TREES AND CONSTRUCTION

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Philip van Wassenaer, B.Sc., MFC
1248 Minnewaska Trail
Mississauga, Ontario
web: www.urbanforestinnovations.com
email: info@ufis.ca

URBAN FOREST INNOVATIONS INC.

SPEAKER PROFILE

URBAN FOREST INNOVATIONS INC.

Philip van Wassenaer

Speaker Profile

Urban Forest Innovations, Inc.

Since 1994, we have specialized in the preservation, enhancement and management of the urban forest through a research and science based approach.

Expertise in:

- Advanced risk assessment
- Ravine stewardship
- Appraisals and valuations
- Tree preservation planning
- Urban forest inventories
- By-law and regulation development
- Tree injection methods and materials
- Strategic urban forest management planning

Speaker Profile

Outline

- Urban forestry and the benefits of trees
- Tree biology
- Trees and construction: Potential effects
- Best Practices for construction near trees
- The role of the arborist/urban forester

Urban Forestry and the Benefits of Trees

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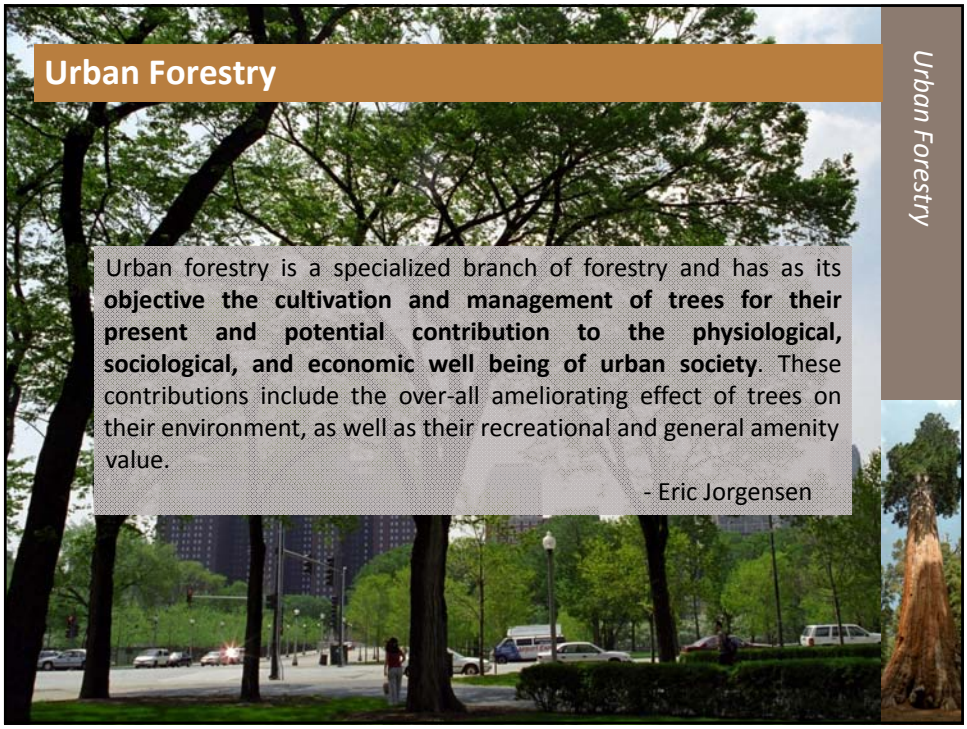
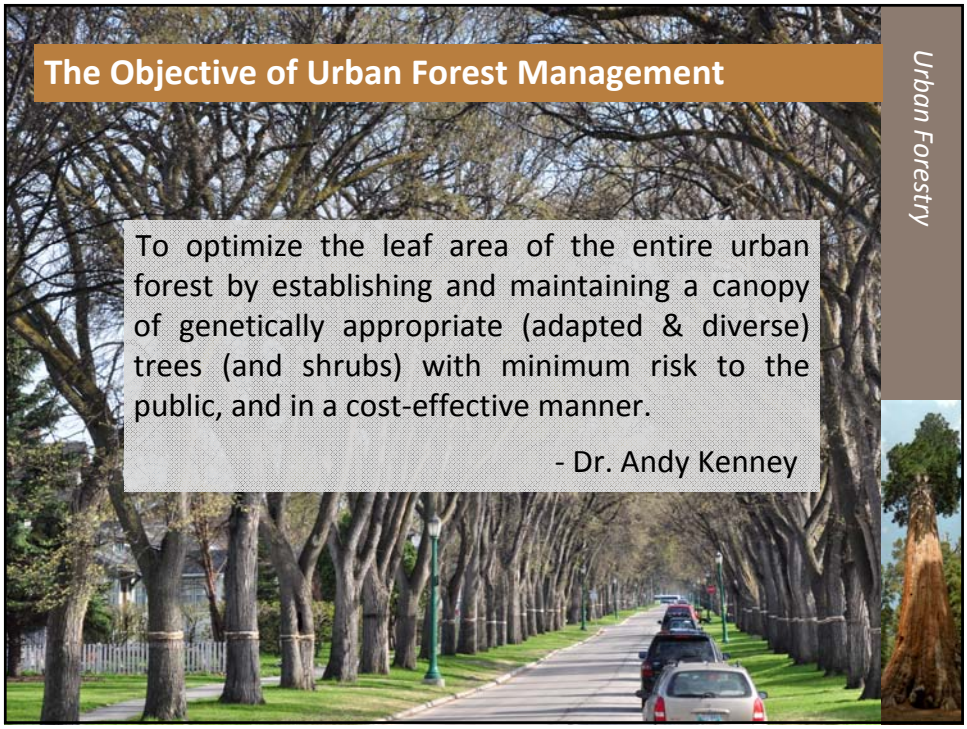

Urban Forestry
Urban forestry is a specialized branch of forestry and has as its **objective the cultivation and management of trees for their present and potential contribution to the physiological, sociological, and economic well being of urban society**. These contributions include the over-all ameliorating effect of trees on their environment, as well as their recreational and general amenity value.
- Eric Jorgensen
Urban Forestry


The Objective of Urban Forest Management
To optimize the leaf area of the entire urban forest by establishing and maintaining a canopy of genetically appropriate (adapted & diverse) trees (and shrubs) with minimum risk to the public, and in a cost-effective manner.
- Dr. Andy Kenney
Urban Forestry

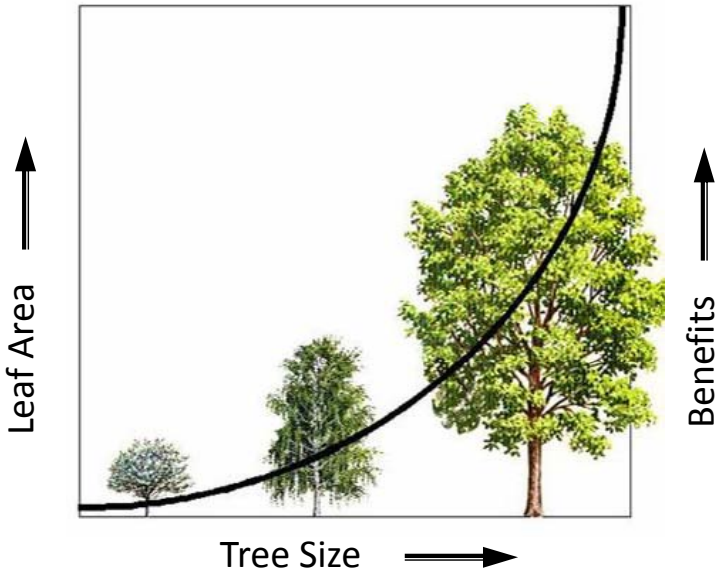
Urban Forest Benefits

The urban forest provides a wide range of services such as:

- Improved air quality
- Micro-climate effects (e.g. shading)
- Property value & Aesthetics
- Storm-water attenuation
- Energy conservation
- Noise reduction
- Wildlife habitat
- Physical & Psychological wellbeing
- etc.

Urban Forestry

Maximizing Leaf Area



Urban Forestry

Tree Biology

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Trees

Tree Biology

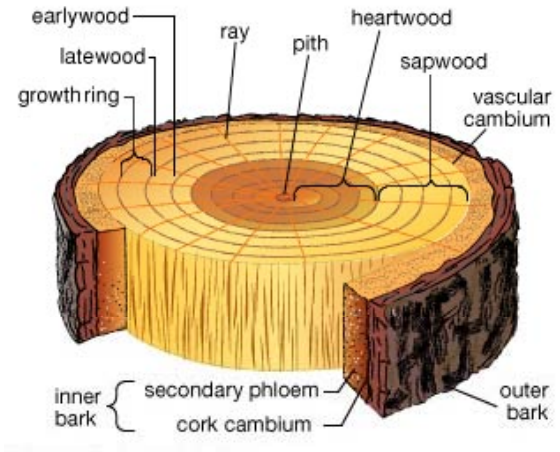
Shigo (1984) described trees as "*highly compartmented, woody, perennial, shedding plants. They are often long-lived and massive.*"

Trees are made up of **cells**, — Meristems and differentiation - primary and secondary

which make up **tissues**, — Cells with similar structure and function - e.g., bark, wood, foliage

which make up **organs**. — 5 organs: **leaves, stems, roots, flowers** and **fruits**

Cross Section of a Tree



Tree Biology

Stems

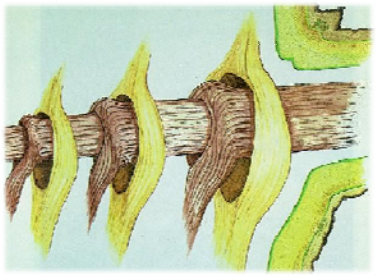
- **Twigs** support flowers and fruits
- **Branches** support twigs
- The **Trunk** supports branches and crown
- **Buds** are where twigs, leaves and flowers originate
  - Apical buds – at end of shoots
  - Axillary buds – along twigs and stems

Tree Biology

Branches

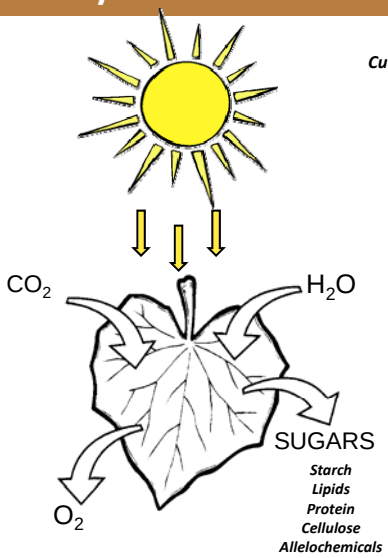
Tree Biology

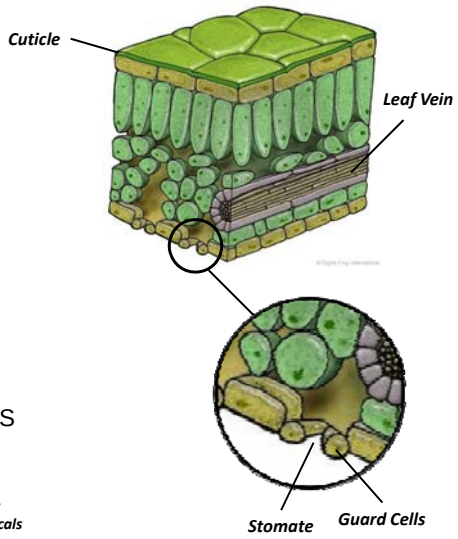
- Branches must sustain themselves and export excess to the trunk.
- Strongly attached below union, weakly above.
- **Branch collar** forms where trunk and branch tissues join.
- **Branch bark ridge** forms in crotch where tissues expand against each other.
- In tight unions, bark is squeezed between and is termed 'included'.



Photosynthesis

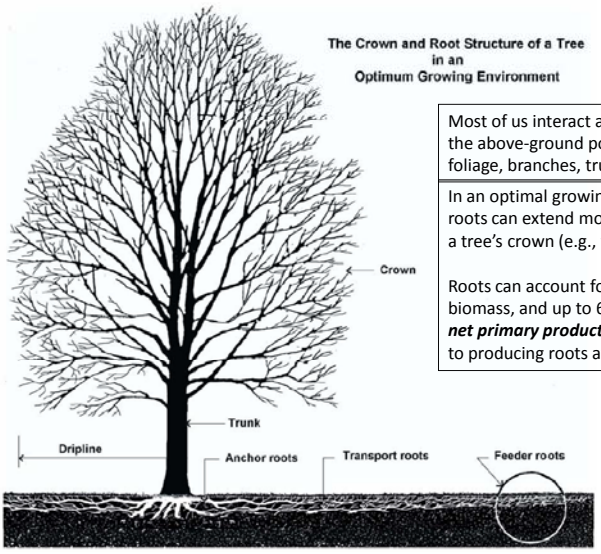
Tree Biology





Trees and Roots

Tree Biology



Most of us interact and are familiar with the above-ground portion of a tree – its foliage, branches, trunk, fruit and flowers.

In an optimal growing environment, a tree's roots can extend more than 6x the width of a tree's crown (e.g., white oak).

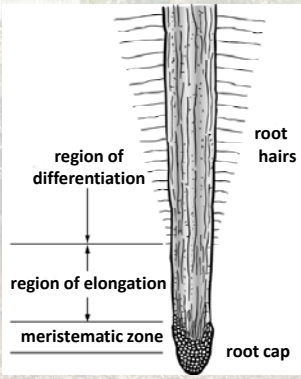
Roots can account for about 50% of a tree's biomass, and up to 60% of a tree's ***net primary productivity*** can be dedicated to producing roots at a given time.

Roots

Tree Biology

- Roots serve several purposes: **anchorage, storage, absorption** and **conduction.**

- Absorbing roots – found in the top 20-30 cm of soil.
- Sinker roots – provide support.
- Tap root – deep central root found only in some species.
- Mycorrhizae – fungi symbiotic with fine roots.

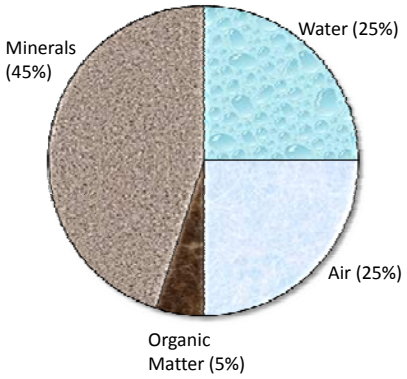


Root Growth Factors

Tree Biology

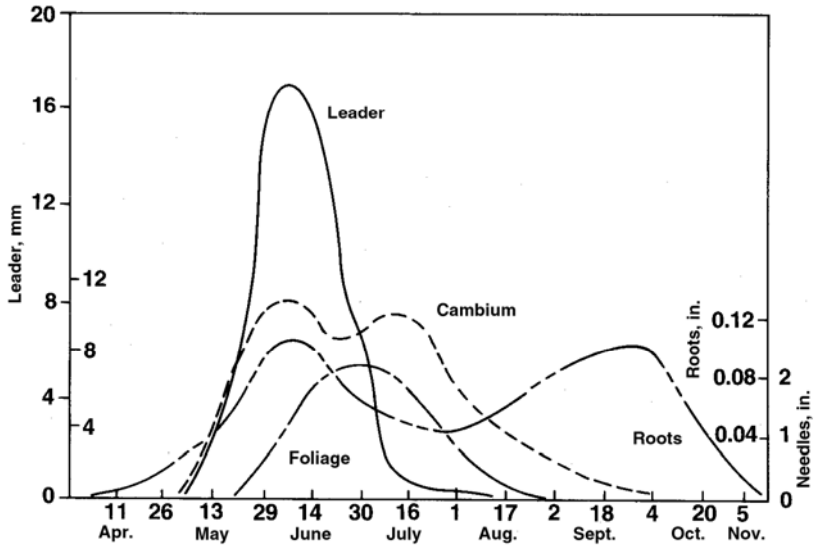
Root growth is limited by the following factors:

- Water
- Air
- Soil temperature
- Soil pH
- Soil structure (micro/macropores)
- Nutrient availability
- Nursery and planting practices



Tree Growth

Tree Biology



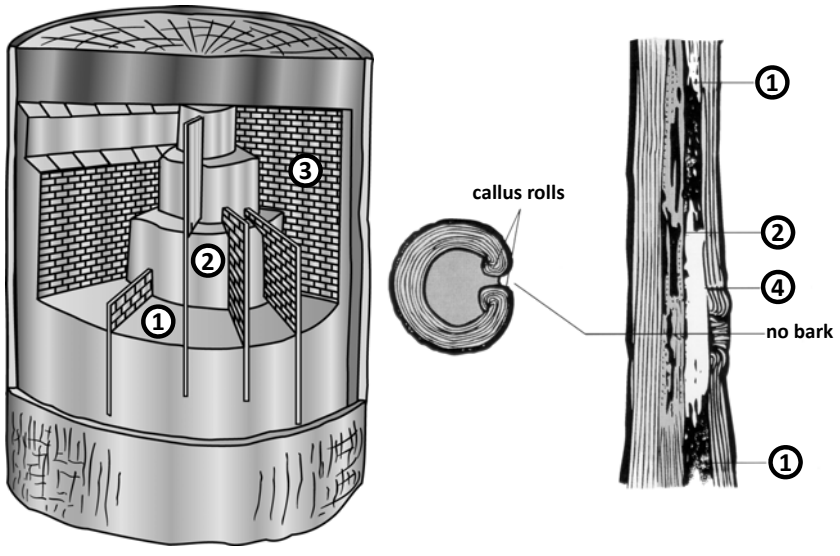
Defence Against Decay

Tree Biology

- Trees can't move away from injury and decay, so they try to cope.
- When a tree is wounded reactions occur to form barriers around the affected area.
- Shigo and Marx (1977) developed the CODIT model – **C**ompartmentalization **o**f **D**ecay **i**n **T**rees
- Walls 1, 2 and 3 (reaction zone) and 4 (barrier zone)
- Wall 1 weakest, wall 4 strongest
- When walls 1, 2 and 3 fail, cavities form.

The CODIT Model

Tree Biology



Trees and Construction

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Construction Effects

Potential Effects of Construction

Impact to Tree	Construction Activities
Root loss	• Soil removal through mass grading • Lowering grade • Subgrade preparation for paving or fill • Excavation for footings, foundations or walls • Trenching for utilities or drainage
Root stress, poor conditions for development	• Soil compaction • Spills and waste disposal (e.g., oil, fuel) • Soil sterilants under pavement • Impervious paving over soil surface • Installation of fill over existing roots (raising grade)
Wounding of tree	• Injury from operation of equipment • Poor or excessive pruning for clearance
Inadequate soil moisture	• Rechanneling of stream flow • Redirection of surface runoff • Lowering water table • Lowering grade
Excess soil moisture	• Raised water table or backup of underground flow • Lack of adequate surface drainage away from tree • Compacted soils – many micropores, few macropores • Stand thinning or undergrowth removal • Over-irrigation

Harris, R.W., Clark, J.R. and N.P. Matheny. 2004. *Arboriculture – Integrated Management of Landscape Trees, Shrubs , and Vines.* Prentice Hall: Upper Saddle River, NJ.

Symptoms of Tree Stress from Construction

- Short shoot elongation (slow growth)
- Small, yellowish leaves
- Thin foliage
- Leaf scorch
- Wilting
- Early fall colours or leaf drop
- Epicormic shoots
- Heavy seed production
- Twig dieback
- Branch dieback
- Irregular wounding
- Attack by borers and other pests
- Decay at wound sites
- Death

Construction Effects

Symptoms of Tree Stress from Construction

Construction Effects

Symptoms of Tree Stress from Construction

Construction Effects

Root Loss

- Removing soil from the root zone will damage roots and may destabilize a tree.
- Grade lowering of 6 in. or more will likely kill a tree unless implemented properly.

Construction Effects

Root Loss

Construction Effects

Root Loss

Construction Effects

Root Loss






Root Loss

Being able to take a picture of the canopy through the roots is never a good thing.

2 x 4s around the trunk do not count as tree protection.

A gas station needs pipes.
Does the tree not need roots?

Potential Effects of Construction

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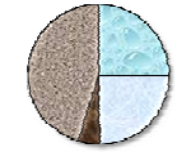
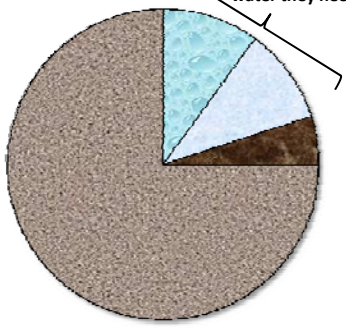
Root Stress and Poor Conditions

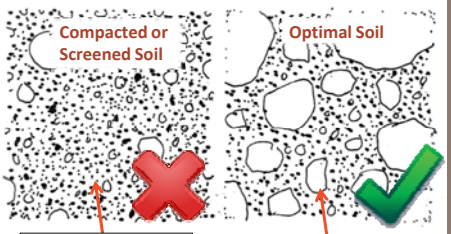


Optimal Soil

Not enough macropores deny roots the air and water they need.

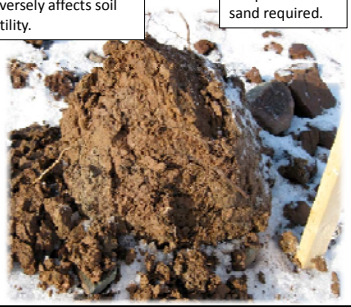


Compacted or Screened Soil



Few macropores, requires addition of sand to allow drainage. Adversely affects soil fertility.

Macropores maintained with soil peds. Less sand required.



Root Stress and Poor Conditions

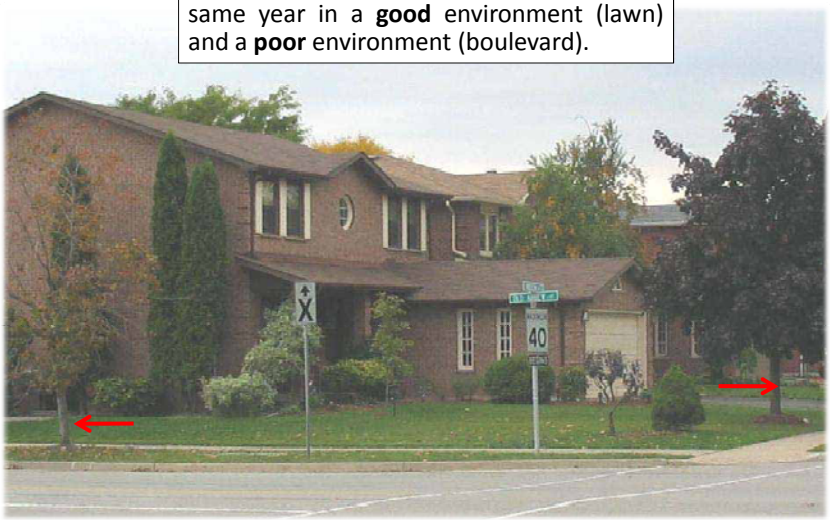
Compacted soils can lead to shallow roots, if the tree can grow at all.

Trees planted in compacted urban soils have an average life span of only 7 years.

Construction Effects

Root Stress and Poor Conditions

Compare the Norway maples planted in the same year in a **good** environment (lawn) and a **poor** environment (boulevard).



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Wounding of the Tree

Physical tree injury to trunks and roots contributes to the development of decay. Over time this can create significant hazards.

Old wound and root damage likely caused during sidewalk replacement.

Potential Effects of Construction

Construction Effects

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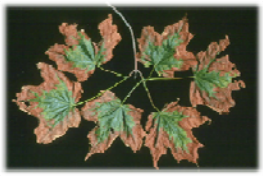
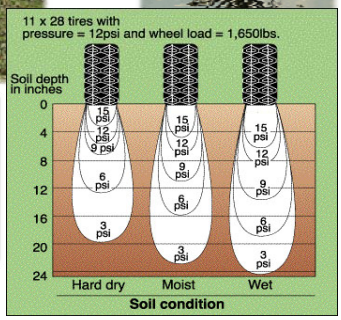
Soil Moisture Problems

Construction Effects

With excess water, trees drown and die. Excess water is caused by poor grading, inadequate drainage, backup of underground flow, etc.

Inadequate soil moisture creates stress, making trees more susceptible to secondary pathogens or killing them outright. →





Wet soils are more susceptible to compaction. →

Best Practices for Construction near Trees

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Best Practices for Construction near Trees

Tree Protection Practice	Objective
Planning and Design Phase	• Minimize the cost and complexity of tree establishment and protection at the front end. • Maximize the benefits provided by existing trees.
	Preconstruction Treatments
Arboricultural Treatments	• Improve tree health to maximize resilience to construction.
Tree Protection Zones (TPZ)	• Protects trees (proactive) rather than treating injury (reactive). • Excludes all activity within "critical root zone" and area of key feeder roots.
Sensitive Excavation / Root Pruning	• Prevents root tearing, shattering and decay.
Grading Considerations	• Minimize root loss
Soil Compaction Avoidance	• Maintains optimal soil structure.
	Post-construction Treatments
Root Zone Therapy	• Restores soil structure.
Replanting	• Restores trees.
Monitoring	• Ensures long-term tree health, implementation of remedial actions.

Best Practices

Planning and Design Phase

Planning – assesses the potential land uses, selects the most feasible uses, determines the general project layout.

Design – develops plans and supporting documents to describe the project.

Tree preservation ***cannot wait*** until the construction phase.

Best Practices

Steps to Effective Tree Protection

1. Perform a tree inventory – know what trees are on site, what condition they are in.

2. Identify trees suitable for preservation – not all trees are sacred: unhealthy, unsound, unsafe, invasive can be considered for removal/replacement.

3. Assess potential impacts to trees – review all development and construction plans for possible impacts to trees on the site.

4. Suggest modifications to development plans – identify areas where impacts are too severe upon the trees. In clay soils, consider how water demand may affect soil stability.

5. Identify required tree work prior to tree removal and grading – arboricultural prescriptions such as crown pruning, pest management, transplanting, etc.

6. Prepare and implement tree protection specifications – dictate how and where work will be performed. Should generally include protective fencing at a minimum.

7. Monitor trees during construction – Arborist should be on hand regularly, and whenever specific treatments (e.g. root pruning) are required.

8. Prepare post-construction maintenance plan – including monitoring, decompaction, etc.

Best Practices

Transplanting

Best Practices

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Best Practices

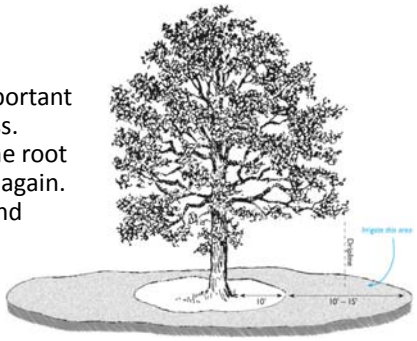
Arboricultural Treatments

Best Practices

Before construction begins, a number of treatments can:

1) make trees more resilient to construction impacts,
2) provide clearance for equipment and materials,
3) protect the tree from damage, and
4) clear unwanted vegetation.

Irrigation – Possibly the single most important treatment for trees under drought stress. Avoid light, frequent irrigations. Soak the root zone, allow water to be absorbed, soak again. Wet top 2-3 feet of soil under canopy and beyond.



Fertilization – Depends on history of tree care. Generally should be preceded by a soil analysis to determine deficiencies.

Arboricultural Treatments

Best Practices

Pest Management – Control pests before, during and after construction.

Pruning and Preventative Maintenance – Crown pruning to provide clearance for equipment may prevent future irreparable damage. Generally a minimum of 2.4 m (8') above sidewalks or 4.3 m (14') above roads is required. All pruning must be done in accordance with ***good arboricultural practices. Trades persons must not prune trees.***

Mulching – Mulch can protect roots, conserve soil water, and should be left on site after construction. Mulch should cover as wide an area as possible to a maximum depth of 10 cm (4").

Best Practices for Construction near Trees

Best Practices

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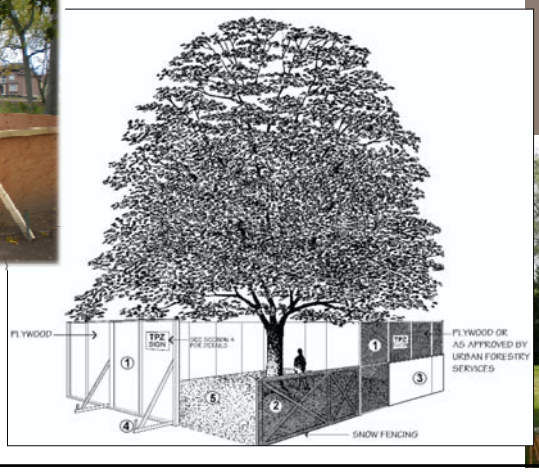
Tree Protection Zones

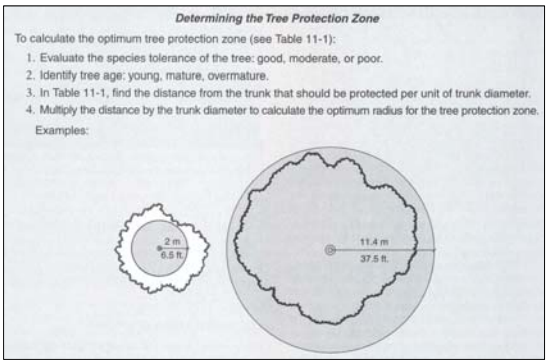
Best Practices

The first and foremost goal is to protect the tree rather than repair damage. Tree Protection Zones (TPZs) are the most effective way to accomplish this. TPZs should almost always be enclosed by sturdy temporary fencing.



Tree Protection Zones

Best Practices



Guidelines for optimum tree protection zone for trees

Species Tolerance	Tree Age	Distance from Trunk per Unit Trunk Diameter (m/cm)	(ft/in.)
Good	Young (< 20% life expectancy)	0.06	0.5
	Mature (20 to 80% life expectancy)	0.09	0.75
	Overmature (> 80% life expectancy)	0.12	1.0
Moderate	Young	0.09	0.75
	Mature	0.12	1.0
	Overmature	0.15	1.25
Poor	Young	0.12	1.0
	Mature	0.15	1.25
	Overmature	0.18	1.5

Source: Modified from the British Standards Institute (1991). Guidelines are for trees of average to excellent vigor.

There are many ways to determine minimum TPZ size.

Oakville Specifications

DBH (cm)	TPZ (m)
<10	1.2
11-40	2.4
41-50	3.0
51-60	3.6
61-70	4.2
71-80	4.8
81-90	5.4
91-100+	6.0

Tree Protection Zones

Best Practices

TPZs must be maintained ***throughout*** the course of the construction process, and must not be moved for any reason unless authorized by the project consulting arborist or urban forester.

Best Practices for Construction near Trees

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Best Practices

Sensitive Excavation/Root Pruning

Most grading and excavation is conducted to remove a large amount of soil, quickly. **This is bad news for roots**, which can be torn and shredded for a long distance by excavation equipment.

Root pruning can prevent this.

Before excavation begins, sensitive excavation *at the edge of the TPZ* combined with root pruning will maintain roots intact.

Hydrovac, Airspade, or hand digging can expose roots without damage, enabling an arborist to properly prune them.

Roots can be pruned by root pruning saws, but only to a depth of about 30 cm. For deeper excavations, rock saws or trenchers can be used, but they usually result in jagged cuts, which must be cleaned with a saw.

Best Practices

Sensitive Excavation/Root Pruning

***Hydrovac** sensitive excavation and root pruning.*






Construction Effects

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Tree Protection Zones (TPZ)	• Protects trees (proactive) rather than treating injury (reactive). • Excludes all activity within "critical root zone" and area of key feeder roots.
Sensitive Excavation / Root Pruning	• Prevents root tearing, shattering and decay.
Grading Considerations	**• Minimize root loss**
Soil Compaction Avoidance	• Maintains optimal soil structure.
	Post-construction Treatments
Root Zone Therapy	• Restores soil structure.
Replanting	• Restores trees.
Monitoring	• Ensures long-term tree health, implementation of remedial actions.

Best Practices

Grading Considerations – Fill

Best Practices

Filling is raising a grade by adding more soil in compacted layers, usually atop a stable base. Thus, unfavourable conditions for root development are created *and* roots are often lost.

It is therefore important to keep fills outside of root zones as much as possible. Any fill over 150 mm (6") may kill most species of trees.

The most common methods to alleviate the effects of fill on roots is to build a "tree well" with an aeration system. **To date, there is no scientific evidence that these expensive and complicated systems have positive effects on tree health.**

The most effective way to avoid the adverse effects of grade change by fill ***is to avoid it in the first place.***

If it is unavoidable, only then should you consider designing a large, well-drained tree well system.

Grading Considerations – Cut

Best Practices

Cutting is the removal of soil to lower a grade. Removal of soil from under a tree's canopy removes a significant amount of roots.

Cutting may destabilize the tree, especially if roots are removed from within the "Critical Root Zone" – approx 1.5x DBH.

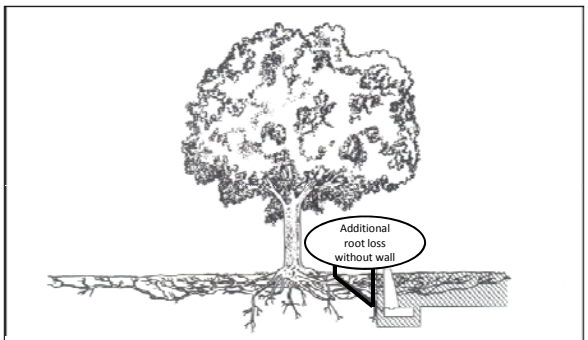
Roots cut *well within Critical Root Zone* led to failure by uprooting.

Grading Considerations – Cut

Best Practices

Careful exploration for the extent of roots is the key to minimizing loss by cutting the grade.

Retaining walls *with discontinuous footings* can reduce the horizontal distances of grade change, best for > 300-600 mm (1'-2') grade changes.



How grade transitions are handled can significantly affect root disturbance. Retaining walls can be used to reduce the horizontal distance for grade changes for a cut or fill, thereby reducing root impacts.

Best Practices for Construction near Trees

Best Practices

Tree Protection Practice	Objective
Planning and Design Phase	• Minimize the cost and complexity of tree establishment and protection at the front end. • Maximize the benefits provided by existing trees.
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Soil Compaction Prevention

Best Practices

When construction must take place over root zones, it is possible to minimize the degree of soil compaction which occurs.

An effective prescription includes:

- Landscape fabric lain on the ground over as large an area as possible.
- 15 cm of granular stone spread over the fabric.
- Landscape fabric lain over the stone.
- 15 cm of bark or wood chip mulch lain over the stone.
- Steel plates or ¾" plywood lain over the top.
- Decompaction of soils after construction is completed, as required.

This prescription must be implemented ***before*** the commencement of construction.

Soil Compaction Prevention

Construction Effects

Construction Practices

Construction Practice	Objective
Directional Boring	• Minimizes root loss and damage.
Paving Design	• May maintain roots, access to water and air.

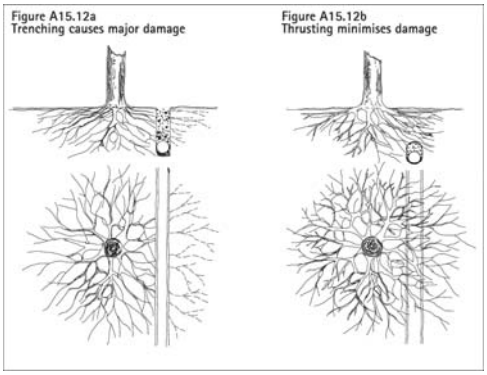
Best Practices

Directional Boring

A variety of services must generally be placed underground.

Most require access from above ground, and have different depth and spacing requirements.

Roots are often there first, and also must share limited below-ground space.

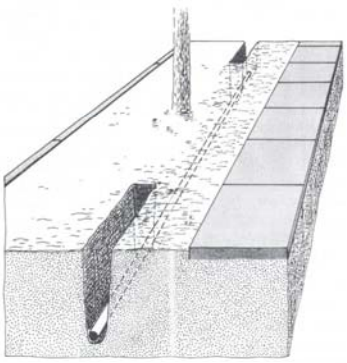


Trenching is the most common method of installing utilities; also the most damaging.

Directional boring minimizes root loss by routing utility bundles below roots instead of through them.

Best Practices

Directional Boring



Trenching for utility pipes and cables can be stopped and tunneling begun at the limit of the tree protection zone or when major roots are encountered.

Directional boring, or tunneling, can be initiated at the edge of the tree protection zone.

Depth should be below the zone of most absorbing roots, which won't be more than 60 cm (2') for most trees.

There is a variety of boring techniques available; site conditions must be evaluated to determine which is appropriate.

Best Practices

Sensitive Trenching

An alternative to boring is to continue trenching, but to excavate roots with Hydrovac or Airspade and install utilities in between the roots.

Best Practices

Paving Design

Best Practices

Pavements can be problematic for trees, but some will grow well even with paving as close as 50 mm (2") to trunks.

However, when subbase preparation is required, there are far more adverse impacts. A typical pavement section can extend more than 1 m (3') below grade.

The most important factors to protect trees against are ***root loss*** and ***compaction***.

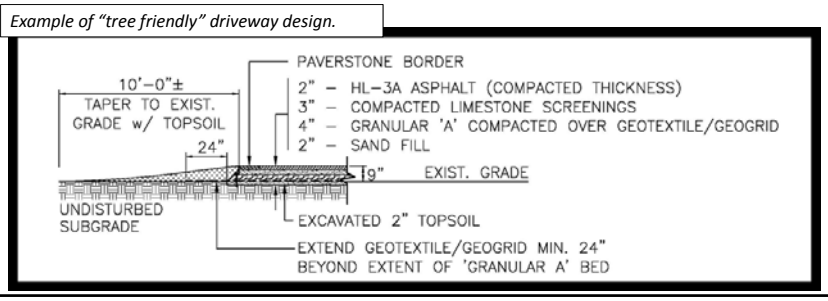
Paving Design

Best Practices

Impacts on trees can be reduced by:

- *Using the pavement type which requires the thinnest section;*
- *Placing heavy-load corridors away from trees;*
- *Using a "no-dig" design – place finished grades above natural grade;*
- *Increasing strength of paving to reduce reliance on section and sub-base;*
- *Placing geotextile fabric at bottom of pavement section to protect from displacement into soft soil.*

Example of "tree friendly" driveway design.



Innovative Foundation Design

Best Practices

Best Practices for Construction near Trees

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	Post-construction Treatments
Root Zone Therapy	• **Restores soil structure.**
Replanting	• Restores trees.
Monitoring	• Ensures long-term tree health, implementation of remedial actions.

Best Practices

Root Zone Therapy

Best Practices

"Root Zone Therapy" is the amelioration of site conditions after works are finished. Examples include:

Method	Description	Selected Study Results
Organic mulching	Wood chips applied 10 cm deep within dripline.	Soil density significantly reduced, pH lower, more mycorrhizae, greener foliage.
Radial trenching	15 x 30 cm (d x w) trenches dug in star pattern from trunk, filled with good topsoil	Significantly increase shoot and diameter growth.
Compressed air decompaction	Terralift or similar used to inject compressed air into compacted soil, generally on 1 m grid spacing.	Mixed results. Some increased growth.
Vertical mulching	5 cm ø holes dug 45 cm deep on 0.5 to 1.5 m grid. Filled with porous material or left open.	Inconsistent or even negative effects on soil and tree health. Affects small amount of soil.
Soil disturbance	Backhoe used to scoop and shake out compacted soil, or soil is rototilled.	Generally very good, but root damage is easy.

"The most dramatic results I have ever seen in a soil compaction experiment come from using mulch by itself" – Tom Smiley, 1996

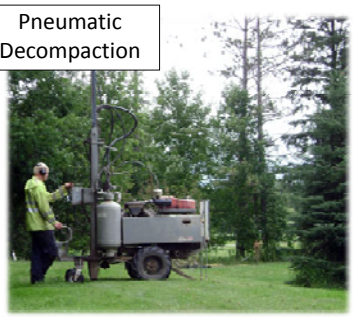
Root Zone Therapy

Best Practices

Vertical Mulching

Radial Trenching

Pneumatic Decompaction



Mulch

Best Practices for Construction near Trees

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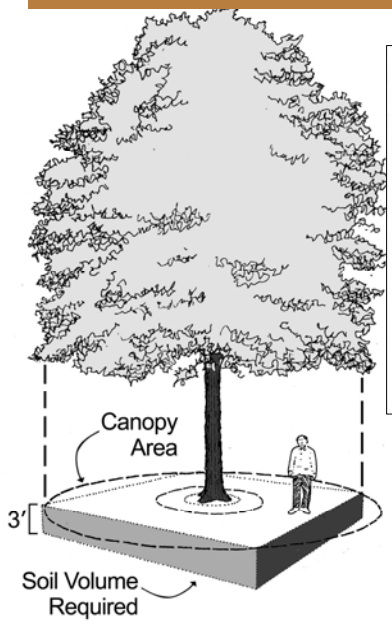
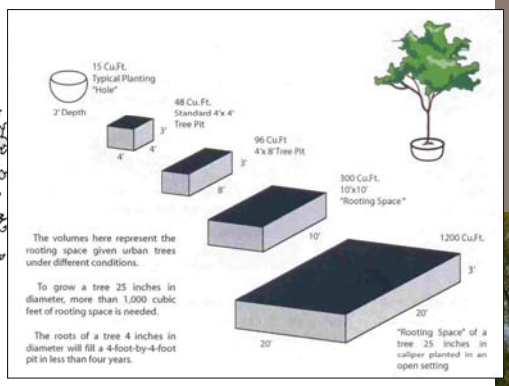
Planting - Soil Volume Requirements

Best Practices





Approximate canopy area to soil volume ratio

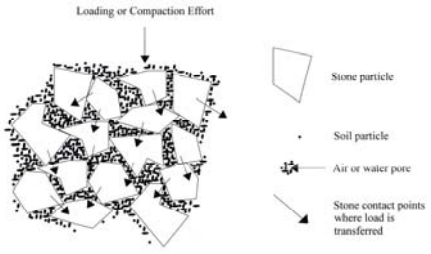
2 cubic feet (60 cm^3) of soil
for each
1 square foot (0.1 m^2) of canopy

Planting – Sub-base Options

Best Practices

Silva Cells

CU Structural Soil



Planting – Tree Selection

Best Practices

"Right Tree in the Right Place" – Right tree includes a *good* tree.

10. Tree is a cull if it has a root greater than 1/10th the diameter of the trunk circling around more than 1/3rd of the trunk in the top half of the root ball.

Many trees planted in municipalities today don't meet this standard!

Planting – Proper Depth

- The top-most root must not be below the landscape soil.
- Generally, set B&B rootball above soil level, as top roots are often already too low.

E. Gilman

Best Practices

Planting – Proper Depth

- Planting too deep causes girdling roots and kills trees.
- Green line (right) shows planting level. Tree died in 2 years.
- Make sure planted tree has a visible ***root flare*** at grade.

E. Gilman

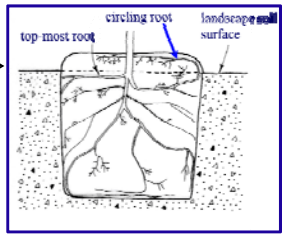
Best Practices

Planting – Preparing the Root Ball

Best Practices

Good root flare

Tree grown too deep in container



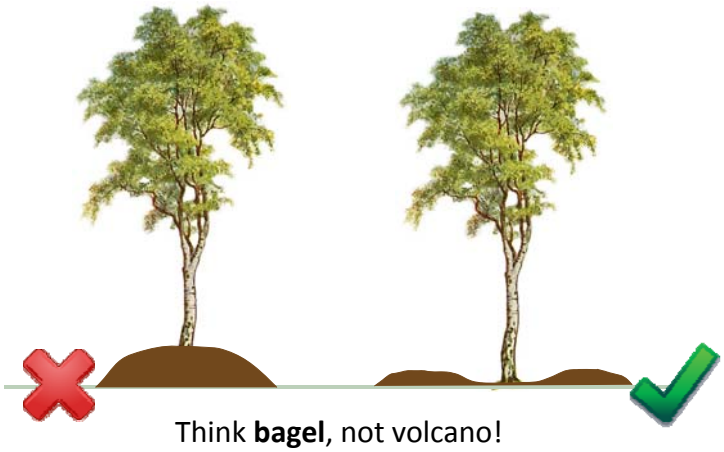
Cutting circling roots

E. Gilman

Planting – Mulch

Best Practices

Mulch is one of the best things you can do for new trees – ***if it's done right!***



Think **bagel**, not volcano!

Planting – Improper Mulch

Best Practices

- Kee
- Incr on t
- Intercepts rain and irrigation meant

http://forestcitytree.wordpress.com/

Planting – Proper Mulch

Best Practices

- Ap are
- 3”
- Mulch at least 10” away from trunk
-
-

n.
nic

E. Gilman

Planting – Overview

Best Practices

- Pre-planning
- Select good nursery stock
- Utility locates
- Look up for wires/lights/conflicts
- Dig shallow/wide hole
- Find the top-most root
- Place tree in hole
- Position top root 1-2” above landscape soil
- Straighten tree
- Remove synthetic materials
- Add backfill soil and firm the root ball
- Add mulch to cover root ball sides
- Stake if needed

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Monitoring

Best Practices

Construction-related effects can take up to ***ten years*** to become evident. Many won't appear until 3-5 years as trees continue to live off of stored reserves.

Effective monitoring during this time can help ensure that appropriate treatments are implemented before irreversible decline begins.

The Role of the Arborist/Urban Forester

URBAN FOREST INNOVATIONS INC

Steps to Effective Tree Protection

Role of the Arborist

1. Perform a tree inventory – know what trees are on site, what condition they are in.

2. Identify trees suitable for preservation – not all trees are sacred: unhealthy, unsound, unsafe, invasive can be considered for removal/replacement.

3. Assess potential impacts to trees – review all development and construction plans for possible impacts to trees on the site.

4. Suggest modifications to development plans – identify areas where impacts are too severe upon the trees. In clay soils, consider how water demand may affect soil stability.

5. Identify required tree work prior to tree removal and grading – arboricultural prescriptions such as crown pruning, pest management, transplanting, etc.

6. Prepare and implement tree protection specifications – dictate how and where work will be performed. Should generally include protective fencing at a minimum.

7. Monitor trees during construction – Arborist should be on hand regularly, and whenever specific treatments (e.g. root pruning) are required.

8. Prepare post-construction maintenance plan – including monitoring, decompaction, etc.

Take-home Message

Role of the Arborist

Trees are valuable resources, worthy of protection in the same way as other infrastructure is protected during construction.

The arborist/urban forester should be involved at the ***front end, and throughout the entire project***.

Tree protection cannot wait until construction begins!

Everyone on the design and construction team should understand the basic requirements of tree protection, planting and maintenance.

QUESTIONS? COMMENTS?

Philip van Wassenaer, B.Sc., MFC
ISA Certified Arborist ON-0361A
ASCA Member

1248 Minnewaska Trail
Mississauga, Ontario, Canada
L5G 3S5
(905) 274-1022

e-mail: pwassenaer1022@rogers.com or info@ufis.ca
http://www.ufis.ca

Urban Forest Innovative Solutions

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