Evaluation of Residential Lot Level Stormwater Practices

TECHNICAL BRIEF

Healthy Soils Projects

Low Impact Development (LID) designs attempt to mimic pre-development hydrology through improved site design and distributed lot level practices that treat runoff at the source. Lot level practices include engineered structures such as rain gardens, soakaways and permeable pavements that filter, infiltrate and evaporate runoff. They can also include non-structural practices such as directing roof downspouts to gently sloping landscaped areas that contain topsoil of sufficient permeability, depth and quality to absorb and evaporate runoff during and after wet weather events.

'Pervious' landscaped areas such as yards, gardens, parks and sports fields that provide aesthetic and functional benefits, have been shown to generate 40-60% of residential runoff when constructed on compacted poor quality soil (Wignosta et al., 1994)

Although draining roof downspouts to landscaped areas is standard for new residential developments in the Greater Toronto Area, not much is known about the effectiveness of this practice to manage runoff. Furthermore, there is little known about how much more effective it could be by increasing topsoil depth and quality in landscaped areas receiving roof drainage. This study (Young et al., 2013) helps to address this knowledge gap by evaluating at the catchment scale, the hydrologic benefits of widespread application of two types of lot level stormwater management practices in newly constructed residential developments:

- Increased topsoil depth; and
- Rear yard infiltration trenches with grass swale pretreatment.

To verify conclusions drawn from the catchment scale evaluation of increased topsoil depth and to characterize what further benefits could be achieved with addition of a compost blanket amendment (i.e. increased topsoil depth and quality), evaluations of test boxes designed to simulate turf grass landscaped areas exposed to natural precipitation were also conducted.

STUDY SITE

The study site is the community of Box Grove residential subdivision, located in Markham, Ontario, just north of Toronto (Figure 1). Drainage from the community enters the Little Rouge River, which is a cool-water tributary to the Rouge River. Subsoils consist of glacial drift deposits of sandy silt till and silty sand till up to 2 m below the ground surface with estimated infiltration rates of 12 and 30 mm/h, respectively. Below 2 m depth is a silty fine sand layer of variable depth with an approximate infiltration rate of 50 mm/h, which influenced the decision to incorporate infiltration trenches.

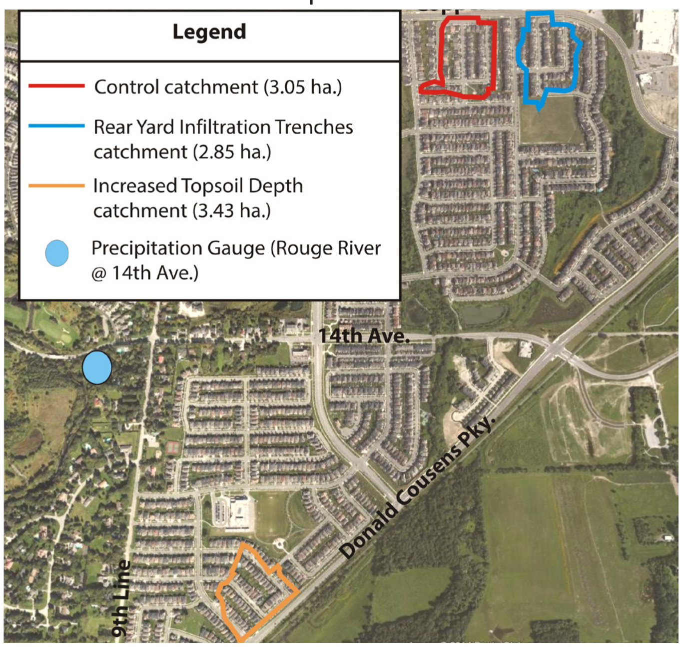

Figure 1. Location of the Box Grove community and study area catchments.

APPROACH

Community Scale

The community scale evaluation study involved simultaneous monitoring of storm sewer flows from three differently treated catchments of similar size and development density within the same residential neighbourhood (Table 1). Measured total runoff volumes and flow rates per hectare of drainage area from each catchment were assessed on a storm event basis and cumulatively over a 2.5 year monitoring period. The results were used to evaluate the effectiveness of each type of treatment practice to reduce runoff in comparison to the conventional design control catchment.

The Control (CTL) catchment contains 58 lots in which 10 to 15 cm of topsoil was applied to landscaped areas over compacted subsoil. An Increased Topsoil Depth (ITD) catchment contains 52 lots, where topsoil was applied to all landscaped areas to a typical depth of 30 cm and up to 120 cm along 3.5 m wide swales oriented along rear lot lines. However, measurements of topsoil depths showed that additional topsoil was only applied to rear yard areas. A Rear Yard Infiltration Trenches (RYIT) catchment contains 60 lots, whereby runoff from rear draining portions of roofs and yards from 30 of the lots was directed to three infiltration trenches via grass swales oriented along rear lot lines. Unfortunately, the inlets were clogged with sediment during the construction period. Attempts to unclog the inlets were only partially successful, making it difficult to evaluate the true benefits of this type of treatment.

Test-Box Scale

This component of the study was conducted at the Living City Campus at Kortright, Vaughan, where test boxes designed to simulate turf grass landscaped areas were subjected to soil treatments. The soil treatments were: i) standard topsoil depth (10 cm); ii) increased topsoil depth (25 cm) with compost blanket (5 cm) amendment; and iii) increased topsoil depth (30 cm). The 2.1 m^2 surface area test boxes were exposed to natural rainfall and monitored for runoff and infiltration volume following each storm event, and evapotranspiration loss and change in topsoil moisture between storm events over a summer to fall monitoring season. Two boxes were constructed for each soil treatment using topsoil obtained from a construction site near the Box Grove community and were monitored side-by-side.

Table 1. Study area catchment characteristics.

Parameter	CTL		ITD		RYIT	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Drainage area	3.05	100	3.43	100	2.85	100
Total pervious cover	1.06	34.7	1.38	40.3	1.15	40.2
Total impervious cover	1.99	65.3	2.05	59.7	1.7	59.8
Roofs	1.05	34.4	1.18	34.3	0.79	27.9
Paved Areas	0.94	30.9	0.87	25.4	0.91	31.9

FINDINGS

The ITD catchment consistently produced less runoff than the CTL catchment for all storm event depth ranges examined. When total runoff depth over the monitoring period was compared (Table 2), it was found that for small to medium size storm events (i.e. 5 mm ≤ events ≤ 15 mm), the ITD catchment produced 22% less runoff per unit area than the CTL catchment. For large storm events (i.e. > 15 mm), the ITD catchment produced about 27% less runoff per unit area than the CTL catchment. However, measurements of trench water levels in the RYIT catchment showed that rear yards with conventional topsoil depth did not produce runoff during storm events less than 15 mm in depth and 6.6 mm/h. This finding was further supported by the test boxes results.

Table 2. Runoff reduction ratios observed over the monitoring period by event depth range. RYIT data are taken after an unclogging attempt was made.

Catchment Comparison	Runoff Reduction Ratio*					
	Events >5 mm		Events >15 mm		5 mm< Events <15 mm	
	Ratio	N	Ratio	N	Ratio	N
ITD vs. CTL	0.26	38	0.27	17	0.22	21
RYIT vs. CTL	0.15	18	0.14	9	0.16	9

*Runoff reduction ratios were calculated by summing the total runoff depth for all events that occurred during the monitoring period that fall within the event depth ranges of interest for the Control and treatment catchments and dividing the difference between the Control catchment total and treatment catchment total by the control catchment total.

Therefore, the 22% less runoff observed from the ITD catchment during small to medium size events is likely due to differences in catchment land cover alone, particularly differences in paved areas directly connected to storm sewers, which comprised 31% and 25% of the control and ITD catchment drainage areas, respectively (Table 1). This finding further suggests that the hydrologic benefits of ITD are limited to large and intense storm events.

The observation that runoff reduction increased to 27% for large storm events suggests that these are the conditions when increased topsoil depth in rear yards begin to provide runoff reduction benefits and that the magnitude of the benefit is in the order of 5% less runoff over the monitoring period (i.e. 27% – 22%). The results of this study suggest that application of increased topsoil depth in rear yard areas alone, with no efforts made to reverse subsoil compaction prior to topsoil spreading, nor to amend site topsoil with compost to increase organic matter content, may only provide minor runoff reduction benefits when examined over a range of events at a catchment scale.

During intense storm events, the ITD treatment resulted in reduced runoff and peak flow attenuation as compared to the CTL catchment. While overall runoff reduction ratios for the ITD catchment over the monitoring period were quite small, it is clear from examination of event hydrographs and comparisons of event runoff depths during large and intense storm events that the deeper topsoil applied to rear yard areas provided substantial benefits during some of these infrequent events. Event based differences in runoff depth between the ITD catchment and CTL catchment indicate runoff reductions in the range of 20 to 60% were achieved during some of the most intense storm events (Figure 2). Additionally, the hydrograph peak flow was attenuated for the ITD catchment, which has a mitigating effect on erosion of receiving streams compared to the peak flows produced from the CTL catchment.

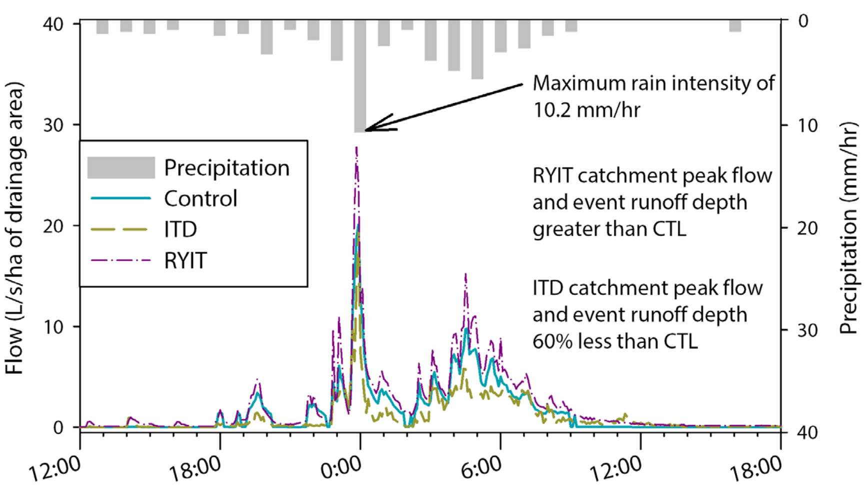

Figure 2. Hydrographs for the three catchments during an intense 40.6 mm rain event, October 19-20, 2011.

Water level monitoring in the infiltration trench wells indicated that only one of the three trenches in the RYIT catchment was receiving runoff from its drainage area. After an attempt to unclog the trench inlets, mean runoff coefficients in the RYIT catchment were slightly lower than the CTL catchment, but differences were quite small and the same for all event depth ranges. Hydrograph comparisons showed very similar hydrologic responses from the RYIT and CTL catchments, even during large and intense storm events (Figure 2) suggesting that the rear yard infiltration trenches did not treat a sufficient quantity of water to allow detection of runoff reduction benefits through the catchment scale evaluation approach applied in this study . When total runoff depth over the monitoring period from small to medium sized storm events was compared, (Table 2) it was found that the RYIT catchment produced 14% to 16% less runoff than the CTL catchment but these differences are likely due to differences in catchment land cover and the number of homeowners that re-directed roof leaders to driveways, which is a well-documented practice in residential communities. It should be noted that monitoring data clearly show that RYIT do have the capacity to significantly reduce runoff. Based on observed drainage times the functioning 1.2 metre deep trench was achieving an infiltration rate of approximately 11 mm/h, which would have been sufficient to infiltrate most of the runoff directed to it from year yards.

The Standard Topsoil Depth (STD) test boxes produced the highest volume of runoff and the

Table 3. Summary of gravimetric analyses of test boxes.

Test Box Type	Runoff		Infiltrate		Water Storage		Runoff, Infiltrate and Storage		ET	
	kg	*%*	*kg*	*%*	*kg*	*%*	*kg*	*%*	*kg*	*%*
STD	0.9	1	14.3	19	5	6.3	19.86	26.5	55.2	74
ITDCB	0	0	10.1	14	8	10.5	18	24	57	76
ITD	0.3	0	9.8	13	6	8.1	16.17	21.5	58.8	78

least storage and evapotranspiration (ET) compared to the treated boxes. Over the August 8 to November 23 monitoring period, a total of 348 mm of rain fell over 41 discrete rain events. The largest and most intense rain event occurred on September 4, 2014, when 43.4 mm fell with a maximum rainfall intensity of 30.2 mm/hr. Over the monitoring period, the Increased Topsoil Depth with Compost Blanket (ITDCB) had the least runoff (none) and stored the most water while the quantity of rain that infiltrated and evapotranspired was similar to the Increased Topsoil Depth (ITD) boxes (Table 3). These results confirm that the practice of applying increased topsoil depth (25 to 30 cm) to grassed pervious areas produces less runoff than a standard 10 cm depth and that additional runoff reduction and water storage benefits can be provided by amending topsoil with compost. It is important to note that rainfall was the only input to the boxes, which was reflected in the small amount of runoff generated even for the STD box.

Soil moisture at 10 cm depth was consistently higher for the ITDCB treatment in comparison to ITD. These results suggest that applying a compost blanket amendment to topsoil in pervious areas prior to laying sod or planting grass seed would provide additional benefits of creating a more drought resistant, lower maintenance lawn that can survive for longer periods of time without irrigation. Therefore, this practice could help conserve water, save property owners money and reduce the amount of time and effort they spend maintaining their lawns.

CONCLUSIONS AND RECOMMENDATIONS

1. The results of this study confirm that applying increased topsoil depth in landscaped areas provides runoff reduction benefits and supports widespread implementation of this lot level stormwater practice in future developments. Applying increased topsoil depth to all pervious areas receiving drainage from impervious surfaces, rather than just in rear yards, and adding a compost blanket amendment prior to planting would increase runoff reduction and produce more drought tolerant, lower maintenance landscaped areas.
2. Lot level stormwater practices should be thoroughly inspected by the municipality prior to acceptance, including continuous water level monitoring over several natural storm events or a simulated storm event to determine if the system is functioning as designed.
3. To help ensure the function of lot level BMPs installed on private property are maintained over time, property owners should be made aware of their presence and presented with information on their function, inspection and maintenance needs or the municipality should maintain easements. Agreements between the municipality and property owners should be put in place and attached to the property agreement, in order to ensure that maintenance responsibilities transfer when the property ownership changes.
4. Inlets to rear yard infiltration trenches should be accessible from the catchbasins to facilitate inspection and maintenance. Locating structural stormwater management practices in front yards and within road rights-of-way, or within easements oriented along the rear lot lines of residential properties would be more sustainable from a long-term inspection and maintenance access perspective.

REFERENCES

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For more information on STEP's other Low Impact Development initiatives, or to access the full report for this study, entitled Evaluation of Residential Lot Level Stormwater Management Practices, visit us online at www.sustainabletechnologies.ca

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