops for partners on May 1 and May 8, 2020 on Draft 1 of Urban Forest Management Best Practices Guide for Peel. • Provided review of and input to Draft 1 of both report 2 and Report 3
Region of Peel
October 2019 and June 2020 • No regional standards or guidelines in place at the moment – this is a significant gap. • Current practices include: visual inspections of ROW trees / veg; Hazard and dead tree program – in good shape; Stumping in progress – but no formal program; No pruning of established trees; Some replanting – try to get trees as far from roadway as possible • Lack of tree aftercare program is an urgent need – 333 trees came off warranty in 2019. Also need a stumping program. • Interest in knowing if others are preparing sites before planting (e.g., scarifying and/or replacing soil) – just digging hole for rootball not adequate. • Approx. 17,000 trees in Peel ROWs; last inventory in 2013 but needs updating.

University of Guelph Arboretum (including a non-commercial tree nursery)

February – June 2020
• Shared information on their native plant growing practices, challenges with sourcing seed and stock, and thoughts on contract growing over several interviews held between February and April 2020.
• Provided verbal feedback on nursery practices at the June 16, 2020 workshop.
• Key input and feedback included:
    o need for better communication between municipalities and growers;
    o input on planting methodology, nursery stock production and availability, pest control methods, species sourcing, and gene conservation.
    o suggested species native to the eastern USA that would be good candidates for street trees;
    o educational / skill barriers to producing lesser known species that may be candidates for inclusion in the urban forest;
    o links to resources on climate change modelling and species migration.

Verbinnen's Nursery

June 2020
• Shared information on their native plant growing practices, challenges with sourcing seed and stock, and thoughts on contract growing.
• Key feedback on native plant sourcing included:
    o Can be willing and ready to provide Ecodistrict information if required. Currently tracks to seed zone. Demand must come from the customer.
    o Lack of certification an issue; no way for nurseries to be held accountable
    o Collection of seed south of the border: unknown if network exists; growers in Ontario would need to establish relationships with collectors south of the border – would be a slow process.
    o Support seed collector training and sees it as essential to continuation of availability of Ontario native woody plant stock.
    o Ontario Tree Seed Plant – even if re-opened may not fill the supply gap; irrespective people are not asking about provenance.
• Key feedback on contract growing included:
    o Currently does contract growing, often with customer-supplied seed. Contract growing only really works for large orders (500+ plugs, 250+ container stock)
    o Open to contract growing opportunities and partnerships

Urban Forest Innovations (UFI)

Input shared as part of the June 16, 2020 webinar:
• Good root systems key to establishment - this starts at the nursery (root flare exposed) but municipalities must reject trees with poor roots as well so nurseries learn to check this. Use of Urban Tree Foundation cue card god for stock inspection
• Not all soil volumes are equal – best practice generally 30 m3 minimum soil volume if loam, but more needed for poorer soils and/or to account for volume of tree cells. Not all soils are the same
• Drainage is also critical and sometimes overlooked
• Key strategies for sustaining quality include:
  o dry wells in planting pits move water and simultaneously flush salt;
  o use structural soil cells (72%- 93% efficient; cells account for some space);
  o avoid gravel-based structural soils (20% efficient);
  o see James Urban's soil resources on-line.
• Good to explore both active and passive watering and drainage: Active = tree diapers / gators, bubbler, watering. Passive = water directed to tooting area through design / drainage e.g., accepting road runoff - can be ok where flushing is also provided.
• https://www.greeningcanadianlandscape.ca/ has a good tool for species selection.
• Best to use local soils whenever possible; imported soils can be helpful when needed but must be tested.

CanPlant
Input shared as part of feedback following the June 16, 2020 webinar: • There is not currently enough stock of source-identified trees for large scale tree planting, also it is very difficult to require contractors to buy from particular nurseries. • *No more than 5% genus-level diversity* - This may be difficult to implement, there are not a lot of trees that work in urban conditions unless Peel is OK with including non-invasive non-native species on its acceptable tree list. • Source identified contract grown stock is not the cheapest stock. • There are non-native, non-invasive species that should be considered for municipal tree plantings as these trees may do better in harsh urban conditions than native trees. Also it will help in achieving the diversity requirements you are recommending. • 90 cm – 1 m depth recommended: This is a small range and will be very difficult to achieve on most sites • 10 m o.c. - Trees can often be planted more closely together than is recommended in urban planting guidelines while maintaining health and structure. • Lifts of 30-45 cm: These are very big lifts. Lifts of 15 – 20 cm are usually recommended elsewhere. • Undertake manual scarification and loosening of the planting hole side walls: Good practice, but most contractors won't do this. There is a lot of good information and detail in this document, and I commend the Region of Peel for taking a proactive approach to their urban forests. However, most of the suggestions will be very difficult, if impossible, to implement given the nature of current construction techniques and the coordination required between disciplines to achieve these standards.

Forest Gene Conservation Authority (FGCA)

Input shared as part of feedback following the June 16, 2020 webinar:
• There are no provisions within the MNRF Seed Transfer Policy to have Southern Ontario nurseries label stocklots by ecodistrict unless grown for Crown land, nor to record total number of contributing parents (measure of genetic diversity), this must be requested by the client.
• To achieve reportable metrics, Peel must track or monitor single source-identified provenance from BMP #1 nurseries first. Changing and tracking seed zones or sources each order seems more likely to achieve an urban forestry mix of the same species over time.
• Appropriate climate—ready stocklots could be better given if Peel were to help establish and maintain purposely designed production orchards of specified provenance %s.
• For genera with known pests - contribute to conservation programs with at-risk species where healthy natural individuals or stands persist, don't cut pre-emptively, i.e. ash, butternut, beech, hemlock, etc.
• Seed Plant maintenance and seed collection: Support FGCA and Partners instead on both; no longer MNRF mandate
• Contract growing:
    o upholding contracts and deposits will make Ontario seed collection and source-identifying larger stock more feasible for Peel
    o registering stands that seed collectors can safely access with FGCA's SCAN project is a good third-party step for traceability; Forests Ontario and nurseries best dealing with seed collectors for actual contracts and delivery.
    o mixing seed from different provenances requires oversight and tracking, designed orchards like FGCA's, or complete trust in the nursery or contract to do so.
• Clearly define the geographic boundaries for what is considered "native" to Peel. Would this not be most appropriate and easily mapped on a Conservation Authority watershed basis for natural migration pathways? Native (or indigenous better term?) plant lists would exist already from flora surveys within the watershed yes? Is Peel considering specifically designed climate refugia to maintain particularly vulnerable indigenous plant communities?
• Amendments: Addition of perennial-weed-free, active compost where organic matter is needed not of use when topsoil has been removed? Mycorrhizal fungi for very poor soils?

UFORA (Urban Forest Associates Inc.)

Input shared as part of feedback following the June 16, 2020 webinar:
• Ontario Tree Seed Plant is no longer under provincial jurisdiction
• For balled and burlapped stock preferably remove as much of the wrapping material as possible
• For container stock tightly rootbound plants should be returned to the nursery.
• Plant with the root collar at or slightly above the final grade, regardless of where the root collar is in the container when received.
• Young tree pruning:
    o Generally, it is a good practice to reduce multiple leaders to allow dominance of one main upright leader to prevent future crown breakage.
    o Work with nurseries to grow trees with better form. Reduce multiple leaders, better branch spacing.
• Competition management: coarse woodchip mulch is preferred to fine textured mulches, as they take longer to break down and provide greater aeration and moisture permeability.
• One of the greatest impediments to good practices is caused by restrictive purchasing policies that favour the cheapest trees over all other considerations and …(thereby) favours suppliers that import all of their stock from the US.
    o Find ways to facilitate better seed source and plant supply at a reasonable cost, with cost not as important as plant quality.
    o Adjust the supply chain to provide stock of the desired quality by providing payments and incentives for desired practices.
    o Favour local suppliers who cooperate with the program.
    o Work with trusted partners instead of using open bid processes as much as possible. Emphasis is on quality, not price.
    o Purchase stock for use by others, instead of issuing supply/install contracts or require contractors to supply stock for public and development projects that meets these quality specifications, no exceptions, and inspect their material.
    o Reject it if it doesn't meet specifications.
    o Always have an inspector on site to check stock before its planted.
• Misidentification of species … is a common problem, especially if an invasive species is substituted. Once a tree is planted it is very unlikely that it will be taken out and replaced, even if it's the wrong species.
• Work to educate staff and nurseries how to correctly identify species and reject misidentified stock immediately. Don't compromise at the delivery site for the sake of convenience.
• Go beyond a two-year survival guarantee as the only measure of planting success.
• Create and enforce more detailed standards and apply them to everyone, including municipal and CA staff.
• Work more on soil quality on urbanized sites. It does no good to plant a quality tree in a hole that is made of broken concrete and salty soil.

Appendix C

Site Assessment and Tree Selection for Stress Tolerance Checklist (UHI 2009)

Recommended Urban Trees:

Site Assessment and Tree Selection for Stress Tolerance

Urban Horticulture Institute
Department of Horticulture
Cornell University
Ithaca, New York

RECOMMENDED URBAN TREES:
Site Assessment and Tree Selection for Stress Tolerance

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To Order Contact: urbanhort@cornell.edu
Copies - $16.95 (Bulk order discount available)

A companion video, 'Tough Trees for Tough Sites'
is available from the e-mail address above for $21.95

USING THIS BOOK

Scientific Name & Common Name: A **species** is the most important unit in plant selection. A species is written as two words, the genus as in *Acer* (the genus for maple) and *saccharum* (the specific epithet). The genus and species (**spp.** for plural abbreviation and **sp.** for singular abbreviation) names are either underlined or italicized in print. Together, *Acer saccharum* describes the species name for the commonly named Sugar Maple.

A species is a group of plants that share many of the same characteristics that are passed along from generation to generation. However, each member of the species is genetically distinct. In some species there may be considerable variation between individuals in terms of leaf shape and color, flower color, fruit size, growth habit, performance and vigor, while in others there may be little variation.

When a distinct variation within a species can be in inherited from generation to generation by seed it is said to be a **variety (var.) or subspecies (ssp)**. *Acer saccharum* ssp. *nigrum* describes a subspecies of Sugar Maple, Black Maple, from the western part of the Sugar Maple's range in the United States. It can be written *Acer saccharum nigum*. However, it is worth noting that some people feel that *A. nigrum* is a separate species unto itself. There may still be considerable variation within a variety or subspecies.

A **cultivar** (for cultivated variety) is a tremendously important designation in horticulture. A cultivar is chosen because of distinctly superior notable traits such as form, autumn leaf coloration, flower color or size, vigor, cold hardiness or disease resistance to name a few. Most of the time, cultivars are genetically identical or clonal. It is possible to have a cultivar of a variety or of a species. They are propagated asexually in order to maintain the genetic character of a specific plant. *Acer saccharum* 'Bonfire' is an example of a cultivar of the species, *Acer saccharum*. *Acer saccharum nigrum* 'Green Column' is an example of a particularly drought tolerant selection of *Acer saccharum nigrum*. The cultivar is always capitalized and put in single quotes. When the species derivation is complex, cultivar names can be added to the genus name directly as in *Malus* 'Adirondack' (Adirondack Crabapple) or *Crataegus* 'Vaughn' (Vaughn Hawthorn).

Trademarked™ or **Registered Trademark®** names are also noted where they apply. These are names given to cultivars to aid in marketing. For example, the Crabapple (*Malus* sp.) cultivar 'Sutyzam' has the registered trademark name Sugartyme®. The trademarked or registered trademark name is typically (although not correctly) listed in place of the cultivar name by many nursery retailers.

Environmental Conditions: It is important to note that some trees are adaptable to a fairly wide range of environmental conditions while others have a narrow range in which they will grow well. By presenting the following tree list we are providing information about adaptability. All trees will grow well under near optimal conditions with a pH of 6.8 and consistently moist but well drained soil. However, we rarely find these conditions in the urban environment. It is our purpose to highlight those trees that tolerate broader, less ideal conditions while still providing the benefits for which we planted them. These more adaptable plants don't prefer poorer conditions, but can still grow adequately in them. This specific information is key to making informed plant selections.

Hardiness Zone: All trees listed here are hardy to Zone 6 (minimum winter temperature of -5° to -10° F) or colder based on the USDA Plant Hardiness Zone Map (see on page 12). A hardiness zone listed in parenthesis for a tree or cultivar indicates that there is some speculation or literature supporting the tree's hardiness extending into that noted colder zone.

SITE ASSESSMENT CHECKLIST

1. Site Location ______________________________

2. Site Description ______________________________

3. Climate

a. ***USDA Hardiness Zone***

__6b __5b __4b __3b
__6a __5a __4a __3a

b. ***Microclimate Factors***

__Re-reflected heat load
__Frost pocket
__Wind
Other ____________

c. ***Sunlight Levels***

__Full sun (6 hrs. or more)
__Partial sun or filtered light
__Shade

d. ***Irrigation Levels***

__No supplemental irrigation
__Automatic irrigation system
Irrigation amount and rate:
____

4. Soil Factors

a. ***Range of pH Levels*** _______
(Note actual readings on sketch)

b. ***Texture***

__Clayey
__Loamy
__Sandy

c. ***Compaction Levels***

__Severely compacted
__Moderately compacted
__Somewhat compacted
__Uncompacted

d. ***Drainage Characteristics***

___Presence of mottled soil
___Low-lying topography
Indicator plants suggest site drainage:
___wet ___well-drained ___dry
Percolation test results (in./hr.)
___poorly drained (< 4"/hr.)
___moderately drained (4"- 8"/hr.)
___excessively drained (> 8"/hr.)

e. Other Soil Considerations

__Indications of soil layer disturbance
__Evidence of recent construction
__Presence of construction debris
__Noxious weeds present:
____
____
____
____
__Evidence of excessive salt usage
__Erosion of soil evident
__Evidence of soil contamination
__Usage that compacts soil

f. ***Specific Soil Problems***

____
____
____
____
____
____
____

5. Structural Factors

a. ***Limitations to above-ground space***

___Overhead wires (height:_________)
Proximity to buildings/structures:
Other___________________________

b. ***Limitations to below-ground space***

__Utilities marked and noted on sketch
Approximate rooting volume for site
Length:__ Width: __ Depth: __

6. Visual Assessment of Existing Plants

a. *Species*	b. *Size*	c. *Growth Rate*	d. *Visual Assessment*

Sketch of Site

Note north arrow; circulation patterns; pH readings; location of overhead wires, underground utilities, buildings and pavement, as well as problem drainage areas.

COMPLETING THE SITE ASSESSMENT CHECKLIST

Suggested Tools and Materials

Cornell pH test kit and instructions	shovel and trowel
soil texture by feel instructions	plastic bags
wash bottle filled with water	wristwatch or timer
at least 4 gallon jugs of water	weed identification manual
paper towels	ornamental plant identification manual
measuring tape	hand pruners
yardstick	pencil/pen and extra paper

Optional tools: diameter tape, penetrometer, soil probe, vials containing alcohol for unknown insects, infrared thermometer

1. Site Location

Note the address of the site. You may also wish to note the nearest cross streets and/or page and grid of the maps your firm uses.

2. Site Description

A brief overview of the site including: general use or function, approximate size, accessibility, general topography (steep hill, gentle slope, etc.)

3. Climate

a. *USDA Hardiness Zone*

Check the USDA hardiness zone of the site. If planting in containers above ground you may want to regard the site as a zone colder than listed, as trees in containers are more susceptible to cold winter temperatures than trees in the ground.

b. *Microclimate Factors*

Re-reflected heat load: Determine if the site, or some portion of it, has heat pockets due to reflected and reradiated heat loads from pavement, automobiles, buildings or other surfaces. This can cause a tree to heat up and lose water from its leaves at a faster than normal rate. These pockets are often south facing and have a tremendous amount of heat load. On sunny days, these areas will be noticeably warmer than nearby spots. Drought-resistant trees should be chosen in these situations.

Frost pocket: Frost pockets are often found in low areas at the bottom of a slope or bowl. Cooler air, being heavier, collects in these areas, lowering air temperatures.

Wind: Excessively windy sites will often place stress on trees, particularly those with large leaves which may result in leaf tatter. Also, trees in these sites may need supplemental watering to prevent them from drying out as quickly. Signs of excessive wind are trees leaning or growing in the same direction. Plants will have stunted growth on the side that faces the full force of the prevailing wind. Wind tunnels are common in urban areas where wind is funneled between tall buildings.

Other: Are there other factors that might affect the climate or precipitation levels? For example, are there wide rain shadows formed by the overhang of a building? Is the site located near a large body of water that may moderate the climate?

c. *Sunlight Levels*

Shady sites determined by the sun and shade patterns around buildings may limit the choice of trees. Consider that a site has full sun if it receives more than 6 hours of direct sunlight. Partial sun has direct sun (often morning sun) for less than 6 hours, or filtered light (as would be common under a tree with fine textured eaves) for most of the day. An area is consider shady if it receives little or no direct sunlight, or if it receives less than 6 hours of filtered light.

d. ***Irrigation Levels***

Note the presence or absence of an automatic irrigation system. If possible record the method of delivery (overhead, drip, mini-sprinkler), the weekly amount of water applied and the rate at which it is applied. You may wish to test the system by setting out collection containers in different on the site and running the system for a specified amount of time to test the delivery rate. Comparing the actual amount delivered with the manufacturer's specifications for the system will indicate its efficiency.

4. Soil Factors

a. ***Range of pH Levels***

Check the pH for several areas on the site. Pay particular attention to the pH near sidewalks and parking areas, concrete or masonry buildings or foundations. These limestone-containing materials in the street environment result in the high ph levels (from neutral to alkaline) of most urban soils. Note the range of levels on the front side of the checklist. Note the sample locations and exact readings on the sketch on the back of the checklist.

b. ***Texture***

In the field, test the soil texture using the soil texture-by-feel technique, and record the results on the checklist. If you must know the exact soil texture, record the general soil type on the checklist and collect several samples to be analyzed by a soils lab. A sandy soil will suffer less from the effects of compaction but may be less able to supply water to trees. Conversely, compaction may render a heavy clay soil too wet, making oxygen less available.

c. ***Compaction Levels***

There are several ways to test for soil compaction. A simple one is to use a penetrometer. Record the average depth of penetration at which the probe measures 300 psi. Alternately, you may take several soil cores using a soil probe and analyze them for soil density. Perhaps the simplest test is to dig a small pit and gauge the difficulty of hand digging. Repeat the 'shovel test' in several spots.

d. ***Drainage Characteristics***

Determining the drainage characteristics of your site is a multi-faceted task.
Presence of mottled soil: The strongest indication of poor drainage is mottled soil. Dig a soil pit at least 12" to 15" deep and remove several clods for examination. Clods that have grey mottling and/or have a foul odor indicate poor drainage.
Low-lying topography: Study the topography for low-lying areas that collect surface runoff and that may be poorly drained.
Indicator plants: Plants that indicate poorly drained (wet) sites include Willow, Pin Oak, Swamp White Oak, and Tupelo. Plants that indicate moist soils are sycamore and tulip trees. Plants that indicate well-drained sites are sugar maple, red oaks and hickories.
Percolation test: To perform a percolation test, dig a pit approximately one foot deep. Fill the pit with water and allow this water to drain completely. Once the water has completely drained, refill the pit with water, measure the depth of water in the pit and note the time. After 15 minutes, note the depth of water and calculate the rate of drainage in inches per hour. (The initial filling and draining of the pit is to saturate the soil to test more closely for gravitational water movement.) Classify the soil into one of the three drainage classes: poorly drained (< 4"/hr); moderately drained (4"-8"/hr); or excessively drained (> 8"/hr).

e. ***Other Soil Considerations***

Indications of soil layer disturbance: Look for areas that show evidence of regarding cuts or fills. Clues include mature trees that do not show a trunk flare (due to soil piled against the trunks), or have retaining walls near their bases. You may wish to dig a pit approximately two feet deep in order to examine the soil horizons, especially if the site has recently had construction activity. Soil layers that are noticeably lighter in color than lower layers indicate that subsoil has been spread on top of the original grade. Conversely, the absence of a rich brown, organic layer at the top may indicate that the topsoil has been removed.

Evidence of recent construction: Clues include newly-pave surfaces, turf that is noticeably thinner than in surrounding areas, new retaining walls, soil 'humps' or subsidence, and the like. Also consider the route or routes taken by heavy equipment into the site and where materials were stored during construction.

Presence of construction debris: Construction debris is likely on almost all construction sites, particularly if tipping fees for debris are high in your area, and if construction involved the renovation or removal of a building or pavement.

Noxious weeds present: Use a guide to identify weeds. Pay particular attention to perennial noxious weeds that must be eradicated before landscape installation. Perennial weeds that are commonly found in urban landscapes include: bindweed, poison ivy, mugwort, wild violet, nutsedge, quackgrass, and healall.

Evidence of excessive salt usage/salt injury**:** Look (particularly near walks and parking areas) for white powder that has precipitated out on the soil surface. Prostrate knotweed is a weed that indicates salty compacted soil. Brown needle tips, marginal leaf scorch, or witches' broom on ornamentals indicate salt injury. Carefully examine areas where salt-laden snow has been dumped. These areas are likely to have high soil salt concentrations.

Erosion of soil evident: Determine the extent and severity of soil erosion. Note the presence and size of eroded gullies, rills, or soil slumps. Factors that affect soil erosion include: rainfall intensity, quantity, and runoff; slope length and gradient; amount of stabilizing plant material or other erosion control practices; the infiltration rate and the structural stability of the soil.

Evidence of soil contamination: Look for signs of dumping by restaurants or open-air food stalls of wash water, old dumping areas, construction dumping areas, oil and gas dumping, and the like.

Usage that compacts soil: Is the area used for open-air markets or parties? Are there pathways that pedestrians have created? Is the area sometimes used for parking? Are there other social activities that are planned for the site that tend to compact the soil?

f. ***Specific Soil Problems***

Use this space to record specific soil problems that occur on the site.
Problems might include an inability to surface drain a site, possible soil chemical contaminants, and the like.

5. Structural Factors

a. ***Limitations to above-ground space***

Overhead wire height: Describe the location and estimate the height of over head utility wires.

Proximity to buildings and structures: Note the location of buildings and structures on the back of the checklist. Check the box on the front side of the checklist if you anticipate buildings or structures having an impact on the canopy space of landscape plantings.

Other: Are there any other limitations to above-ground space? Examples include: building or planting setbacks, emergency access lanes that must be kept clear, heat vents, and signs that must be readable from the road.

b. ***Limitations to below-ground space***

Utilities: Mark utilities on the sketch. Identify individual utilities if possible. Know that you must hand dig within two feet on either side of the marked line.

Estimate rooting volume: In order to estimate the available rooting volume of a planting site, measure the length and width of available soil, and multiply area by the estimated depth of rooting. Remember that compacted soil will have a very shallow rooting depth.

6. Visual Assessment of Existing Plants

a. ***Species***

Identify the species of plant. The more specific identification is, the better. You may wish to collect leaf and/or bud samples to bring back to the office for identification of obscure plants or plants not in leaf.

b. ***Size***

Approximate the height and spread of the plant material using the following field method: Place a yardstick (or other object of known height) against the trunk. Step back so that the whole tree is in your sight. While holding a pencil or pen at arm's length, line up the top of the yardstick with the tip of the pencil. Using your thumbnail, mark the base of the ruler on the pencil. Sighting up the tree, determine how many 'rulers' fit into the tree. Multiply this number by the length of the yardstick for a height approximation. Use the same method to estimate the canopy spread. You may also wish to note the diameter of the trunk at breast height (4.5' above ground level).

c. ***Growth rate***

Quantify this year's annual shoot extension by measuring the twig length between growth tip (terminal bud) and the bud scale scar. Past years' growth is the length between bud scales. Measure several branches growing in the sun in the upper 2/3 of the canopy. Record the average growth rate. Less than 2" of growth is considered poor, 2" to 6" is moderate growth, and greater than 6" per year is vigorous growth.

d. ***Visual Assessment***

In general: Note aesthetic quality and general health of each plant. Indicate mechanical injury to plant parts. Also note the presence of insects or disease. Keep in mind that diseases and insects often attack stressed trees and may not be the primary cause of health problems.

Trunk assessment: Look for evidence of mower or string trimmer damage at the base of the trunk. Also look for excessive suckering or bark splitting. Note any trees that do not exhibit a trunk flare (indicative of recent regrading activity or that it was planted too deep).

Roots: Note excessive surface rooting and girdling roots. These may signify poor drainage, too-deep planting, and/or compacted soils. Test the stability of newly planted trees by gently rocking them. If there is excessive movement, the trees may have root problems, or the roots were never able to establish after transplanting.

Leaves and branches: Stressed trees often exhibit small, off-color leaves that drop early in the fall. Also note trees whose leaves show marginal leaf scorch and whose branches have tip die-back. If there is significant die-back, is it all on one side of the canopy or is it on both sides? Do all of one species on the site exhibit the same symptoms? Note the presence of witches' broom, watersprouts, or other abnormalities.

Appendix

Tree Grading Cue Card (RPG 2015)

Tree Grading Cue Card
2015 Edition

provided by RPG, ACT, Florida Chapter ISA & UF/IFAS

1 Choose appropriate tree matrix type.

Type 1 – tall and wide form
ex. black-olive, live oak, mahogany, southern magnolia

Type 2 – tall and narrow form
ex. bald-cypress, East Palatka holly, Japanese blueberry, pine

Type 3 – short/wide and multi-trunked form
ex. silver buttonwood, tabebuia, yaupon holly, crape-myrtle

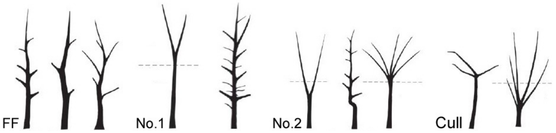
Refer to the matrix tables in the Grades and Standards to determine tree height, crown diameter and root ball or container size requirements.

a) For multi-trunked small maturing trees measure the container or root ball size.

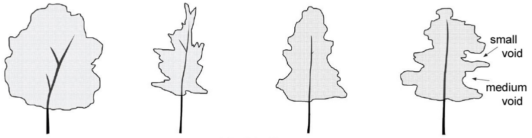
b) For all other trees measure the caliper.

Trunk caliper is measured 6 inches above the ground on trees up to and including 4 inches in caliper, and 12 inches above the ground for larger trees. Diameter at breast height (DBH) is not considered an appropriate measurement for nursery trees.

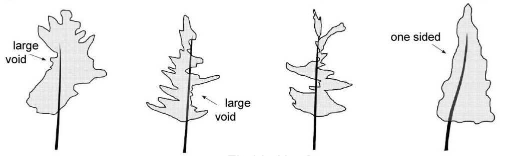
2 Grade the tree according to trunk structure.
Small-maturing trees skip step 2.



3 Grade the tree according to crown uniformity.



Florida Fancy



Florida No. 2

Not all shapes and forms are represented here; however, these images represent what would be acceptable for Florida Fancy or Florida No. 2 of other shapes and forms. Note: For crown uniformity there is no Florida No. 1 or Cull grade.

4 Record the lowest grade determined in Steps 2 and 3.

5 If one of the following statements is true, reduce the grade determined in Step 4 by one.

If two or more are true, reduce the grade by two. Reference tree caliper and appropriate matrix for 5a, 5b, and 5d. For multi-trunked small maturing trees, use container size or root ball diameter (not caliper) for 5b and skip 5a and 5d.

a) Tree does not meet height requirement.
b) Crown does not meet diameter requirement.
c) Root ball is not secure enough to successfully transplant.
d) Root ball or container is undersized. If two or more sizes, reduce grade by two.
e) Tree with a trunk caliper larger than two inches requires a stake to hold the trunk erect. For multi-trunked trees, this applies to each trunk individually.

6 If two of the following statements are true, reduce the grade determined in Step 5 by one.

If three or more of the statements are true, reduce the grade by two. It takes only one true statement to reduce Florida Fancy to Florida No. 1.

a) Flush cuts were made when pruning branches from the trunk.
b) Branch stubs were left beyond the collar.
c) Open trunk wounds are evident.
d) More than 10% of the crown exhibits necrosis, chlorosis or damage from pests, diseases or tip dieback.
e) The crown is thin and sparsely foliated (allow for harvesting/ time of year).
f) Included bark between the trunk and a major lateral branch or between main trunks.
g) Trunks and/or major branches are touching.

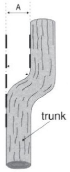
7 The tree is a Cull if one of the following conditions is true:

a) Top-most structural root emerges from trunk more than two inches below the top of the root ball surface. Soil, substrate and/or roots can be removed from the top 1/3 of the root ball to conform to this depth requirement.

b) One or more roots greater than 1/10 the trunk caliper, circle more than 1/3 of trunk in the top 1/2 of the root ball. Circling roots less than 1/3 the trunk diameter can be cut at the point just inside where they begin to circle, following cutting, the tree is no longer a Cull.

Grading notes

- A dogleg is a significant S-shaped deformation in the trunk below the crown. If there is a dogleg in the clear trunk portion, the tree is graded Florida No. 2. If the dogleg is in the crown portion of the tree, the tree is not downgraded. The distance 'A' can be no more than the trunk diameter.



- Grades and Standards do not apply to specialty trees like braided stems, poodles, espalier, topiary and bonsai.

- To download the complete G&S document visit http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry

ROOTS PLUS GROWERS ACT Grower ISA FLORIDA CHAPTER UF UNIVERSITY of FLORIDA IFAS Extension

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