Sustainable Technologies
EVALUATION PROGRAM

TECHNICAL BRIEF

Assessing the Health of Toronto Street Trees Irrigated by Stormwater

This study, conducted in partnership with the City of Toronto, assesses the health of street trees planted in 'soil cells' and conventional tree trenches. Three sets of the same two tree species (Freeman Maple and American Elm) planted in 2009 on Queensway Boulevard in Toronto were compared. The first two sets of trees were planted in supported soil cell systems (silva cell™). The others planted further west in tree trenches according to standard City of Toronto tree planting specifications were used as controls. One set of soil cell trees has been receiving stormwater runoff since the trees were planted. The other adjacent set of trees had the stormwater inlet pipe intentionally plugged by Toronto staff after 2 years to facilitate assessment of the effects of stormwater runoff on tree health. The standard control trees were not irrigated with stormwater runoff.

Measurements of tree height, trunk diameter, crown volume and leaf area showed that the stormwater trees were taller, had thicker trunks and larger crowns, but similar leaf densities compared to control trees planted in the conventional tree trench. The soil cell not receiving stormwater was shorter and had a smaller crown than the cell receiving stormwater runoff. These results suggest that trees grow better when irrigated with runoff from stormwater, and that trees in soil cells are healthier than those in tree trenches. While salt can be toxic to trees, good drainage and ample supplies of salt-free stormwater delivered to the soil cells in the spring, summer and fall likely helped prevent damaging salt ions from accumulating. A separate study of the stormwater performance of the soils cells conducted by Toronto Water and University of Ryerson soon after installation showed that the stormwater cells significantly improved water quality while also reducing flow volumes and rates.

Cities worldwide recognize the benefits of street trees in providing shade, sequestering carbon, enhancing biodiversity, reducing air pollution and improving human health and psychological well-being. Ambitious urban canopy targets have been set by Toronto and other Canadian municipalities to help capture these benefits. As street trees can be subject to stresses like compacted soils, limited moisture, extreme heat and road salt, technologies that help to improve their growing conditions, like soil cells, will be valuable in helping to achieve these targets.

INTRODUCTION

The City of Toronto and other urban centres in Canada are increasingly using soil cells or suspended pavement systems to improve the health and longevity of street trees. These systems can be designed and installed with or without an inlet for stormwater runoff from the adjacent paved area. Draining stormwater runoff through the cells can help irrigate the trees and improve the quality of runoff but there is concern that road salts will accumulate in the soil media leading to die-back, stunted growth, reduced canopy volume or even death. Road salts are toxic to plants at high concentrations but are also highly mobile, and readily flushed from soils in the early spring (STEP, 2019). To assess whether road contaminants in runoff (including salts) adversely affect the health of trees, this study compared the health of ten year old trees in soil cells with and without stormwater drainage, and compares these to street trees planted at the same time in a standard trench configuration.

STUDY SITE

The site of the study was on Queensway Boulevard, a 4 lane arterial road in Toronto (Figure 1). Three sites with at least one American Elm (ulmus americana) and Freeman Maple (cross between acer saccharinum and acer rubrum) planted in the same year (2009) were selected for evaluation. These sites included (i) trees in soil cells (silva cells™) with stormwater drainage (referred to as stormwater cells), (ii) trees in soil cells with stormwater drainage during the first 2 year establishment phase (referred to as dry cells), and (iii) eight trees (5 Elm and 3 Maple) planted in a standard trench configuration according to Toronto guidelines (referred to as the control). The stormwater and dry cells were adjacent to one another on the north side of Queensway Blvd. The control trees were further west on the same street adjacent to a retail parking lot. Sodium chloride road salts are used for de-icing of Queensway Blvd during the winter.

The design of the soil cells is presented in Figure 2. Stormwater runoff drains from the road into a streetside catchbasin where it is directed into the soil cell via a perforated 100 mm diameter distribution pipe. Water from the distribution pipe is filtered by the proprietary sandy soil mixture in the cells and drained by perforated pipes at the base to a storm sewer. Note that the inlet distribution pipe is located away from the root ball to protect roots from salt and other contaminants during the establishment phase.

APPROACH

Comparisons of the three sets of trees were based on measurements over a single summer in 2018 of the tree height, crown volume, leaf area index and breast height trunk diameter. The tree height was measured by free moti software (by Bern University of Applied Sciences) employing a smart phone's gyroscope. The crown volume is a measurement of the outside edge of the tree's crown in all directions, accounting for the density of leaves within the outline using free UrbanCrowns software (Win, 2011). The leaf area index was determined by Pocket LAI (Confalonieri and Foi, 2016) using the phone camera to measure leaf density from beneath the crown. Leaf area index is a measure of how many overlapping leaves the tree has on average between the very top and the ground. Finally, the diameter of the trees at breast height was measured at 130 cm from the ground.

An earlier study was conducted by Toronto Water and Ryerson University on the water quality and quantity performance of the soil cells after construction. Results are summarized here based on a presentation provided at the TRIECA conference in 2017 (Cheung and Anderton, 2017). The Ryerson University researchers also did some

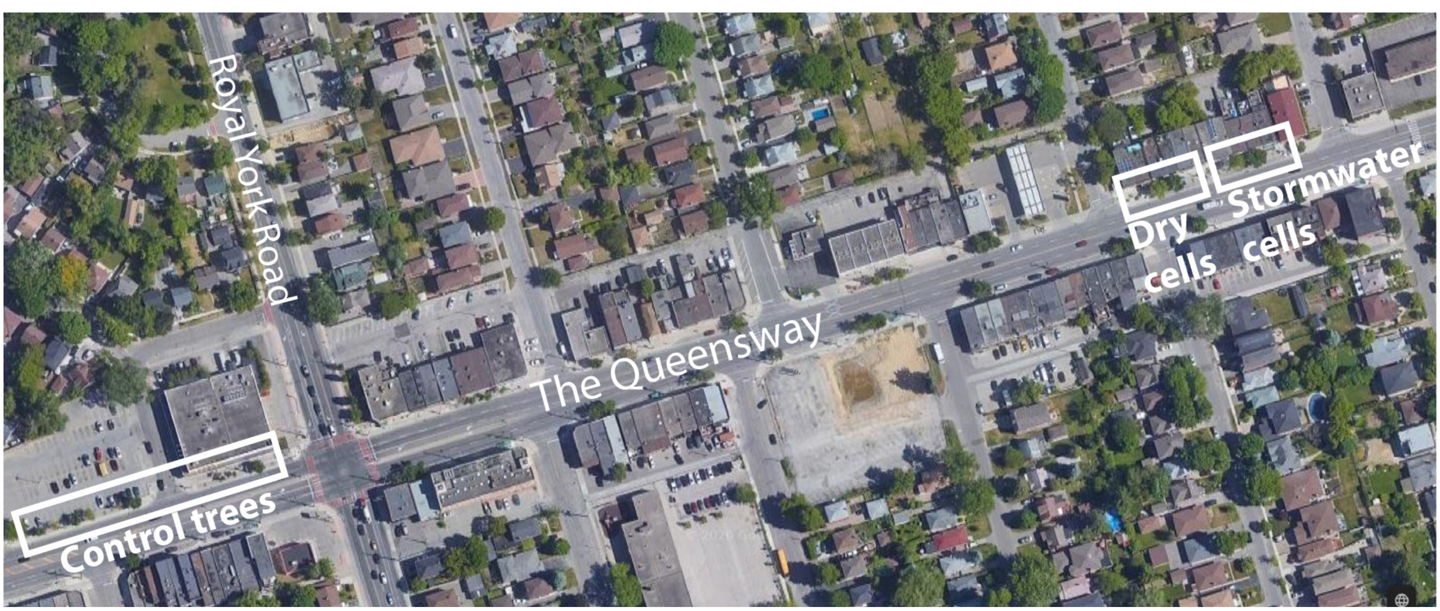

Figure 1. Location of Soil Cells (dry and stormwater) and Control Trees on Queensway Blvd in Toronto

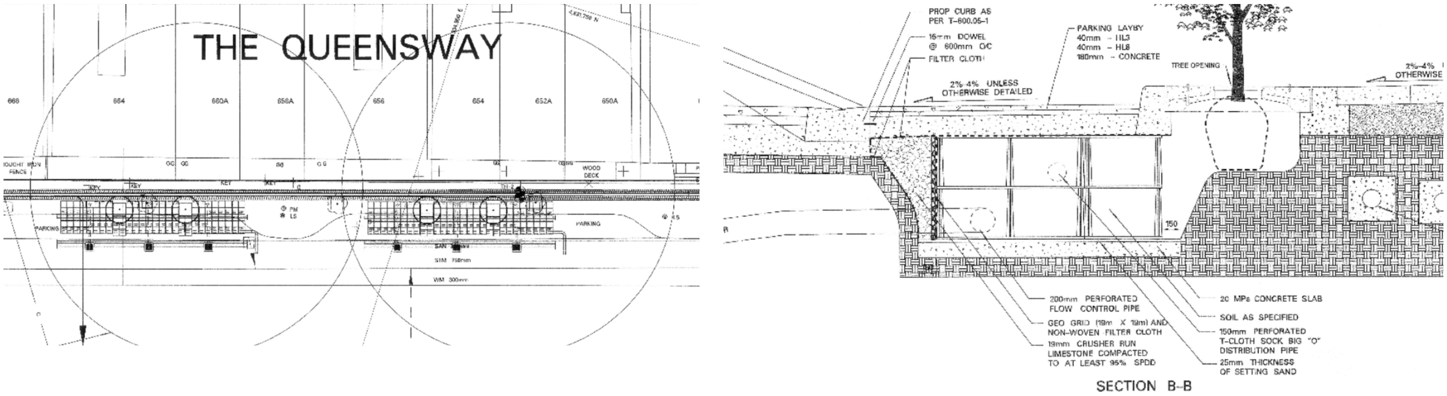

Figure 2. Schematic showing soil cells in plan view (left) and cross section (right).

Figure 3. Stormwater tees (top) and dry cell trees (middle) and control trees (bottom) in June 2018

modelling work based on monitoring data from the project that examines the influence of inlet hydraulics on soil cell performance (Li et al., 2020).

STUDY FINDINGS

Tree Health Study

The study results showed that soil cells had larger trees than those in standard tree trenches. The breast height tree diameter and height of the Elm and Maple trees in soil cells were both greater than those in tree trenches (Figure 5). Among the two sets of soil cell trees, those with continuous stormwater irrigation had larger diameters and were taller than those with stormwater provided only during the first two years.

Similar results were shown for crown volumes, with the stormwater cell trees registering the largest volume, followed by the dry cell trees and then the control trees (Figure 6 and 7). The control trees had much smaller crown volumes than the trees in soil cells. City of Toronto Parks and Forestry staff suggested that lower levels of manual irrigation of the control trees during the establishment phase may have contributed to this result. Unfortunately, data were not available to confirm and quantify the influence of this factor.

The dry cell trees had the greatest leaf area index, followed by the stormwater cell and control trees. Leaf area indices (LAI) for the stormwater cell and control tree Elms were similar, as were the Maples, although the stormwater cell Maples showed higher LAIs than the control in the months of September and October.

Unlike the other trees in this study, the stormwater cell Maple was surrounded by concrete slabs that caused damage to the base of the tree trunk as the tree matured. This caused suckers to spring up at the base. It is unknown how this scarring may have affected overall growth and health of the tree. Shoots developing from the tree base are often considered to be a sign of stress.

Figure 4. Soil cell construction and final planting (source: P. Cheung)

These results support previous research by Grey et al (2018) in Melbourne, Australia that compared four tree pit stormwater control measure (SCM) designs with a control street planting (non-SCM) over an eight month period. The trees in the study were newly planted hedge maples (acer campestre) and the tree pits were of similar size but with different soil textures. The authors found that trees planted in tree pits with appropriate drainage grew at double the rate of the control trees without stormwater drainage. Waterlogging was a problem in some tree pits without adequate drainage because of fine textured native soils.

Stormwater Management Study

Performance monitoring conducted by Toronto Water and Ryerson University researchers (Cheung and Anderton, 2017) showed that the soil cells provided

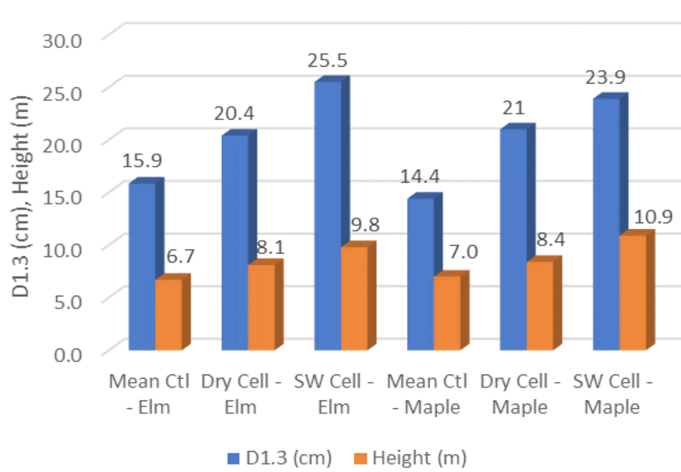

Figure 5. The height and diameter of the stormwater cell, dry cell and control trees

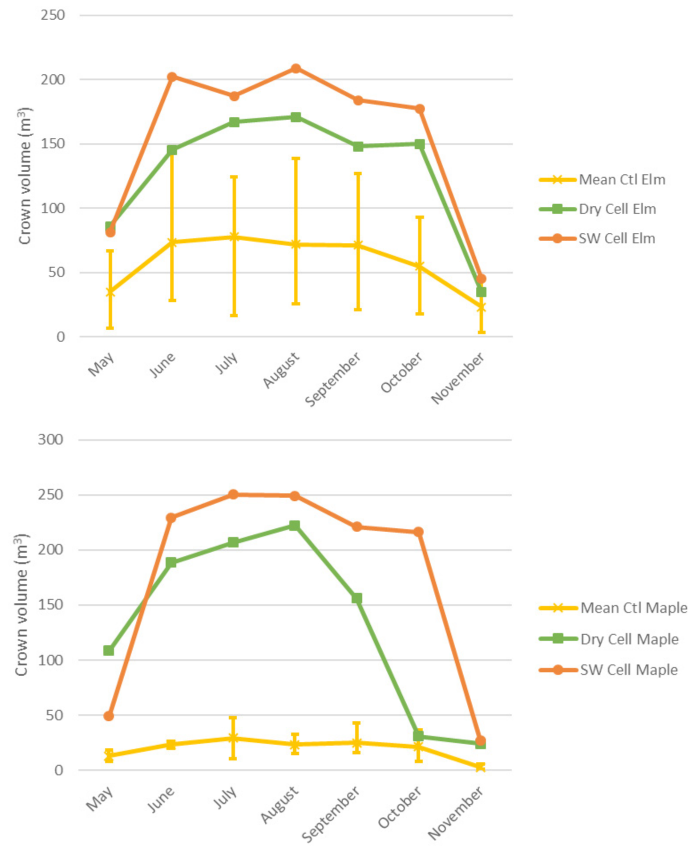

Figure 6. The crown volumes of the stormwater cells, dry cells and control trees. Elm (top) and Maple (bottom). Error bars for the control trees represent the minimum and maximum observed values.

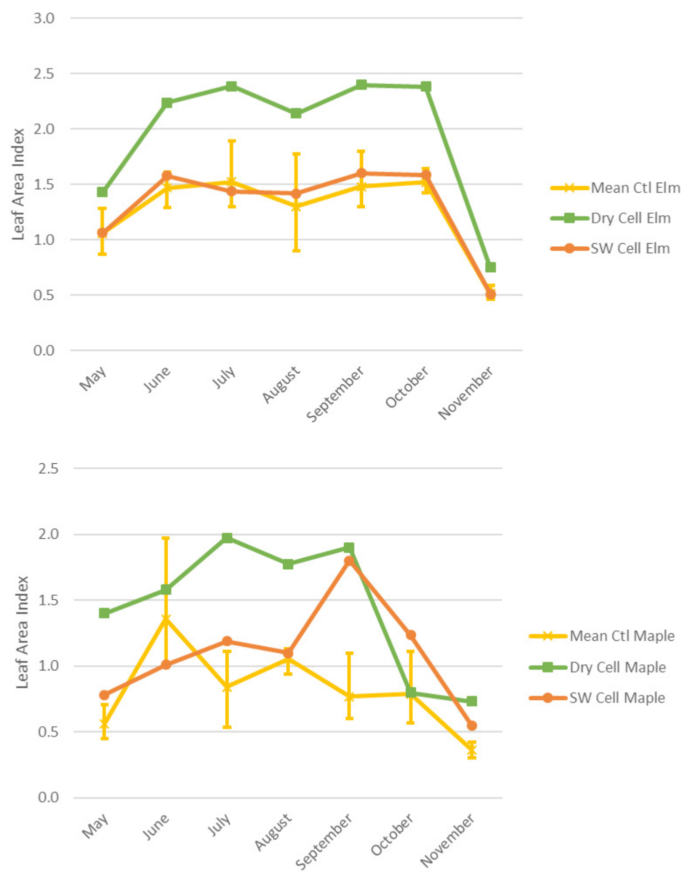

Figure 7: The leaf area indices of the stormwater cells, dry cells and control trees. Elm (left) and Maple (right). Error bars for the control trees represent the minimum and maximum observed values.

good overall stormwater runoff treatment (Table 1, Figure 8). Effluent total suspended solids concentrations were consistently below 20 mg/L, and most contaminants showed positive removal except nitrate, which was likely augmented through leaching from the soil. Dissolved pollutants such as orthophosphate, chloride and nitrate are often not effectively removed by soil filtration (STEP, 2019).

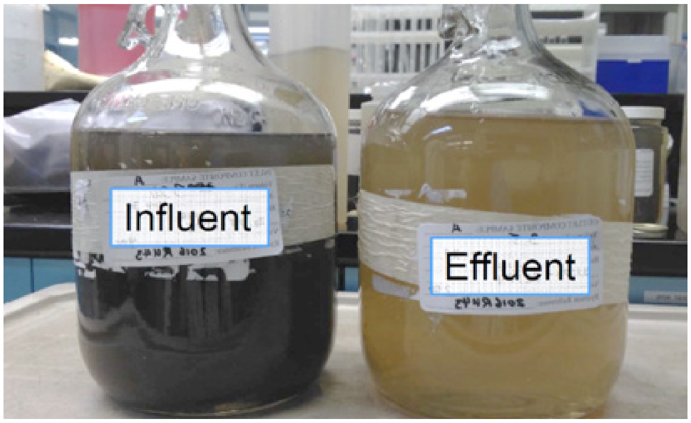

Figure 8. Distinct colour differences were observed at the inlet and outlet of the facility. Picture courtesy of Cheung and Anderton, 2017

Flow and soil moisture measurements during summer storms also showed appreciable volume reductions with some rain events less than 6 mm producing no runoff (Figure 9). Since the cells were lined to prevent infiltration, the observed volume reductions were attributed primarily to temporary soil storage and evapotranspiration. Some losses to infiltration may have also occurred through leaks in the liner.

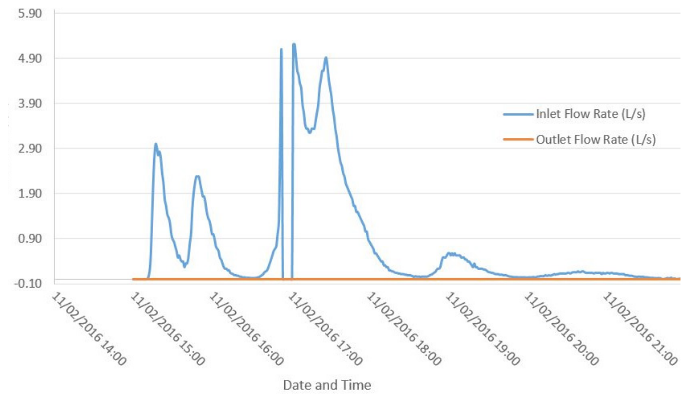

Figure 9: A 5.8 mm rain event on November 2nd , 2016 that generated no outflow. Source: Cheung and Anderton, 2017

Table 1. Concentrations and percent removal of selected water quality variables during a small and large rain event

Variable	Small Event (4.2 mm)			Large Event (19.4 mm)		
	Inlet (mg/L)	Outlet (mg/L)	Percent Removal	Inlet (mg/L)	Outlet (mg/L)	Percent Removal
TSS	40	2	95	65	15	77
TP	0.18	0.08	53	0.28	0.11	62
Nitrate	0.3	0.46	-53	0.02	0.68	-132
Lead	0.008	0.0006	92	0.005	0.001	81
Zinc	0.059	0.025	57	0.10	003	71
Copper	0.017	0.009	44	0.03	0.01	63
Aluminum	0.97	0.11	89	0.91	0.50	45
Iron	1.19	0.14	89	2.53	0.38	85
Nickel	0.0018	0.0008	58	0.004	0.0009	79
BOD	12	2	83	68	5	93

Source: Cheung and Anderton, 2017

CONCLUSION

This study demonstrated that 10-year-old trees in soil cells receiving street runoff were taller and had larger crown volumes and trunk diameters than trees not receiving street drainage, both in soil cells and in traditional tree trench configurations. While there has been concern that road salts in street runoff can adversely impact the health of trees, this study showed that well drained soil cells can thrive under these conditions. This may be due to enhanced drainage provided by the soil mix used within the cells and the configuration of the inlet pipes further away from the root ball, which helps ensure that most tree roots are minimally impacted by temporary salt accumulation in soils.

In an earlier study of a bioretention cell receiving street drainage in Brampton (STEP, 2018), sampling of soil media during and after the winter season showed that sample concentrations exceeded the Ontario Record of Site Condition Standards (OMOE, 2011) for Sodium Adsorption Ratio (SAR) during the winter months due to salt-laden runoff from streets, but quickly returned to levels below guidelines by the end of April. This finding indicates that spring rain events effectively flush salts from the soils early in the growing season. It is recommended that similar measurements be conducted at various soil cell locations receiving street runoff to better characterize the duration that tree roots may be exposed to salt contamination, and potential effects on soil health.

An important advantage of soil cells in urban areas lies in their capacity to improve the quality of runoff, while also reducing flow volumes and rates. A performance assessment conducted by staff from Toronto Water and Ryerson University showed that the Queensway cells performed well in this regard (Cheung and Anderton, 2017). Preliminary results showed that outlet concentrations were substantially lower than inlet concentrations for several key water quality variables, such as total suspended solids and total phosphorus. The cells also provided effective retention of runoff during small, frequent rain events. Passive irrigation of the trees reduces the need for frequent watering by City maintenance crews, particularly in the period of tree establishment.

REFERENCES

Confalonieri, R., Foi, M., 2016. PocketLAI.

Cheung, P. and Anderton, R. The Queensway Sustainable Sidewalk Pilot Project. Conference Presentation at TRIECA, March 22, 2017

Grey, V., Livesley, S.J., Fletcher, T.D., Szota, C., 2018. Establishing street trees in stormwater control measures can double tree growth when extended waterlogging is avoided. Landscape and Urban Planning, 178 (2018) p.122-129. https://doi.org/10.1016/j.landurbplan.2018.06.002

Li, J., Alinaghian, S., Joksimovic, D. and Chen, L. An integrated hydraulic and hydrologic modeling approach for roadside bio-retention facilities. Water: 2020, 1248; doi:10:3390/w12051248

OMOE, 2011, Ontario Ministry of Environment (OMOE). 2011. Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act. Table 3: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition. PIBS # 7382e01. Toronto, Ontario.

STEP, 2019. Comparative Performance Assessment of Bioretention in Ontario. Technical Brief. Prepared by TRCA

STEP, 2018. Effectiveness of Retrofitted Bioretention Swales – County Court Blvd, Brampton, Technical Brief, Prepared by TRCA.

Winn, M.F., 2011. Urban Crowns: Crown Analysis Software to Assist in Quantifying Urban Tree Benefits

This communication has been prepared by the Sustainable Technologies Evaluation Program. Funding support for the tree health portion of the study was provided by Deep Root and the Regional Municipalities of Toronto, York and Peel. The contents of this report do not necessarily represent the policies of the supporting agencies and the funding does not indicate an endorsement of the contents.

Published in 2020. Visit us at www.sustainabletechnologies.ca to explore our other resources on Urban Runoff and Green Infrastructure.

If you are interested in getting involved through any of our engagement opportunities, please contact us at:

STEP@trca.on.ca | twitter.com/STEPLivingCity

The water component of STEP is a collaborative of:

Credit Valley Conservation — inspired by nature

Lake Simcoe Region conservation authority

Toronto and Region Conservation Authority