SILVA CELL
OPERATIONS AND MAINTENANCE MANUAL

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1.0 Acknowledgments

There are many dedicated, brilliant people working on the challenge of creating healthier, more sustainable, and more efficient cities. We believe the most successful of these places will be those grounded in the principle that nature and engineering can coexist successfully. Soil, urban trees, and sustainable stormwater management are at the core of this effort. We wish to express our tremendous appreciation and gratitude to the many researchers and practitioners whose work we have relied on to inform the guidelines contained in this manual. Thank you to the following people for their specific contributions.

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2.0 Introduction

Silva Cells are a modular suspended pavement system that provides soil volume to support large tree growth and provides stormwater management through interception, storage, evapotranspiration, and pollutant uptake. When filled with soil media of suitable depth and quality, Silva Cells also promote filtration of stormwater runoff through the soil media and infiltration of treated runoff into native site soils, making them a versatile Low Impact Development (LID) Best Management Practice (BMP).

In March 2013, the Washington State Department of Ecology approved Silva Cells as functionally equivalent to bioretention (Ecology 2013a). This approval allows designers in Washington State to design Silva Cells to fully or partially satisfy minimum stormwater requirements for LID, water quality treatment, and flow control in accordance with the National Pollutant Discharge Elimination System (NPDES) Municipal Separated Storm Sewer System (MS4) permit (NPDES stormwater permit). Similar approvals are in place in Montgomery County, Maryland; St. Louis, Missouri; Calgary, Alberta; and North Vancouver, British Columbia. Additional approvals are currently pending in other areas across the United States and Canada as of the date of this manual.

When Silva Cells are installed as part of a permanent stormwater management system to meet stormwater permit requirements, they should be maintained as required by the local jurisdiction for maintenance of stormwater and LID BMPs.

The remainder of this section discusses the purpose of this document, applicable permit requirements, how this manual is intended to be used, and important definitions. Section 3 presents key maintenance considerations, maintenance guidelines, equipment and materials lists, and skills and staffing needs to accomplish the recommended maintenance. Section 4 discusses the repair of Silva Cell facilities. Section 5 discusses programmatic and administrative guidance, while Section 6 provides a list of additional resources relating to LID BMP design, inspection, operation, and maintenance and Section 7 provides a list of additional resources with relevant information on stormwater and LID BMP maintenance.

2.1 Purpose

This document provides guidance to assist owners and operators of Silva Cell facilities with planning and implementation of maintenance to promote long-term system performance in accordance with the design intent. These recommendations should be considered as general guidelines, not requirements, and they should be reviewed and adapted as appropriate to develop site-specific maintenance plans based on the specific design configuration of a given site.

2.2 Permit Requirements

Silva Cells may be designed and installed as LID BMPs that fully or partially satisfy applicable soil and/or stormwater requirements for new or redevelopment projects. Check the local permit requirements to determine whether such requirements apply to your project.

While Silva Cells can be designed as LID BMPs, they can also be used to promote large, healthy trees in dense urban environments, without the intent of formally managing stormwater runoff. In such cases, stormwater permit requirements would not apply.

2.3 How to Use this Manual

Operations and maintenance guidelines are provided in Section 3.0, organized in three subsections, as follows:

- Subsection 3.1 Key Maintenance Considerations - Provides details regarding maintenance activities that should be considered to maintain function of the facility.
- Subsection 3.2 Key Operations to Preserve Facility Function - Discusses the functions of the BMP that need to be preserved to maintain the intended performance.
- Subsection 3.3 Maintenance Guidelines - Provides information that can be used to develop a site specific maintenance plan.

Successful use of this manual requires understanding of the design intent, site and as-built conditions, and knowledge of applicable permit requirements (Section 2.2).

2.4 Definitions

Definitions for important terms used throughout this manual are as follows:

- Best management practices (BMPs) - Activities, practices, procedures, structural features, or products that are designed to reduce the risk of causing adverse impacts to downstream water bodies.
- Drawdown Time - The time it takes water from a given runoff event to completely drain through an infiltration BMP, typically measured from the end of the event to the time the water level in the system returns to baseflow conditions.
- Infiltration – Percolation of stormwater runoff into soil media or native site soils.
- Low Impact Development (LID) - A development approach that manages stormwater by working with nature and the existing site conditions in a manner that will reduce or prevent adverse impacts to the site or downstream environment.
- Macropores – Large, free-draining soil pores, oftentimes found between aggregates or near tree roots.

3.0 Maintaining Silva Cells

This section identifies key component design functions and maintenance considerations, provides guidance on inspection and maintenance activities and recommended frequencies, lists needed equipment and materials, and discusses skills and staff needed to perform the recommended maintenance.

3.1 Key Component Design Function and Maintenance Considerations

Key components of the Silva Cell system include the inlet structures, distribution pipes, the modular Silva Cell units and frames, fill soils, underdrain pipe, flow control structures, trees/vegetation, and surface treatments. Intended general design functions and maintenance considerations for each of these key components are discussed below.

3.1.1 Inlet system

Silva Cell inlet systems can be designed to allow stormwater runoff to flow into the facility in a number of ways. Water can sheet flow from adjacent hardened surfaces, infiltrate via overlying or adjacent permeable surfaces, flow through curb cuts, or be piped from a catch basin, roof drains, or yard drains.

However the inlet system(s) are configured, they must be properly sized and maintained to allow stormwater runoff from the intended contributing drainage area to enter the facility. Key maintenance considerations include providing pre-treatment through temporary erosion and sedimentation control measures in the tributary drainage basin during construction and long-term pre-treatment through stabilization of open soil areas in the tributary basin with plants or mulch and maintenance of inlet capacity by removing sediment, trash, and debris from inlets and the contributing drainage area.

3.1.2 Distribution Pipe

Some installations may include a distribution pipe to distribute inflows across the surface of the facility. Distribution pipes are typically 4- to 8-inch-diameter (100- to 200-millimeter-diameter) perforated or slotted pipes installed on top of or within the soil media. Maintenance activities should preserve the ability of the pipe to distribute the water effectively by removing clogs and repairing or replacing cracked or broken pipes as needed.

3.1.3 Irrigation Systems

If the Silva Cells have been designed to include irrigation, follow the manufacturer instructions for operating and maintaining your chosen irrigation system. Also see the section above (3.1.2) if the irrigation system is passive and includes distribution pipes.

3.1.4 Silva Cell Modular Units

Silva Cell modular units are made from fiberglass-reinforced, chemically-coupled, impact-modified polypropylene with galvanized steel tubes. DeepRoot provides a 20-year warranty for the Silva Cell product, which is included for reference in Appendix A. Each module provides a 92% void volume, which is backfilled with a specified type and depth of soil media (Section 3.1.5) to support tree growth and promote stormwater management.

When used in a typical pedestrian application, the Silva Cell system has an estimated design life of approximately 100 years (DeepRoot 2014). The units themselves are not expected to require maintenance within that design life duration when properly designed and installed.

3.1.5 Soil Media

The soil media filled within the Silva Cell units (Section 3.1.4) performs critical functions of supporting tree growth and managing stormwater runoff. Organic matter in the soil media is important for both of these functions; because it helps trees build soil structure, provides a nutrient reservoir, and increases soil water holding capacity. In order to preserve a healthy balance of soil organic matter and soil biology, excess soil compaction must be prevented and proper drainage through the system must be maintained.

Silva Cells protect soils under pavement from excessive compaction by providing a post and beam structure that supports the pavement, allowing the soil media backfill to be lightly compacted. The lightly compacted soil media creates a healthy rooting environment for trees, which deliver increasing amounts of organic content to the soil system as the roots grow and decay. Stormwater inputs also deliver nutrients, such as nitrogen and phosphorus, helping to maintain soil organic matter over time.

Routine maintenance of the soil media is generally not needed provided the installation process of the cell and soil has been carried out correctly and the inlet (Section 3.1.1) and distribution (Section 3.1.2) systems are properly designed, installed, and maintained.

3.1.6 Underdrain Pipe and Flow Control Devices

Silva Cells may include underdrains when infiltration of treated stormwater runoff into native soil is not feasible or not desirable. Underdrains may be located at the bottom of the facility, or may be elevated to promote nitrogen removal and peak flow detention, depending on the design intent.

Typically, underdrain systems consist of 6- or 8-inch-diameter (100- to 200-millimeter-diameter) perforated or slotted pipe. The pipe may be installed in an aggregate filter blanket layer or may be wrapped with a geotextile liner for separation. Proper design and specification of the aggregate filter blanket or geotextile liner is critical to minimizing or preventing fines from the soil media or the native site soils from clogging the pipe.

Some underdrains may be designed with flow control devices (e.g., orifii or upturned elbows) to enhance nitrogen removal, detain peak flows, increase infiltration, or some combination thereof. These flow control devices should be maintained to prevent clogging and allow treated flows to discharge to the downstream conveyance system or receiving water as intended by design.

3.1.7 Trees / Vegetation

Silva Cells fundamentally promote tree growth, and are typically designed with one or more trees that are planted either in the facility or next to the facility in a way that allows the roots to grow into the soil media. Properly designed Silva Cells provide the needed soil volume and quality, water flow, and air flow to allow the trees to reach their true mature size.

As healthy trees grow, their canopies provide increasing capacity over time for interception, storage, and evapotranspiration. As the roots grow, they increase the trees' ability to uptake stormwater and associated pollutants and enhance infiltration by maintaining macropores in the soil column. Maintaining the trees as part of the Silva Cell system is therefore important to the overall performance of the facility over time. See Table 1 for recommended maintenance activities and schedule.

Trees and vegetation adapted to site conditions, such as climate, hydrology, and soil type, should be selected wherever possible to reduce chemical inputs and reduce or eliminate the need for watering. Proper design, installation, and maintenance of the inlet system (Section 3.1.2) and distribution system (Section 3.1.3) are also important to maintaining trees and vegetation properly watered. Similarly, proper design, installation, and maintenance of the underdrain pipe and flow control devices are important to maintaining desired watering regimes and draw-down rates.

3.1.8 Surface Treatment

Silva Cells can be designed to provide structural support for a variety of surface treatment types, including hard surfaces (e.g., permeable or impermeable asphalt, concrete, pavers, etc.) or natural surfaces (e.g., soil, lawn, vegetation). Surface treatments should be maintained in accordance with manufacturer recommendations and local jurisdiction requirements (i.e., pertaining to sidewalks, roadways, etc.), as applicable.

3.2 Maintenance Guidelines

The following table provides a breakdown of recommended routine inspection and maintenance activities and frequencies, conditions that trigger non-routine maintenance, and the associated recommended non-routine (triggered) maintenance activities for key Silva Cell components.

Table 1: Silva Cell Maintenance Guidelines

Component	Recommended Frequency		Inspection Activity	Condition when Maintenance is Triggered	Recommended Maintenance Actions
	Inspection	Routine Maintenance			
Silva Cell Units					
Frames (or base and posts) and Deck	As needed	None	Not Applicable	Facility shows signs of damage from external source (i.e., excessive loading from the surface, nearby construction, or similar)	Repair damaged component (refer to the Protection and Maintenance section of the Silva Cell Operations Manual included in Appendix B, pages 9-11).
Tree Opening	Spring, Fall, and after major storms	As needed	Check for clogging, standing water, sediment, trash, and debris	Evidence of clogging, standing water, accumulation of sediment, debris, or trash	As needed.
Inlets/Outlets/Pipes					
Inlet/outlet structures	Annually	After major storms	Check that the structures are operating properly	Water is not being directed properly to or out of the Silva Cell facility	Remove any blockages and clean pipe as needed.
Energy dissipation component at inlet (if applicable)	Annually	After major storms	Check that the energy dissipation is working correctly	Where applicable – Energy dissipation (i.e., splash block, rock, or cobbles) is removed or missing and concentrated flows are being directed into the facility improperly	Replace or restore the energy dissipation component of the facility to the original design.
Flow restrictor (if applicable)	Annually	After major storms	Check that the flow restrictor is operating properly	Water is not passing through the flow restrictor per the design flow rate	Remove material causing the blockage and repair component as needed.
Distribution pipes	Annually	Annually	Check that the distribution pipes are allowing water to distribute properly	Water is not being distributed within the facility per design	Remove blockages from pipes (e.g., jet clean, rotary cut roots/debris).
Underdrain pipes	Annually	Annually	Check that the underdrain pipes are	Water is not being drained through the underdrain pipes per design	Remove blockages from pipes (e.g., jet clean, rotary cut roots/debris).

Component	Recommended Frequency		Inspection Activity	Condition when Maintenance is Triggered	Recommended Maintenance Actions
	Inspection	Routine Maintenance			
Trees/Vegetation					
Tree	Biannually	As needed	Check need for pruning	Tree requires pruning for safety reasons, to promote healthy growth or to prevent the tree from growing in an undesirable manner.	Prune tree as needed for safety to promote healthy growth and to avoid conflicts with adjacent features (i.e., power lines, clearances from buildings or sidewalk, or similar). Pruning should be performed by a landscape professional that has experience pruning trees and per the guidance of an arborist certified by the International Society of Arboriculture.
	Spring, Fall, and after major storms	As needed	Check tree safety	Signs of potential danger include broken, dead, or hanging branches, cracks, fungi, cavities, weak trunk or branch unions	Remove components of the facility above the frames and decks in a manner that minimizes damage to the facility. Use HydroVac and hand tools to remove soil if soil removal is needed. Cut and remove roots as directed by an arborist. Do not cut or damage frames. Install new tree and Silva Cell components as needed to restore the facility to its designed configuration.
	Spring and Fall	As needed	Check tree health	Check tree for mower and weed whip damage, vandal damage, and animal damage. Inspect leaves, branches, crown and trunk for signs of insect or disease problems	Diagnose cause of problem: e.g. mower and weed whip damage, vandal damage, animal damage, over- or under-watering, pest or disease, soil problems, etc., and remedy.
	Every 4-5 years	As needed	Check for girdling roots	Girdling roots are found	Remove girdling roots.
	Annually	As needed	Check for soil or mulch on root collar	There is soil or mulch on the root collar	Clean soil or mulch off root collar until the first set of roots is found, take care not to harm roots.
	Annually	As needed	Check safety	Tree is dying, dead, diseased, or has become a safety hazard	Remove components of the facility above the frames and decks in a manner that minimized damage to the facility. Use HydroVac and hand tools to remove soil. Cut and remove roots as directed by an arborist. Do not cut or damage frames (or base and posts). Install new tree and Silva Cell components as needed to restore the facility to its designed configuration. Refer to the Protection and Maintenance section of the Silva Cell Operations Manual included in Appendix B.

Component	Recommended Frequency		Inspection Activity	Condition when Maintenance is Triggered	Recommended Maintenance Actions
	Inspection	Routine Maintenance			
Tree					
Vegetation	Biannually	As needed	Check tree health	Dying, dead, or unhealthy plants	Remove and replace dying, dead or unhealthy plants.
Weeds	Monthly	Monthly	Check for weeds	Weeds present in the facility	Remove weeds as necessary. Noxious weeds should be removed in accordance with local standards. Avoid using herbicides and pesticides in an effort to protect water quality.
Mulch	Monthly	After weeding	Check much coverage	Mulch layer has bare spots or a depth less than two inches (50 mm).	Cover bare spots and replenish mulch as required.
Watering		As needed	Not applicable	Tree/vegetation shows signs of being deprived of water or watering is anticipated during prolonged dry periods	Water frequency will vary depending on species, climate, and site conditions. Water appropriately to maintain a health of the tree or vegetation. Ensure water is reaching the entire soil column and perimeter, not just the tree opening.
Pest Control					
Nuisance Animals	Biannually	As needed	Check for signs of damage from animals	Damage or erosion caused by animals	Remove/reduce the item that is attracting the nuisance animals. Consider placing decoy predator species or pet waste bag stations to promote responsible activities.
Insects	Biannually or as needed	As needed	Check the presence of insects and or insect nests	Tree/vegetation shows signs of wilting, chewing of bark, spotting, or other indicators appropriate for the region.	Remove diseased or dead plants. Remove or reduce the source attracting the insects if possible. Follow the pest management procedures appropriate for the region.
Surface Treatment					
Hard Surfaces (i.e., permeable or impermeable concrete, asphalt, pavers, or grid systems)	Annually	As needed	See applicable manufacturer recommendations.		
Permeable Surfaces (i.e., vegetated areas)					

3.3 Equipment and Materials

The text box to the right provides a list of equipment and materials that may be needed to perform maintenance and inspection activities. The list should be reviewed and approved by the Silva Cell owner or operator and should be modified as appropriate for the specific installation. For instance, if the installation does not have a planter strip area, weeding equipment may not be needed. Similarly, if underdrains are not included, vactor, water jets, and pressure washing equipment may not be needed, etc.

3.4 Skills and Staffing

The skills and staff required to inspect and maintain Silva Cells will vary depending on the size of the installation, complexity of the system, surface treatment, and site constraints. Routine maintenance and inspection activities for the above-ground features will generally be similar to that of a street tree, planter strip, or sidewalk. Routine maintenance for the below-ground features will generally be similar to that of an underdrain or footing drain system.

The Table 2 summarizes the staffing resources that may be required for routine maintenance and inspection activities:

- Safety Equipment – As appropriate for the site (i.e., high visibility vest, gloves, long pants, boots, traffic control equipment, etc.)
- Inspection Equipment
  - Camera
  - Tape measure
  - Manhole key and lifter to open manhole, cleanout, or inspection port lids
  - Flashlight
  - Field report sheet
  - Inspection records and photos from previous inspections
  - As-built information
  - Manufacturers' product information
  - Method of inspecting pipes and structure without entering them (i.e., camera or mirror on an extendable pole)
  - Equipment to measure drawdown time (i.e., stopwatch, measuring stick, water source, and hose)
- Maintenance Equipment
  - Broom, rake, and shovel
  - Weeding equipment
  - Bucket, wheelbarrow, garbage/leaf bags, and tarp
  - Tree trimming and pruning equipment
  - Hand tools
  - Plumbing snake
  - Vactor truck
  - Water jet
  - Pressure washer
- Maintenance Material
  - Pipe repair material
  - Replacement pipe material per the original design
  - Replacement surface material (i.e., pavers, asphalt, concrete, or natural material)

Equipment and materials that may be needed to perform typical maintenance and inspection activities. Adapted from the Western Washington Low Impact Development (LID) Operation and Maintenance (O&M) Guidance Document (Ecology 2013b).

Table 2: Skills and Staffing Table

Maintenance Activity	Staff Skills
Landscaping	Staff must have appropriate landscaping skills, including plant care, watering, and weeding, based on the trees/vegetation present; staff must have the ability to identify plants, weeds, and invasive weed species and have knowledge of the timing of weed seeding and growing periods.
Pruning and tree care	Staff conducting pruning and tree care activates should be a certified arborist or have equivalent training.
Pest Management	Staff conducting pest management activities must be able to identify pests applicable to the region and be familiar with methods to address those issues.
Erosion Control	Staff must have general knowledge of identifying sources of erosion, prevention methods, and removal methods.
Drainage System Maintenance	Staff inspecting drainage system must have general knowledge of the drainage system components included in the facility, specific knowledge of how the facility was built and its intended to function, and maintenance history. Staff preforming maintenance activities must be trained to operate the specialized equipment to conduct those activities (i.e., jet cleaning, root cutting, vactoring, CCTV inspection).

4.0 Repairing Silva Cells

As the Silva Cell is a system that interacts with other infrastructure, repairs to adjacent elements, such as paving surfaces or utilities and services, must be undertaken with an understanding of the site-specific installation. Repairs to all system components and adjacent or nearby elements should be done per local guidelines and individual manufacturer directions, as applicable.

Each Silva Cell stack is independent of the Silva Cell stack adjacent to it. Therefore, if an individual stack is disturbed, the entire system is generally not expected to be compromised.

Examples of repair processes are provided in the Tree Planting Solutions for Hard Boulevard Surfaces Best Practices Manual, included in Appendix B. This manual documents two demonstration projects conducted by the City of Toronto, in which they field-tested a water main break scenario and a gas lateral and riser installed through Silva Cells. In both cases, the Silva Cells were found to pose no significant hindrance to their utility work.

Section IV of the Silva Cell Operations Manual (DeepRoot 2011), included in Appendix C, provides general information on how to protect installed Silva Cell systems, manage utilities in the vicinity of installed systems, repair or replace overlying pavement, and remove or replace Silva Cells and trees as needed.

5.0 Programmatic and Administrative Guidance

This section discusses regulatory requirements for LID BMP maintenance (if applicable) and the available programs and tools to help with implementation.

5.1 Regulatory Requirements for LID BMP Maintenance Programs

As discussed above, this manual provides general maintenance guidelines that can be adapted to site specific maintenance plans based on given site conditions. If Silva Cells are installed as part of a permanent stormwater management plan to meet minimum stormwater requirements for new or redevelopment, local requirements for maintaining LID BMPs would apply. Consult the local standards and requirements to determine the maintenance requirements that will need to be addressed.

5.2 Tools for Implementing an LID Maintenance Program

A range of administrative tools can be used to assist jurisdictions in implementing required maintenance activities for stormwater BMPs, such as Silva Cells. The tools vary depending on jurisdiction requirements, but may include (Ecology 2013b):

- Stormwater requirements (i.e., Code, manual, ordinance)
- Legal agreements between private or public owners and the regulatory agency (i.e. access easements, property maintenance covenants, or transfer of ownership)
- Maintenance requirements specified as part of the design process
- Financial liability measures
- Record keeping and tracking requirements
- Inspection and maintenance checklists
- Inspection and maintenance schedules
- Mapping
- Owner education (public or private)

6.0 Additional Resources

The following resources provide additional information on maintenance of LID facilities applicable to Silva Cells.

- Western Washington Low Impact Development Operations and Maintenance Guidance Document http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LID/TRAINING/OperationsAndMaintenance.html
- LID Technical Guidance Manual for Puget Sound http://www.wastormwatercenter.org/files/library/lid-manual-2012-final-secure.pdf
- International Society of Arboriculture http://www.isa-arbor.com/education/publications/index.aspx

- EPA's Integrated Pest Management (IPM) principles site http://www.epa.gov/pesticides/factsheets/ipm.htm
- Water Environment Research Foundation (WERF) BMP and LID Whole Life Cost Tool http://www.werf.org/c/KnowledgeAreas/Stormwater/ProductsToolsnonWERF/BMP_and_LID_Whole_Li.aspx
- Chesapeake Stormwater Network http://chesapeakestormwater.net/training-library/stormwater-bmps/
- Los Angeles County Department of Public Works, Stormwater BMP Design and Maintenance Manual http://dpw.lacounty.gov/ldd/publications/Stormwater%20BMP%20Design%20and%20Maintenance%20Manual.pdf
- Low Impact Development Center http://www.lowimpactdevelopment.org/links.htm

7.0 References

- DeepRoot 2011. Silva Cell Operations Manual, prepared by DeepRoot Green Infrastructure LLC (DeepRoot), 2011.
- DeepRoot 2014. Personal communications between Graham Ray, President of DeepRoot, and Robin Kirschbaum, Senior Engineer of HDR, regarding expected design life of Silva Cells in typical pedestrian application. September 2, 2014.
- Ecology 2013a. Washington State Department of Ecology (Ecology) Equivalent Technology Website (http://www.ecy.wa.gov/programs/wq/stormwater/newtech/equivalent.html), accessed on June 9, 2014.
- Ecology 2013b. Western Washington Low Impact Development (LID) Operation and Maintenance (O&M) Guidance Document, prepared for Washington State Department of Ecology Water Quality Program, July 8, 2013.
- EPA 2014. Incorporating LID Website (http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/IncorporatingLID.pdf), accessed on June 9, 2014.

Appendix A

DeepRoot Warranty

DeepRoot® warrants to the original purchaser of its Silva CellTM product that such product will be free from defects in materials and workmanship, and perform to DeepRoot's written specifications for the warranted product, when installed and used as specifically provided in the product's installation guidelines for a period of 20 years from the date of purchase. This warranty does not cover wear from normal use, or damage caused by abuse, mishandling, alterations, improper installation and/or assembly, accident, misuse, or lack of reasonable care of the product. This warranty does not apply to events and conditions beyond DeepRoot's control, such as ground subsidence or settlement, earthquakes and other natural events, acts of third parties, and/or Acts of God. If this warranty is breached, DeepRoot® will provide a replacement product. Incurred costs, such as labor for removal of the original product, installation of replacement product, and the cost of incidental or other materials or expenses are not covered under this warranty.

DEEPROOT® MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS THE WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. DEEPROOT® SHALL NOT BE LIABLE EITHER IN TORT OR IN CONTRACT FOR ANY DIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOST PROFITS, LOST REVENUES, LOSS OF USE, OR ANY BREACH OF ANY EXPRESS OR IMPLIED WARRANTY.

Some states do not allow the exclusion of incidental or consequential damages, so the above limitations and exclusions may not apply to you. This Warranty gives you specific legal rights, and you may also have other legal rights, which vary from state to state, or in Canada, from province to province.

Appendix B

City of Toronto Tree Planting Solutions
in Hard Boulevard Surfaces;
Best Practices Manual

Project # A21065
Date February 8, 2013
Recipient City of Toronto
Submitted by DTAH, Lead Consultant
ARUP, Engineering
James Urban, Urban Trees + Soils

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ACO Steven Tonaj

Gro-bark

Earthco Soil Mixtures

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* Please note: Appendix B contains excerpts from the City of Toronto's Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual. For full document with all content please contact the Urban Forestry Department at 311@toronto.ca

Executive Summary

The City of Toronto has established a goal to increase both the number and size of its street trees (*Toronto Street Trees: Guide to Standard Planting Options*, April 2010). The City aims to grow large-canopy trees in hard boulevard surfaces that have a complete 40+ year life span and are 40 cm in diameter at breast height.

This manual examines and provides cost-efficient options to reach this goal.

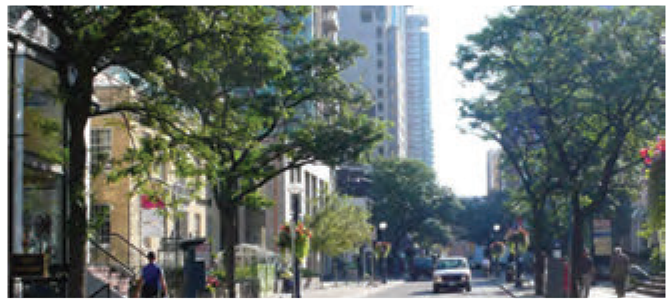
Downtown streetscapes are harsh environments for trees, and many do not survive or never grow to a large canopy size. Large-canopy trees provide enormous climatic, environmental, health, aesthetic and psychological benefits. There is room for considerable improvement in the quality of the urban forest in downtown streetscapes and this report examines how this can be done.

Section 1 of this report, the Introduction, defines 'criteria for success' for urban tree planting in Toronto, and sets the tone for the manual and its future implementation.

Section 2 provides fundamental principles for growing large trees. At minimum, trees require 20 to 30 m3 of soil each in order to grow to maturity. In order to achieve this, integration of soil/root zones with utilities is proposed to reach the target soil volume under urban sidewalks. Larger openings in the pavement also help to increase longevity. Cost savings are achieved by eliminating unnecessary hardware and designing structural concrete to withstand the load of occasional snowploughs and service vehicles, but not firetrucks.

Sections 3 and 4 provide various technical solutions that have been developed as part of this manual. They address both new and retrofit construction and repair techniques to respond to a variety of site-specific requirements such as sidewalk width, public realm condition, and infrastructure arrangement for a range of budgets.

Section 5 evaluates essential material components that are required for successful tree growth in an urban streetscape. These are tree opening area materials such as mulch; flexible plastic mesh bark protectors; passive rainwater harvesting and distribution; and root zone ID markers to prevent construction damage.



Sidewalk trees on Yorkville Ave.

Section 6 offers insightful information to ensure that each planted tree has the best opportunity to thrive. Horticultural topics such as tree preservation, installation and maintenance, tree species suitability, nursery stock quality and soil specific requirements are discussed.

Lastly, Section 7 documents two demonstration projects where the City of Toronto and consultants field-tested a number of the tree planting construction methods. A water main break scenario was recreated and a gas lateral and riser were installed through soil cells. In both cases, the soil cells posed no significant hindrance to utility work.

The Appendices include construction drawings, specifications, cost estimates, letters of product availability, responses to City comments and the street tree precedents review.

Section 3 Types

Section 4 Arrangements	3.5m min. sidewalk width			5.7m min. sidewalk width
	TYPE 1: Pavement Bridge		TYPE 2: On-Grade Pavement Over Soil Cells	TYPE 3: Open Planter
	1A	1B		
Growing Medium Trench	X	X	X	
Open Planter with Curb Edge				X

Compatibility between types identified in Section 3 and arrangements identified in Section 4.

3.0 Construction Methods & Repair Regimes

Three different systems for tree planting in sidewalks are laid out in this section. They form the basis for the proposed City of Toronto tree planting details that accompany this report in the Appendices. In addition, this section makes recommendations for hybrid solutions and retrofits and dealing with sub-standard sidewalk conditions.

3.1 Type-1: Pavement bridge system

A structural pavement surface or subsurface spans between supporting ends over the growing medium trench. Reinforced precast and cast-in-place concrete panels provide the 'bridge'. Refer to the T-1A and T-1B Construction Drawings in Appendix A.

3.2 Type-2: Soil cells system

Modular rigid soil cells support a pavement system above the growing medium. The pavement surface and base can be built directly on top of the hard deck of the soil cells. Refer to T-2 Construction Drawings in Appendix A.

3.3 Type-3: Open planter system

There is no paving around the tree base. Where there is space for this system on the sidewalk, it is the most cost-efficient option available for growing large urban trees. Refer to T-3 Construction Drawings in Appendix A.

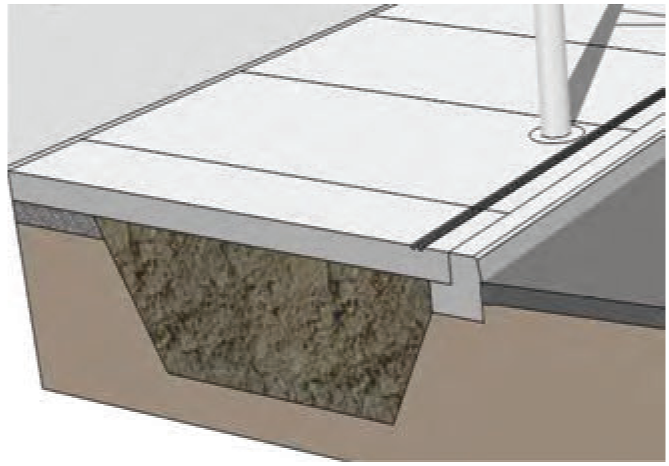
3.4 Hybrid solution and retrofits

The street is not rebuilt wholesale, just one or two trees in a block may be affected.

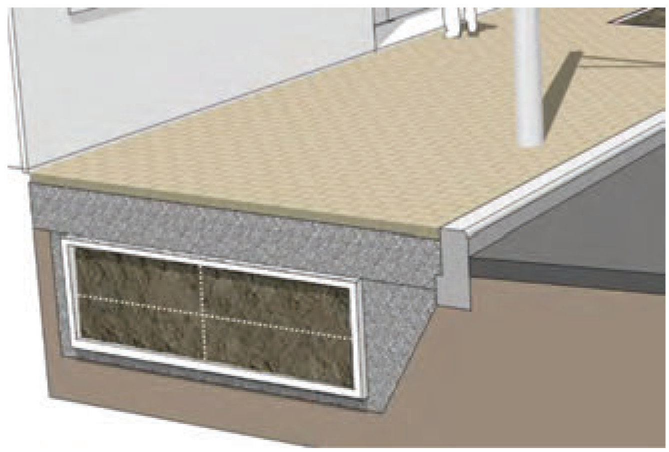
3.5 Sub-standard sidewalk conditions

Conditions where the existing space or utility constraints are such that the standards advocated in this report are not achievable.

Note: In the following descriptions for utility compatibility with various construction methods, review is based upon the general feasibility of working with such utilities and repairs. Ultimately, individual utility companies and City departments will have to reach an agreement for the access and repair of the various conditions generated, and the responsibility thereof. The recommendations in this report are intended to provide a framework for these policy decisions to be made.



3.1 Type 1: Pavement bridge system



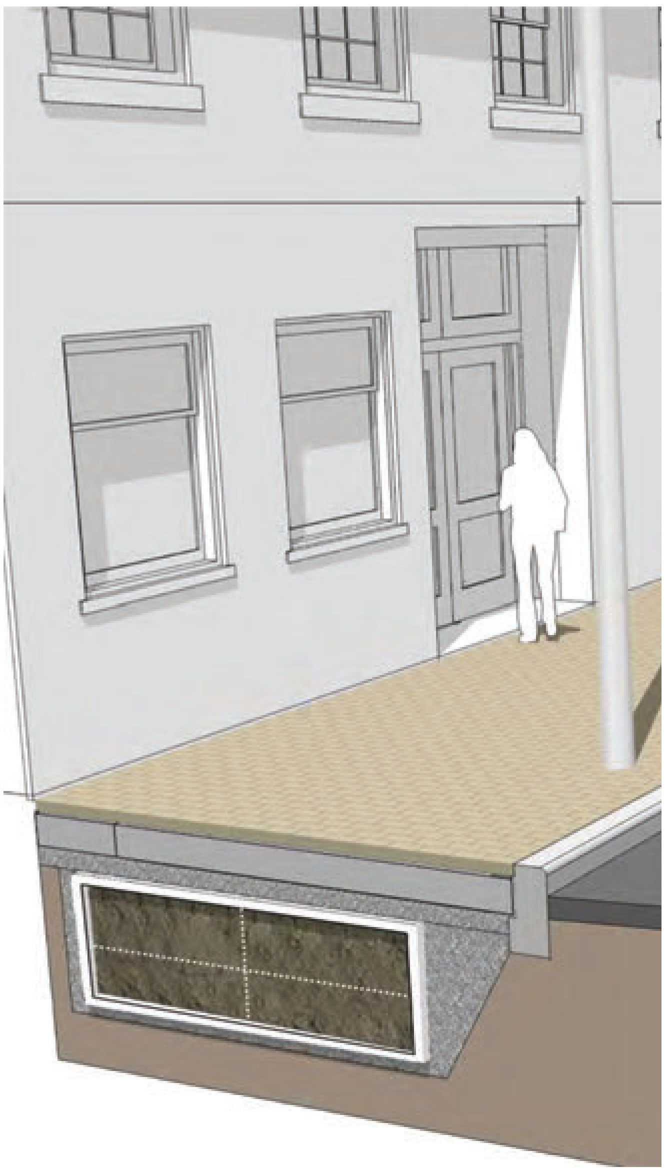
3.2 Type 2: Soil cells system

3.3 Type 3: Open planter system

3.2 Type-2: Soil Cell System

On-grade pavement over soil cells allows for traditional pavement on-grade on top of the soil cell assembly and has been used in a number of pilot projects in Toronto and other North American cities. This system requires utility companies and City agencies to become comfortable with the concept of a modular support system, and will require a new protocol to include removal and replacement of the soil cells.

Construction Drawings T-2 in Appendix A provides details on this system.



Type 2: On-grade pavement over soil cells

Construction

Space allotted for root zone and foundation are excavated out, and a compacted granular base is installed for the soil cells. Soil cells are installed per manufacturer's instructions. The pavement system is installed with granular base above the soil cells. The new paving can be installed in a similar way to any on-grade pavement system.

Utility access

Where there is concrete, the pavement is sawcut. Where there is unit paving, the pavers are removed. Filter fabric is peeled back, and soil cells are removed and set aside. In frozen conditions, the soil cells may be removed forcibly with an excavator, requiring them to be replaced with new soil cells prior to repairing surface paving. Once soil cells are removed, the utility is accessed via excavation of planting soil or granular below.

Repair

After the utility is backfilled with granular to the underside of the root zone and compacted, soil cells are reinstalled per manufacturer's instructions. Filter fabric is laid down on top of replaced soil cells, then pavement system is made good either temporarily or permanently.

Recommended utilities compatible with root zone

On-grade pavement over soil cells is generally compatible with utilities below the root zone, ideally where frequent access is not anticipated. Some shallower utilities may be compatible for placement within root zone/soil cell zone depending on agreement with the utility company concerned such as gas or hydro laterals.

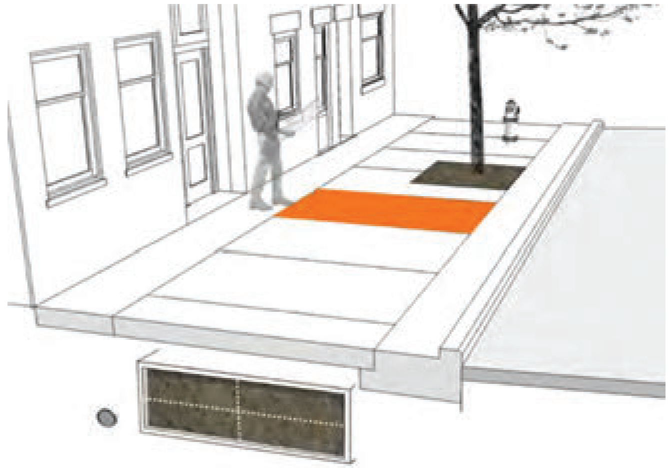
- Utilities below root zones:
- New generation storm line (concrete)
- New generation sanitary line (concrete)
- Concrete-encased hydro duct, combined data
- District energy
- Pressurized water main
- Gas (main or lateral)
- Bare conduit (street lighting, telephone, etc.)

Surface finish

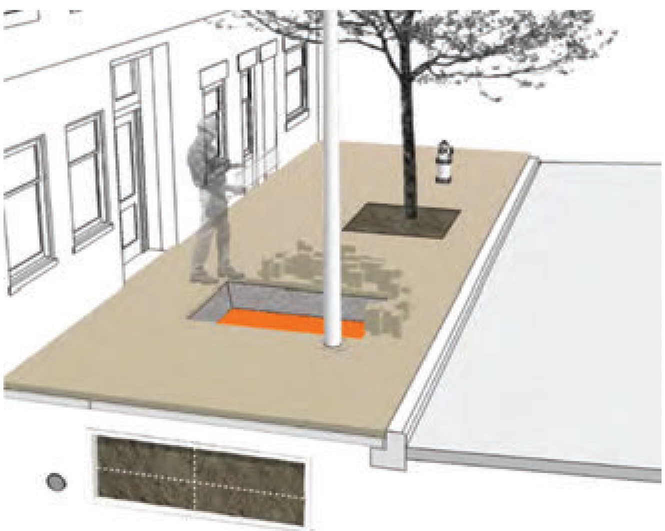
Since the structural support is provided by the soil cells, the pavement system can be any type or finish such as concrete or unit paving over concrete.

Pros / cons

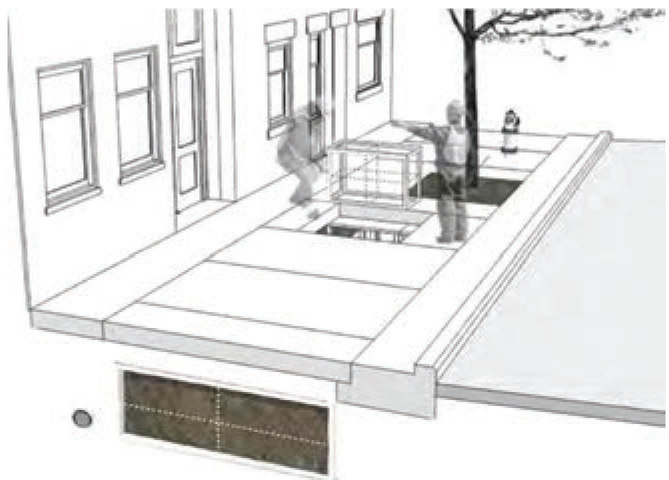
If the work crew is comfortable removing and replacing soil cells, the access and repair procedure is similar to current practices. The pavement system is equivalent to an on-grade construction. It can be repaired as a permanent repair or a temporary two-stage repair.



Utility access, step 1



Utility access with pavers, step 1



Utility access, step 2

Utility access with pavers, step 2

Utility access, step 3

7.0 Demonstration Projects

The consultants and the City organized a soil cell testing exercise at the City of Toronto's Nashdene Yard in Scarborough with utility stakeholders Toronto Water and Enbridge Gas. New utility installation and repair of existing utilities under soil cells was recreated at the Yard:

7.1 Toronto Water utility access exercise

Toronto Water recreated an "emergency scenario" in the middle of winter (Feb. 24, 2012). The scenario involved bursting a water main and testing the effects of water leaking on the soil cell system.

7.2 Enbridge Gas lateral line and riser installation

Enbridge Gas tested access through soil cells to install a gas lateral line.

7.3 Bloor St. W. at Dovercourt Rd. and Concord Ave. demonstration project

A further on-site demonstration project was proposed. However, it was decided not to be implemented as part of this study, due to a larger upcoming resurfacing project in the area.

Note: The soil cell product used at Nashdene Yard was Silva Cells, manufactured by DeepRoot Green Infrastructure, LLC.

Nashdene Yard location, Scarborough.

Soil cell trench filled with soil.

Soil cell decking system.

Backfill installation on top of deck.

Finished installation.

7.1 Toronto Water Utility Access Exercise

Description of the exercise

The cold weather conditions, at -4°C (-10°C with wind chill) provided Toronto Water field personnel a good test for working with soil cells in adverse conditions.

The exercise began at 8:00 am with an on-site briefing where the demonstration project coordinators and Toronto Water personnel discussed the different activities and the order of execution. Water was then turned on into the installed water pipe which was capped on both ends and pre-cut during its installation under the soil cell system. Water fed from a hydrant at 414 kPa ran for approximately three minutes before it started to come out through the already saturated soil adjacent to the demonstration sidewalk. After the water valve was shut off, the following activities took place:

Concrete sidewalk pavement was removed

- Concrete pavement was saw cut into blocks that could later be removed by a backhoe.
- Removal of concrete and granular 'A' base below concrete paving.
- Crew located a geotextile layer that was installed below the granular 'A' and on top of the soil cell top frame deck; the geotextile was cut to expose the soil cell deck.
- Manual removal of two of six soil cell top decks were set aside for re-installation.

Water pipe cut.

Sawcutting concrete pavement.

Water introduced - water bursting out of saturated soil adjacent to installation.

Mechanical removal of pavement to expose soil cell decking system.

Manual removal of two decks, unscrewed and set aside for future re-installation.

Excavation below bottom of soil cells to daylight water pipe.

Mechanical removal of soil cells.

Excavation below bottom of soil cells to daylight water pipe.

Mechanical removal of soil cells, soil and sub-base

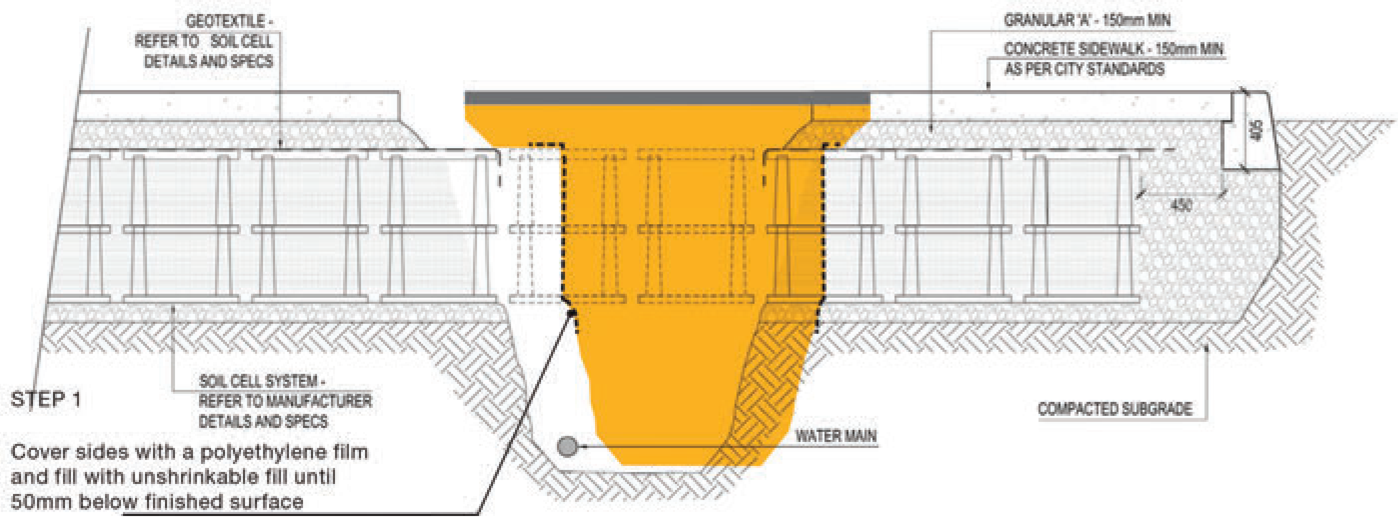
- Backhoe was used to dig out and through soil cells and soil.
- Water pipe was daylighted.

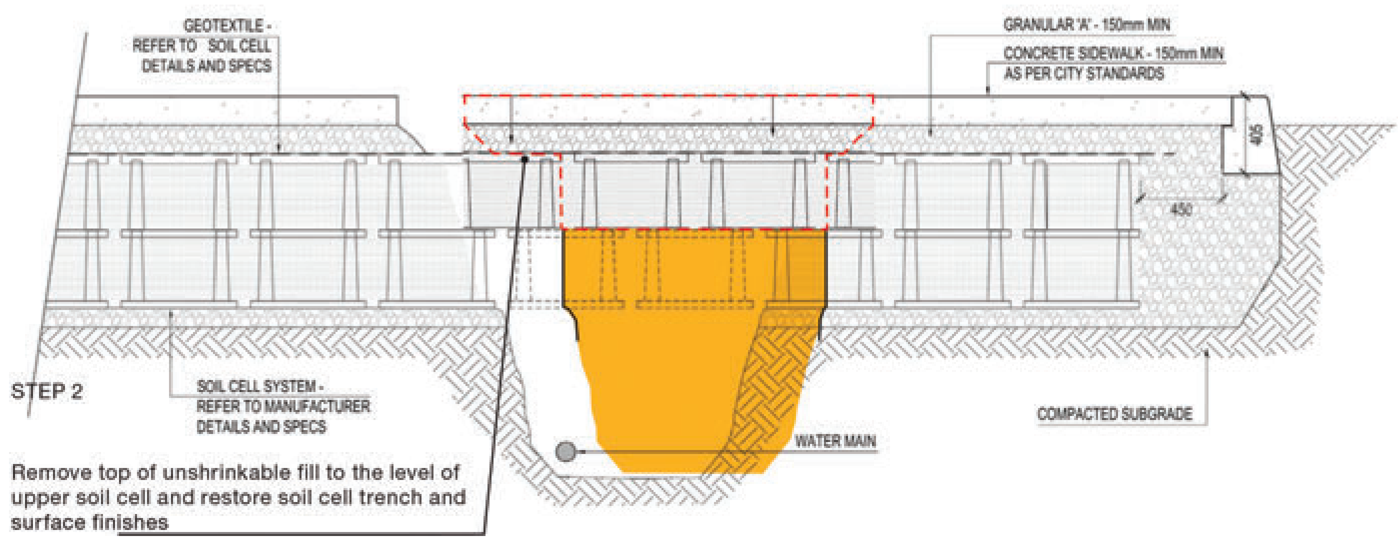
Repair

- The dug trench was temporarily repaired afterwards with unshrinkable fill up to finished grade.
- Weeks later, unshrinkable fill was broken up to the bottom of the first layer of soil cells to restore the cells and surface finishes to the original condition.

Conclusions of the Toronto Water exercise

Once the soil cells were removed, the stakeholders discussed the outcome and lessons learned from the exercise. It was concluded that Toronto Water can easily access its infrastructure through the soil cell system under extreme conditions using the same methods they currently have in place in either a planned or emergency situation. The exercise allayed their concerns that the soil cells would be a hindrance in their field work. Further discussions of a vertical minimum clearance between the utility and the bottom of the soil cells are expected.





7.2 Enbridge Gas Lateral Line and Riser Installation

Description of the exercise

The exercise began at 9:00 am at Nashdene Yard in Scarborough on a late-May day that was partly cloudy and warm. A gas lateral with a long riser was installed under a sidewalk cross-section of unit paving and soil cells. Using a mole with the shortest torpedo hammerhead at 1 .0 m length, the 25 mm gas line was bored through the growing medium and adjacent subgrade. Excavation was only necessary at each end of the gas lateral. For longer horizontal drilling, a directional drill is used which has greater directional control. Enbridge usually uses a torpedo mole for downtown work, which requires less excavation and can be used for horizontal drilling through sidewalk cross-sections. It can drill through tree roots and is only blocked by large rocks. The following took place:

Setting the direction and starting point of the horizontal boring

- Mock building and road sides of the sidewalk were designated for the purposes of this exercise.
- Unit pavers and granular base were removed to locate and confirm the cell deck edge. The torpedo was set to drill horizontally between the soil cell frame legs from the side.
- The crew dug down two cells deep between the building side and the cell, until there was enough room to slide the riser through. Where there is not enough room to dig behind the cell, the cell can be removed to install the riser.
- In alignment with the pit dug at the building end, another pit was dug down approximately 1.2m deep at the road end of the lateral.

Directional boring

- The torpedo was first set to begin at the building side where the riser would be placed. The torpedo did not make it out at the road side because it had great difficulty going from soft material to hard material (i.e.. growing medium to hard clay subgrade) as it does not have enough friction to propel it forward.
- The torpedo was reset to begin on the road side. It bored through the road subgrade then through the soft growing medium and came out at the building side.

Removal of pavers and granular base.

Geotextile is cut through centre of cell deck.

Digging down approximately two cells deep at both lateral ends.

Pulling the lateral through, attaching and setting the riser

- The torpedo was removed and the lateral pipe was attached to the hose end and pulled through.
- The riser was fused to the pipe end and pulled through and set at the correct elevation.
- Granular was backfilled into the cavity.

Torpedo emerges through growing medium and cell decks on the imaginary building side.

Torpedo set to begin at the imaginary building end of the lateral line.

After false start on imaginary building end, torpedo is reset at road end.

Torpedo and hose are pulled up and out of the pit.

Pulling the lateral through the cells and growing medium.

End of lateral at building end.

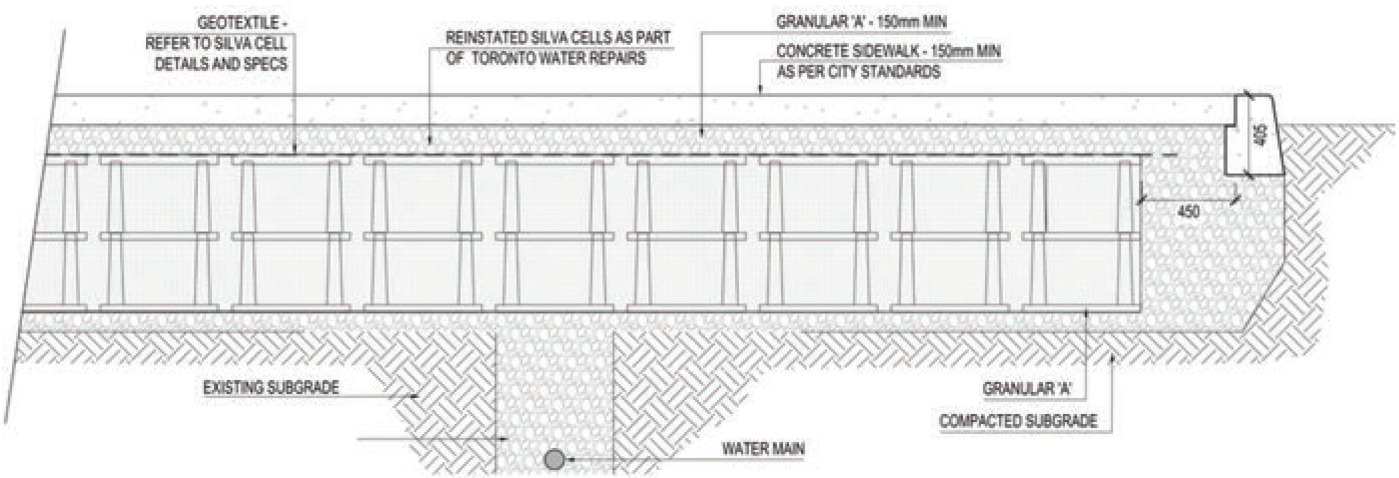
Cover over the cell deck with the cut geotextile and add an overlapping layer of geotextile on top.

Riser is attached and pulled through.

Backfill and ensure riser is set correctly. Conclusions of the Enbridge Gas exercise

Conclusions of the Enbridge Gas exercise

It was concluded that the soil cells pose no obstruction to the installation of a gas lateral and riser. The work is essentially the same as current sidewalk conditions with a few extra considerations. The crew must locate the boundary of the cell frame to set the torpedo to go between the cell deck legs and not collide into them. The crew must be mindful that the growing medium is easily permeable and that the torpedo bores move easily from hard to soft matter and not the other way around. Paving removal need only be limited to where the riser needs to go and the area needed to slide it into place. Where there is enough room between the soil cells and building face to excavate and install the riser, paving on top of the cells could stay intact.



Appendix C

Protection and Maintenance

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Notes: Each Silva Cell stack is independent of the Silva Cell stack adjacent to it – therefore if individual Silva Cells are disturbed, the entire system is not compromised.

Silva Cell frames (or base and posts) and decks should at no time be cut, drilled into, or otherwise structurally modified during any installaion, inspection or maintenance procedure. Any damaged Silva Cell frames (or base and posts) or decks shall be replaced.

1.0 Protection of The Silva Cell System

To help avoid future disturbance of the Silva Cell system the location of the system should be accurately recorded at the time of construction and incorporated into an as-built drawing.

If possible register the location of the Silva Cell system with the local One-Call utility locating program.

Accurately locate the limits of the Silva Cell system prior to any future excavation in the area. (Some types of underground utility locating equipment, such as ground penetrating radar, are capable of detecting Silva Cells and may be used to locate the limits of the system. Contact a professional utility locating contractor for more information).

Utility warning tape/ribbon and locating wires can also be incorporated into the system and are recommended.

2.0 Utility Installation, Maintenance, Relocation or Replacement within Silva Cell System

If the Silva Cell system is accidentally unearthed by future excavation in the area, cease the excavation immediately and consult the as-built drawings to determine the limits of the system.

Using hand tools only, expose the impacted portion of the Silva Cell system and carefully inspect the Silva Cell frames (or base and posts) and decks for any signs of damage or cracking.

Replace any damaged Silva Cell frames (or base and posts) or decks and reconstruct any disturbed portion of the system as per DeepRoot's installation Guidelines.

The Silva Cell system supports vehicle loading equal to 32,000 lbs (14,500 kg) per axle, which allows use in areas that accommodate 3 - 4 axle vehicles such as those used for emergency, delivery, and maintenance. Generally meets AASHTO HS-20 (USA), CSA-S6, 87.5 and OBC 54KN (Canada), and BS EN 1991-1-1:2002 and BS EN 1991-1-2:2003 (UK) loading standards when used with standard paving profiles.

Throughout this document, where H-20 loading is referred to, this is shorthand for the loading standards described above.

To prevent damage to underlying Silva Cells, ensure that machinery operated on the paving above does not exceed loading as described above. Do not operate any machinery over the Silva Cell system without paving being in place.

3.0 Utilities and Accessing The Silva Cell System

The Silva Cell system can be easily accessed for utility installation, maintenance, relocation, replacement, etc. using the following procedure.

First, locate the limits of the Silva Cell system.

Carefully remove the existing pavement. Take care to not operate machinery exceeding H-20 loading on any of the surrounding pavement supported by the system. Do not operate any machinery over the Silva Cell system once the pavement has been removed.

Using hand tools remove the aggregate base course and expose the underlying geotextile fabric. If working near the perimeter of the system there will be also be approximately 12" (30.5 cm) of geogrid that is folded over and attached to the cell decks. Cut the geotextile fabric as needed to allow for the removal of Cell decks. If Geogrid is encountered, detach it from cell decks and fold it back as well. Do not cut the Silva Cell frames (or base and posts) or decks. Remove the Silva Cell decks by removing the four corner screws and set it aside. Remove the soil from inside the frames using hand tools only or a HydroVac. (If the existing soil is to be reused, store it separately to ensure that it does not become contaminated with other spoil material. Otherwise dispose of the soil and replace it with soil meeting the requirements specified for the project. All soil must be inspected and approved prior to reinstallation.) Carefully remove any of the frames (or base and posts) needed to complete utility work. Upon completion of the utility work visually inspect the surrounding exposed Silva Cell parts and remove any of those showing signs of damage or cracking. Restore the disturbed portion of the system using one of the two following methods:

Method 1:

Replace the Silva Cell frames (or base and posts), soil and decks as required per Silva Cell installation details and specifications. Re-wrap geogrid over decks with an overlap at cut seam. Restore the aggregate base course and pavement. Re-use only Silva Cell frames (or base and posts) and decks that have been thoroughly inspected and found to be free of damage or cracking. Replace any parts showing signs of damage or cracking with new.

Method 2:

Structurally bridge the gap with 1 1⁄2" (3.8 cm) clear stone. Install geogrid around the perimeter of the area from which the Silva Cells were removed per DeepRoot's construction guidelines. Fill inside void area with 1 1⁄2" (3.8 cm) clear stone up to the level of the adjacent Silva Cell decks. Cover the stone with geotextile fabric making sure to overlap the existing geotextile fabric by a minimum of 2 feet on all sides. Restore the aggregate base course and pavement.

4.0 Pavement Repair or Replacement over Silva Cell System

When the existing pavement over a Silva Cell system is to be replaced by a different type of pavement, refer to the Silva Cell standard details and specifications. A change in surface materials may require a change in the depth of the underlying aggregate base course.

5.0 Adding Silva Cells to The System/Removing Silva Cells from The System

To make changes to the size of the Silva Cell system, locate the limits of the system. Carefully remove the pavement taking care to ensure that no machinery which exceeds H-20 loading is operated on pavement supported by the Silva Cells and that no machinery is operated over the Silva Cells once the pavement has been removed. Using hand tools remove the aggregate base and expose the underlying geotextile fabric. Cut the geotextile fabric as needed to visually confirm the limits of the Silva Cells. Excavate to no closer than 1' (30.5 cm) of the limits of the Silva Cells. Using hand tools, expose the geogrid which wraps the perimeter of the system. Cut and fold back the geogrid as needed to add or remove cells. If adding to the system, install the new Cells per Silva Cell specifications. Ensure that the gap between the existing Silva Cell frames (or base and posts) and the new Silva Cell frames does not exceed the 3” (7.6 cm) maximum. If removing frames (or base and posts) or decks, re-install the geogrid along the new perimeter of the Silva Cell system and backfill along the new limits of excavation per Silva Cell specifications.

6.0 Tree Replacement

Tree replacement may be necessary based upon unforeseen or severe site, climate or circumstantial conditions. Limit disturbance area as possible. Ensure all equipment meets H-20 loading requirements.

Remove any structure at the tree opening (tree grate, etc.) Remove mulch and any excess soil from above tree root package. Do not damage Silva Cell frames (or base and posts) or decks. Remove soil using hand tools only or HydroVac and set aside. If hand dug, ensure clean storage of soil material by excavating into contained/isolated location and cover during utility work. Soil must be inspected and approved prior to reinstallation.

Consult a certified arborist to remove tree. If necessary to cut tree roots from main root package, do not cut Silva Cell frames (or base and posts) or decks. Remove tree root package from planting bed. If using construction equipment to remove tree, ensure meeting of H-20 loading requirements.

Prior to planting new tree, install additional planting soil, to the depths indicated, within the tree opening adjacent to paving supported by Silva Cells. Assure that the planting soil under the tree root package is compacted to approximately 85-90% to prevent settlement of the root package. The planting soil within the tree opening shall be the same soil as in the adjacent Silva Cells. See Silva Cell specifications for further detail. Replace root barrier.

Plant tree according to owner specifications or at the direction of consulting arborist. Cover the planting soil finished grade with 2” (5cm) of mulch per Silva Cell specifications.

When a large portion of a Silva Cell installation is to be removed, first locate the area of disturbance. Limit disturbance area as possible. Ensure all equipment meets H-20 loading requirements.

Remove paving and aggregate base course. Carefully cut geotextile to allow for removal of Cell decks. Ensure at least 18” (45.7 cm) overlap into new limits of excavation. Do not cut Silva Cell frames or decks. Unfold geogrid from Cell decks and carefully fold away from Silva Cell frames (or base and posts). Remove Silva Cell decks by removing screws and set aside. Remove soil using hand tools only or HydroVac and set aside. If hand dug, ensure clean storage of soil material by excavating into contained/isolated location and cover during utility work. Soil must be inspected and approved prior to reinstallation Remove anchoring spikes from Cell base and set aside. If geotextile is at base of system, carefully cut geotextile at least 6” (15.2 cm) within new limits of excavation.

Install aggregate base course and paving, ensuring no damage to Silva Cells or other installation components.

7.0 Additional Silva Cells to be Installed Adjacent to Existing Installation

When additional Silva Cells are to be installed adjacent to an existing Silva Cell system, first locate the area of disturbance. Limit disturbance area as possible. Ensure all equipment meets H-20 loading requirements.

Excavate up to 12” (30.5 cm) from existing Silva Cells. Excavated remaining 12” (30.5 cm) by hand. Cut geogrid from face of existing Silva Cell system. Do not cut Silva Cell frames (or base and posts) or decks.

deeproot

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