November 18, 2014

Lake Wilcox Sustainable Neighbourhood Retrofit Action Plan (SNAP) -
20 Wheatsheaf Street Front Yard Makeover Stormwater Monitoring Final Report

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1. Introduction

The Lake Wilcox Sustainable Neighbourhood Retrofit Action Plan (SNAP) project focuses on promoting the adoption of more sustainable practices in an existing community in the Town of Richmond Hill. As a strategic means of encouraging community members to renovate their yards to make them more water efficient, more attractive to birds and pollinators, and to absorb more rainfall and snowmelt, a single family detached home in the neighbourhood was selected to receive a "front yard makeover". The makeover showed how eco-friendly design features could be integrated with a beautiful contemporary landscape aesthetic. One of the objectives of the front yard makeover was to demonstrate the lot runoff volume reductions that are possible .

The home located at 20 Wheatsheaf Street in Richmond Hill was selected in part because very few renovations to the yard had been undertaken since it was built. The front yard makeover showcases landscaping that is less water-demanding than conventional turfgrass to help conserve municipal water. It also features lot level stormwater management practices that reduce the amount of runoff that enters the storm sewers during rain and snowmelt events, to help restore more natural patterns of flow and aquatic habitat in Lake Wilcox and the Humber River. A rain garden, sideyard soakaway and permeable pavement walkway were installed and a rain barrel was added to harvest roof runoff for use in landscape irrigation to offset use of municipal water (Figure 1). The renovations took place during the summer of 2012.

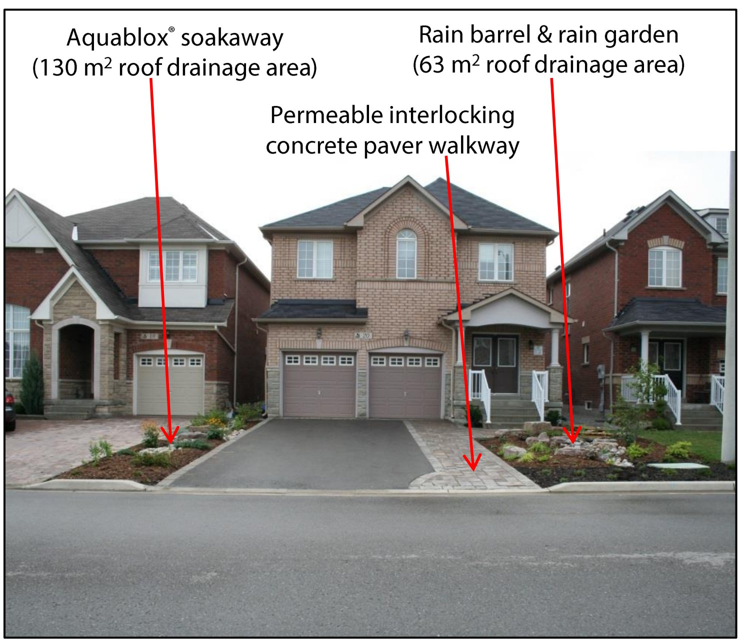

Figure 1: View of the completed front yard makeover of 20 Wheatsheaf Street

2. Information Sources

Stormwater Runoff

Information sources used to evaluate the runoff reduction effectiveness of the Low Impact Development (LID) stormwater management practices implemented as part of the front yard makeover were historical measurements of rainfall depth in the region, field monitoring of rainfall depth in the neighbourhood and water levels in the rain garden and sideyard soakaway. Field monitoring was conducted over an August to November 2012 and June to October 2013 post-renovation monitoring period (9 months).

Historical rainfall data from Environment Canada's Buttonville Airport climate station were used to characterize local rainfall depth, based on 30 year climate normal values that represent the average of 1981 to 2010 data. Environment Canada's climate normal monthly rainfall depth values and derived seasonal totals were compared to measured rainfall depth in the neighbourhood to determine whether or not rainfall during the post-renovation monitoring period deviated substantially from normal values. Rainfall depth in the neighbourhood was continuously measured every 5 minutes by a tipping bucket rain gauge operated by the Town of Richmond Hill located at 13067 Yonge Street, approximately 2.2 kilometres (km) from the property. The relationship between rainfall event depth and the portion of average annual rainfall depth that occurs as events less than or equal to that depth, based on 25 years of historical data (1980 to 2005) from the Buttonville Airport climate station (TRCA, 2013) was also used to predict runoff capture performance of the rain garden and sideyard soakaway in an average precipitation year.

Water levels in the rain garden and sideyard soakaway were continuously measured every 5 minutes with pressure transducers installed in monitoring wells. The rain garden well extended to a depth just below the surface of the amended soil in the deepest portion and provided the means of detecting when the rain garden overflows due to the surface ponding capacity being exceeded, and determining the length of time required to drain ponded water. The soakaway well extended to the base of the practice and provided the means of detecting when the soakaway overflows due to water storage capacity being exceeded, and determining drainage rates and times.

By examining the relationship between rainfall event depth and the frequency of overflow, the size of rainfall event that each practice is capable of fully capturing runoff from on a consistent basis was determined. Using the relationship established by TRCA from the 25 year historical rainfall dataset from Buttonville Airport climate station, predictions were made regarding what portion of annual rainfall depth and runoff volume this represents in an average year. Continuous water level data were also used to evaluate the rate at which each practice drained, the length of time required to fully drain and how drainage rates varied over the monitoring period. This provides insight into the performance of stormwater infiltration practices on fine-textured soil like the sandy clay glacial till subsoil present in this neighbourhood and provides a basis for examining how their drainage performance changes over time as the practices age.

Rainwater Use

The volume of rainwater used by the homeowners over the post-renovation monitoring period was evaluated by collecting continuous water level data in the 377 litre (L) capacity rain barrel installed in the front yard. A pressure transducer was installed inside the rain barrel that collected water level data every 5 minutes over the post-renovation monitoring period.

The volume of rainwater used during each usage event was calculated assuming the rain barrel is cylindrical and using the formula for the volume of a cylinder (i.e. $V = \pi r^2 h$) with the radius dimension being the average measured value and the height dimension being the decline in water level measured by the pressure transducer. Annual volumes of rainwater used were calculated by summing the usage event volumes for each year of the monitoring period.

3. Rainfall

The post-renovation monitoring period included several months when total rainfall depth was much greater than the long-term averages for the area which are based on Environment Canada's 30 year climate normal values from the Buttonville Airport climate station (Environment Canada, 2014). Figure 2 compares observed monthly rainfall totals from the 2012 and 2013 field monitoring seasons to 30 year climate normal values for the area. In 2012, rainfall during the months of July, September and October were much greater than normal with totals during September and October being double the long-term average. The very wet September to October period was followed by a much drier than normal November. In 2013, the months of June, August and October were also much wetter than normal. These particularly wet months also included some extreme storm events. On September 4, 2012, a total of 64.6 mm of rain fell over 16 hours which was larger than the 10 year return period 24 hour storm event for the area (Environment Canada, 2004). On September 20, 2013 48.8 mm of rain fell over 22 hours which was larger than the 2 year return period 24 hour storm event for the area (Environment Canada, 2004).

These very wet conditions were amenable to evaluating the drainage performance of the rain garden and sideyard soakaway as they provide insight into their effectiveness during wetter than normal and extreme storm event conditions. Since drainage of these practices slows down when the underlying soil is saturated, the average drainage rates calculated over the field monitoring period should be considered conservative values. During more normal rainfall periods it can be predicted that drainage rates and runoff capture performance would be slightly higher.

4. Stormwater Runoff

Prior to the front yard makeover renovations, downspouts that conveyed stormwater runoff from the roofs of 18 and 20 Wheatsheaf Street were directed to front and sideyard lawn areas (i.e. simple downspout disconnection to lawn) which drained to a street catchbasin by overland flow. The conventional asphalt driveway at 20 Wheatsheaf Street drained directly to a street catchbasin by overland flow.

Rain Garden

Renovations that were part of the front yard makeover included installation of a 377 litre (L) capacity rain barrel that overflows to a rain garden with a 5 square metre (m^2) surface footprint and excavation depth of 0.45 metres (Figure 3) to which drainage from a total roof area of 63 m^2 was directed. The design objective for the rain garden was to be capable of fully capturing runoff from the roof drainage area that would result from a 15 mm rainfall event, assuming 10% loss of rainfall to evaporation and that the rain garden is fully drained at the onset of the storm. In this region, approximately 60% of average annual rainfall depth occurs as storm events 15 mm in depth or less (TRCA, 2013).

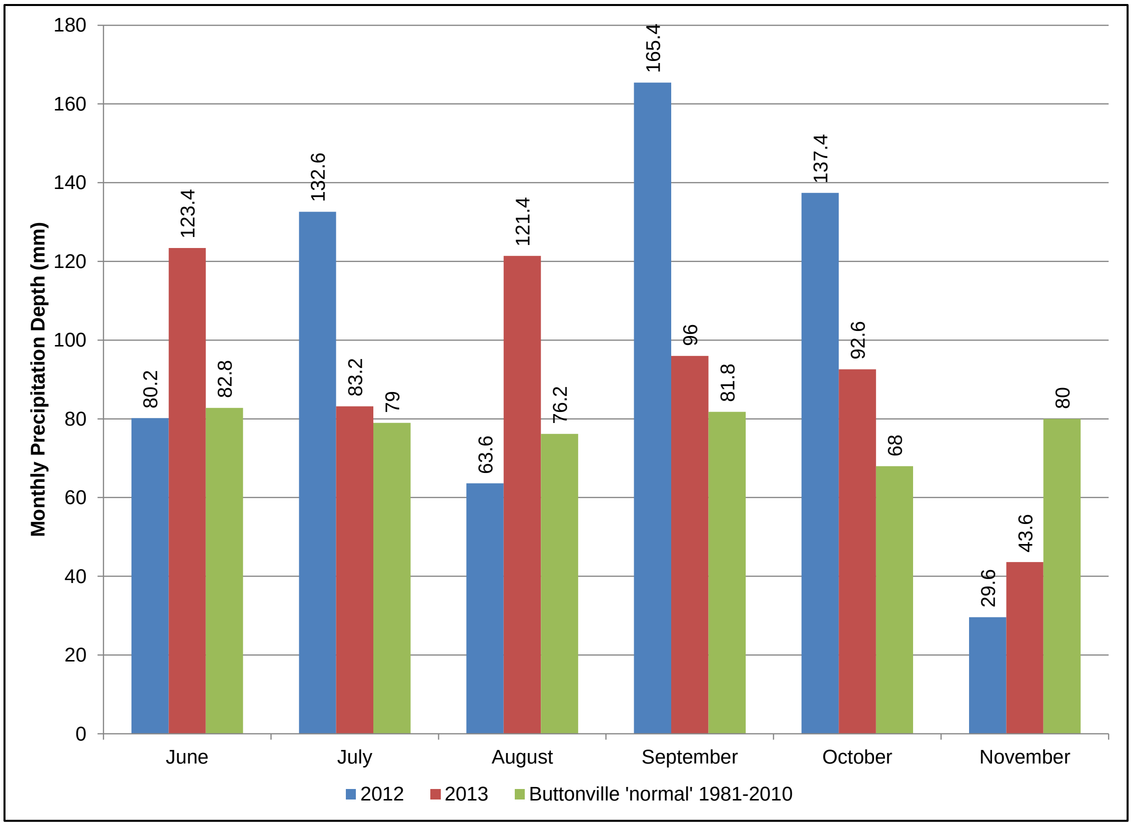

Figure 2: Comparison of Observed Monthly Rainfall Totals with 30 Year Climate Normals

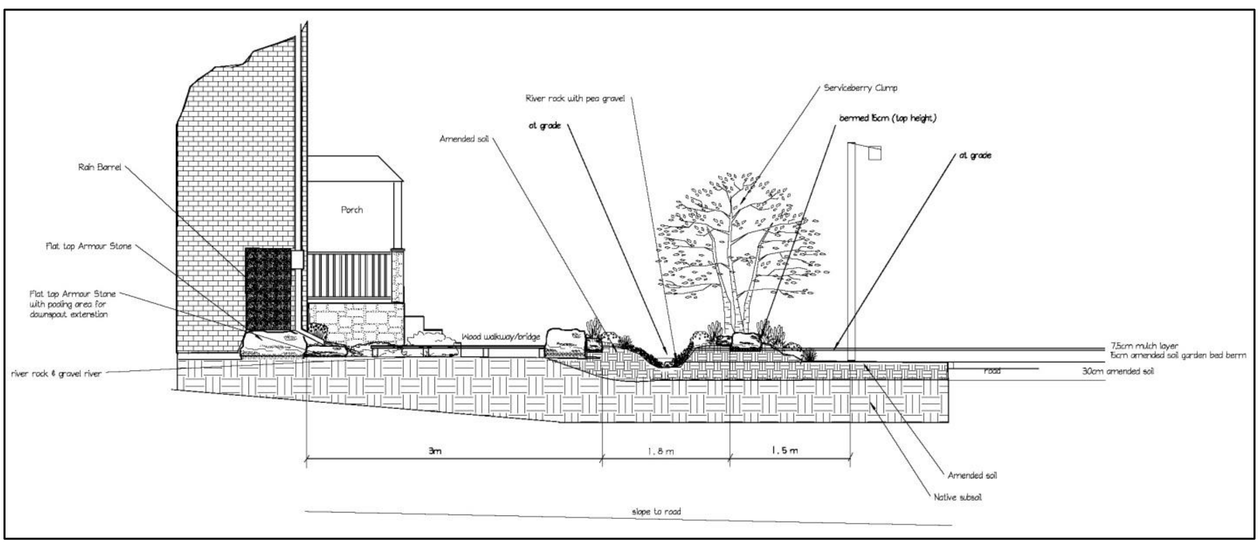

Figure 3: Design drawing of the rain garden

Runoff capture performance of the rain garden over the post-renovation monitoring period is illustrated in Figure 4 which describes the frequency of rainfall events that caused the rain garden to overflow by event depth ranges. Through continuous field monitoring of water level it was observed that the rain garden was capable of fully capturing runoff from rain events up to 13.2 mm depth on a fairly consistent basis. Over the monitoring period, 4 of the 6 rainfall events (i.e. 66%) that were between 10.8 and 13.2 mm in depth produced no overflow. During the majority of rainfall events of 13.4 mm depth or greater, the rain garden was observed to fill to capacity and produce some overflow (Figure 4). Overflow was observed during 27% of the 114 rain events captured through field monitoring.

In this region approximately 54% of average annual rainfall (626 mm) occurs as storm events 13.2 mm in depth or less (TRCA, 2013). Assuming that 90% of rain falling on the roof area generates runoff (i.e. 10% loss to evaporation), it can be estimated that in an average year, the rain garden reduces roof runoff by a minimum of 19 cubic metres (m^3), which is equivalent to 19,000 L or about 120 bath tubs full of water. This is a very conservative estimate considering that the rain garden captures and infiltrates a portion of rain events greater than 13.2 mm in depth as well. The main reason for not achieving the design objective of fully capturing runoff from storm events up to 15 mm in depth is because the rain garden was not fully drained at the onset of most storm events greater than 13.2 mm in depth that occurred over the monitoring period.

Runoff capture performance could be improved by increasing the surface ponding area and depth. Increasing the use of rainwater stored in the rain barrel or routinely draining it to the rain garden during dry periods between storm events would also have increased the runoff capture performance.

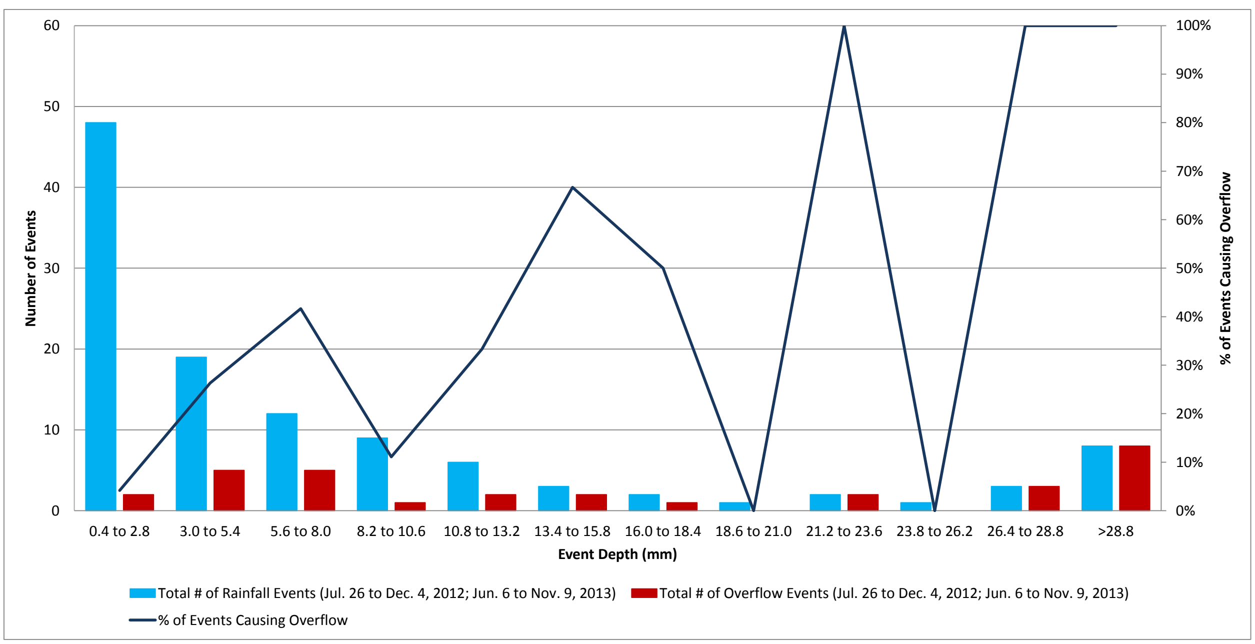

Figure 4: Rain garden frequency of overflow events by rainfall event depth range

Over the monitoring period, water ponded on the surface of the rain garden was observed to fully drain within 12 hours which is well below the recommended guideline of 24 hours (CVC & TRCA, 2010) which ensures the practice will not provide breeding habitat for mosquitos. The average infiltration rate observed over a full surface ponding drainage event was 4.0 mm/h. Observed infiltration rates varied considerably (standard deviation of 1.4) with rates showing a decreasing trend during lengthy periods of wet weather. Drainage rate of the rain garden slowed considerably over the very wet fall of

2012 when rainfall depth was twice (i.e. double) the 30 year climate normal value. Drainage rates during this period likely represent saturated or nearly saturated groundwater flow conditions whereas the higher rates observed during drier periods represent unsaturated flow conditions. With the return of more normal rainfall patterns during July 2013 it was observed that the rain garden drained at rates very similar to those observed in August 2012, when rainfall depths were close to climate normal values.

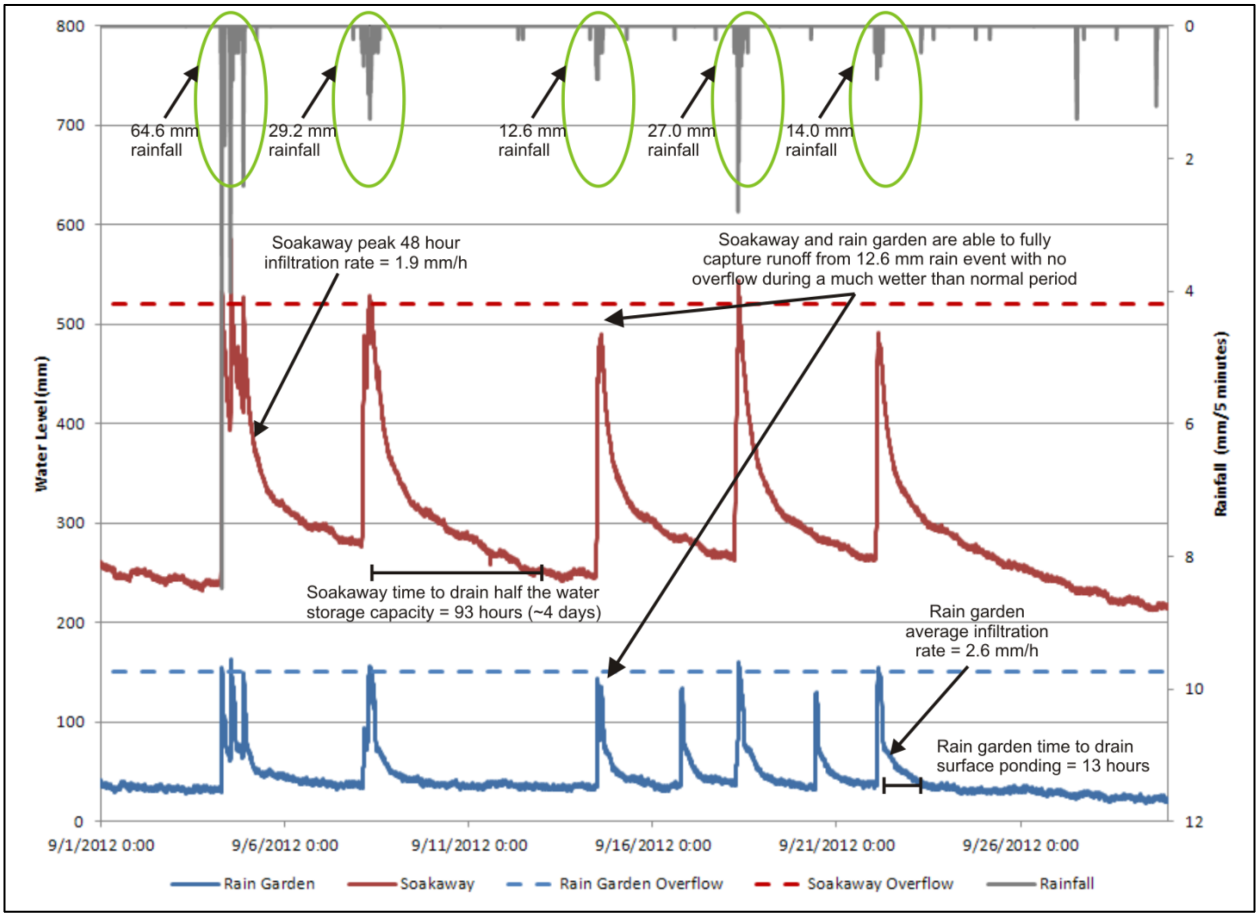

Figure 5: Hydrograph of BMP water levels and rainfall over the month of September 2012

Sideyard Soakaway

Another stormwater management related renovation that was part of the front yard makeover was installation of a soakaway in the shared sideyard area between 18 and 20 Wheatsheaf Street (Figure 6). The soakaway has a 1.4 m^2 surface footprint, an excavation depth of 0.55 metres and includes two Aquablox® D-Raintank® rainwater storage chambers (67 x 40 x 45 cm) wrapped in geotextile filter fabric and surrounded by 20 mm diameter clear stone (Figure 6). The combined water storage capacity of soakaway, including the two Aquablox® chambers (0.24 m^3), the surrounding clear stone gravel (0.21 m^3) and the compost amended topsoil upgradient from the soakaway excavation (0.22 m^3) is approximately 0.67 m^3. A total roof area of 130 m^2 drains to the sideyard area where the soakway is installed.

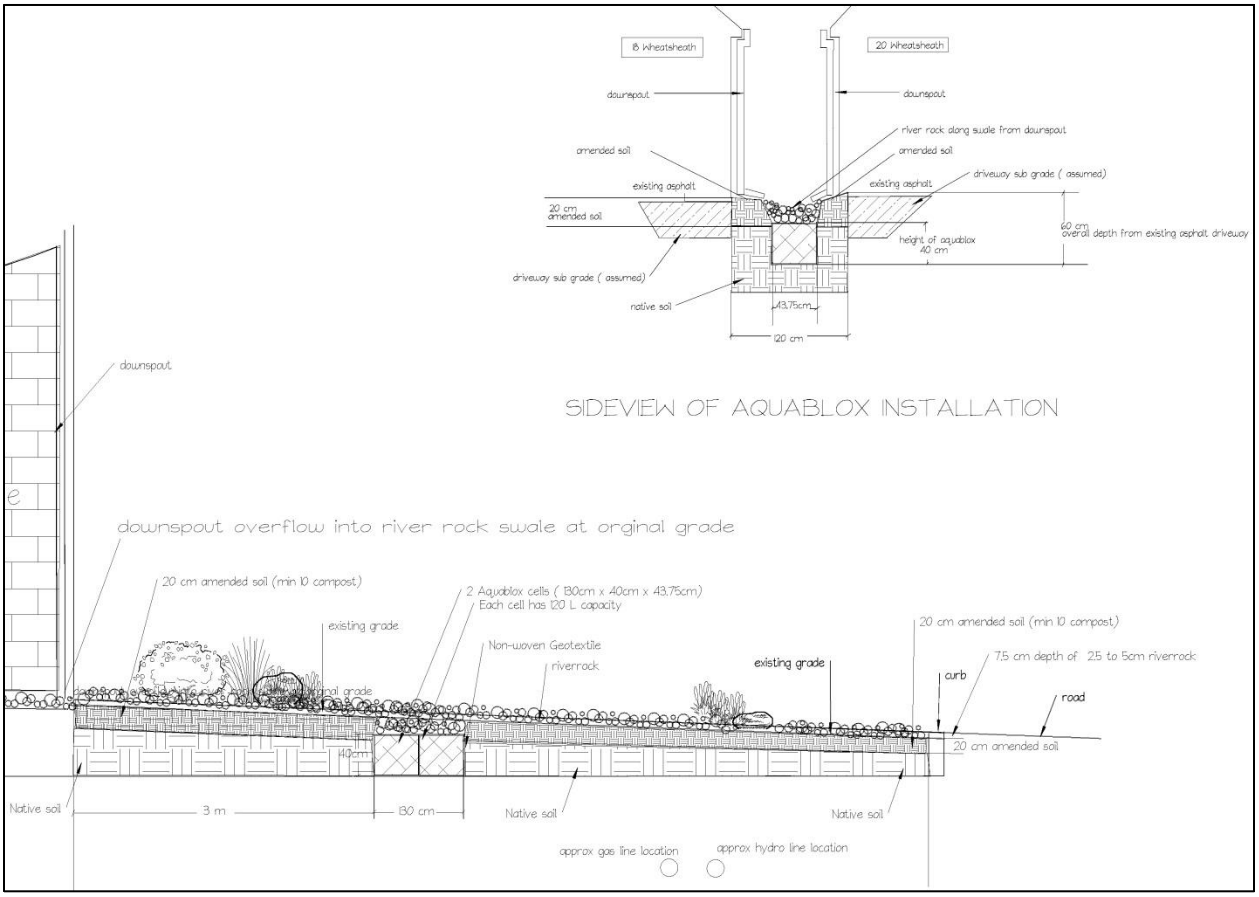

Figure 6: Design of the sideyard soakaway

Runoff capture performance of the sideyard soakaway over the post-renovation monitoring period is illustrated in Figure 7. By continuous field monitoring of water level in the full depth of the soakaway it was observed that, like the rain garden, it was capable of fully capturing runoff from rain events up to 13.2 mm depth on a fairly consistent basis. Over the monitoring period, 4 of the 6 rainfall events (i.e. 66%) that were between 10.8 and 13.2 mm in depth produced no overflow. During the majority of rainfall events of 13.4 mm depth or greater, the soakaway was observed to fill to capacity and produce some overflow (Figure 7). Overflow was observed during 25% of the 114 rain events captured through field monitoring.

In this region approximately 54% of average annual rainfall (626 mm) occurs as storm events 13.2 mm in depth or less (TRCA, 2013). Assuming that 90% of rain falling on the roof area generates runoff (i.e. 10% loss to evaporation), it can be estimated that in an average year, the soakaway reduces roof runoff by a minimum of 40 cubic metres (m^3), which is equivalent to 40,000 L or about 250 bath tubs full of water. This is a very conservative estimate considering that the soakaway captures and infiltrates a portion of rain events greater than 13.2 mm in depth as well.

Runoff capture performance of the soakaway could be further improved by increasing the surface footprint or depth of the excavation and the number of Aquablox® D-Raintank® rainwater storage chambers installed.

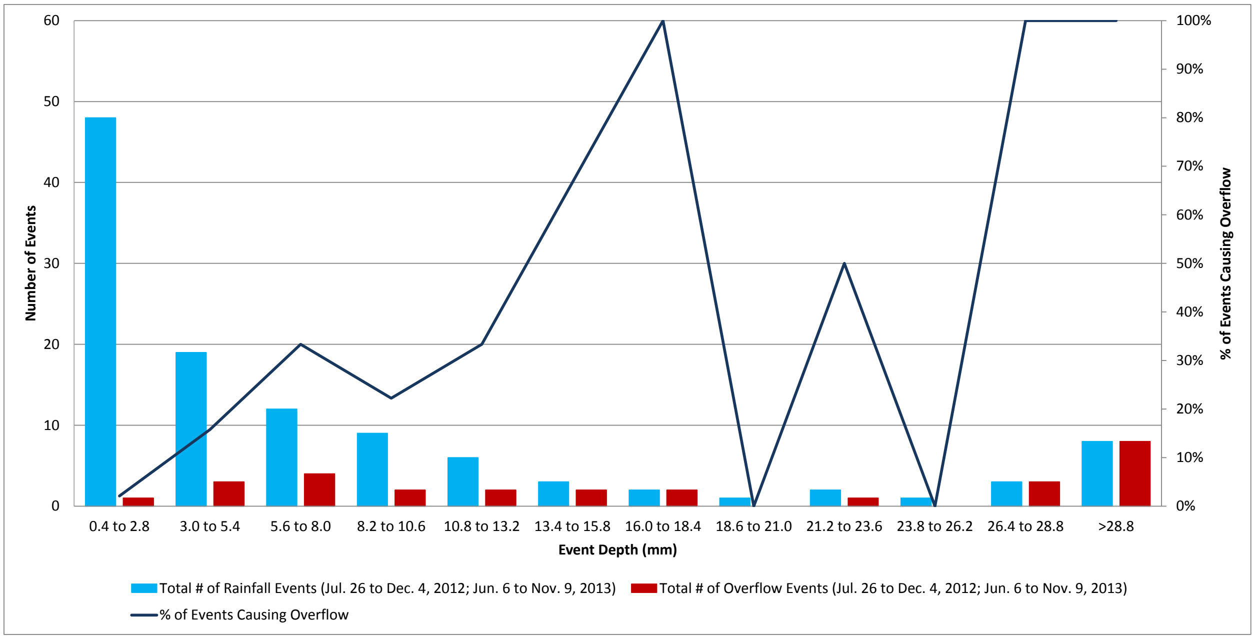

Figure 7: Sideyard soakaway frequency of overflow events by rainfall event depth range

It is important to note that the sideyard soakaway never fully drained and was at least half full of water at the onset of most storm events over the monitoring period. This is due to the relatively slow rate at which it drains (Table 1) and because drainage rates decrease exponentially as hydraulic head (i.e. depth of water) in the soakaway decreases (Figure 8). Once filled to capacity, it takes in the order of 16 hours to drain one third of the water storage capacity, which occurs at an average rate of about 4.1 mm/h over this time period. It takes another 87 hours for the soakaway to drain to the point of being half full (103 hours or 4.3 days in total), which occurs at an average rate of only 0.4 mm/h. When water levels in the soakaway are below the half full point, the rate of drainage is very slow, in the order of 0.2 mm/h (Figure 8) or half the rate observed when it is between two thirds and half full of water. Over a typical 48 hour period following the soakaway being full only 40% of the water storage capacity drains and drainage occurs at an average rate of 1.6 mm/h over this time period (Table 1).

While there will almost always be some water stored in the soakaway, there is very little risk that it will provide mosquito breeding habitat because the water is stored underground and is inaccessible to flying insects. The only connection between the atmosphere and the water stored in the soakaway is the monitoring well, which is sealed with a cap. It is very important that the cap of the monitoring well be secured in place when the well is not being used, to prevent mosquitos from accessing the standing water. There is also very little risk that the water stored in the soakaway will become anoxic and produce bad odors. Water entering the storage space of the soakaway has been filtered through topsoil and filter fabric and should contain little or no sediment and natural debris. Organic material should not accumulate inside the soakaway and anoxic conditions and bad odors, that could occur if organic material accumulated and decomposed without oxygen, should not be a problem.

These drainage characteristics are not surprising, considering the soakaway is installed in fine-textured, sandy clay glacial till subsoil. A typical sandy clay soil can be predicted to have a saturated hydraulic conductivity of about 1.0 mm/h with the range being between 0.2 to 3.0 mm/h (Rawls, 1998). The exponential decrease in drainage rate that was observed as water level in the soakaway declined is also not surprising. As water level in the practice declines there is less pressure forcing water into the underlying subsoil and the total area over which infiltration is occurring also steadily decreases (i.e. surface area of the sides of the soakaway). In this case, drainage rates were much higher when the practice was full in part because stored water could preferentially infiltrate into the topsoil, which would have a higher saturated hydraulic conductivity than the underlying sandy clay subsoil. Once water levels in the soakaway are below the amended topsoil layer (approximately 20 cm in depth), drainage rates become entirely dictated by the hydraulic conductivity of the less permeable sandy clay subsoil.

Table 1: Sideyard Soakaway Drainage Rate Summary Statistics

Parameter	MEAN	MINIMUM	MAXIMUM	NUMBER OF OBSERVATIONS
Infiltration Rate - Full to 2/3 Full (mm/h)	4.1	2.4	7.0	21
Drainage Time - Full to 2/3 Full (h)	16.5	8.2	26.7	21
Infiltration Rate- 2/3 to 1/2 Full (mm/h)	0.4	0.3	0.6	14
Drainage Time - 2/3 to1/2 Full (h)	87.3	63.0	116.0	14
Infiltration Rate – Peak 48 Hour[1] (mm/h)	1.6	1.4	1.9	13

1. Peak 48 hour infiltration rate is the rate observed over a 48 hour drainage period beginning when the practice is filled to capacity with water and rainfall has stopped, which characterizes the highest drainage rate the practice is capable of over 48 hours.

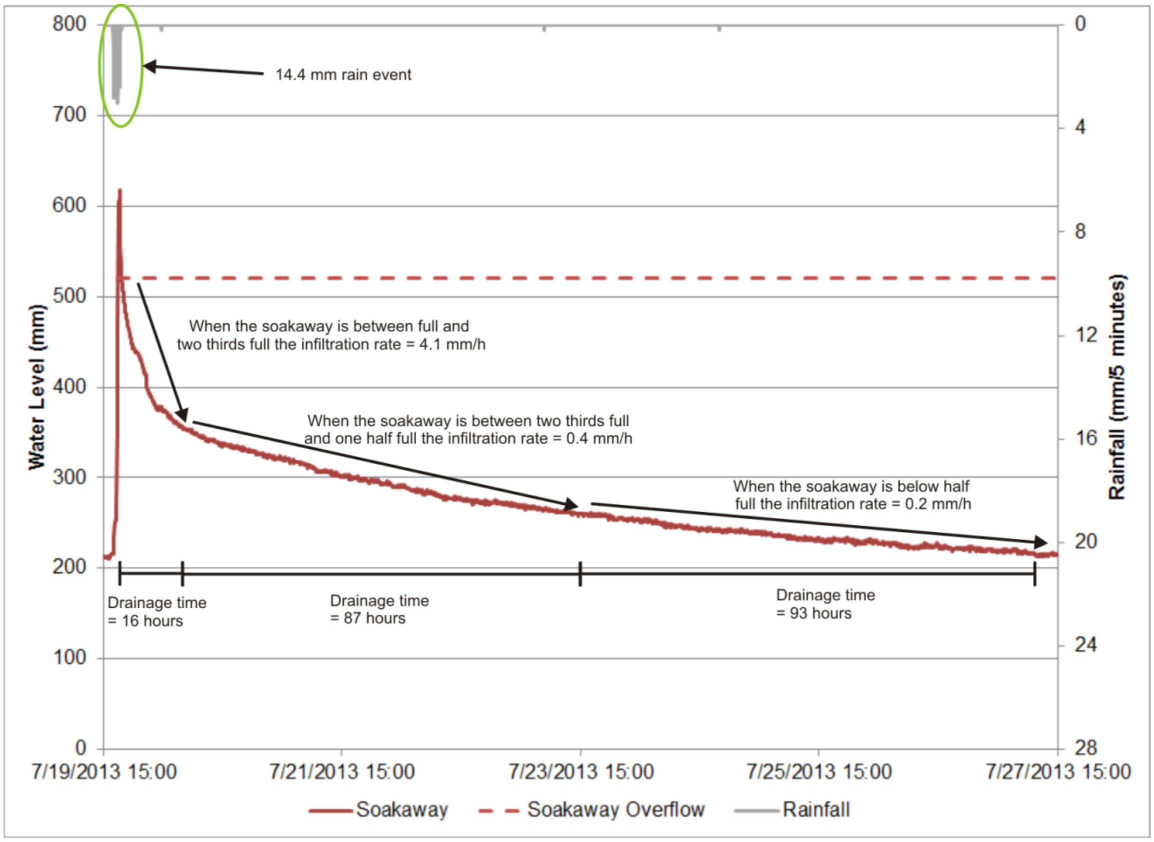

Figure 8: Typical pattern of variation in drainage rate for the sideyard soakaway

Considering these drainage characteristics, it is recommended that other soakaways that are implemented in the neighbourhood should be installed deeper where feasible. This could involve stacking two rainwater storage chambers on top of one another instead of side-by-side, which would help to increase hydraulic head and thereby, increase drainage rate and improve runoff capture performance.

5. Rainwater Use

A total of only 2.63 m^3 of rainwater was used over the monitoring period, indicating that the 377 litre (L) rain barrel was rarely drained between storm events (a total of only 7 times) and mainly used to occasionally fill watering cans. Assuming a water utility rate of $2.9074 per m^3 (Town of Richmond Hill, 2014), a total of $7.65 in water utility bill saving was achieved over the monitoring period. It is noted that the wetter than average conditions, coupled with the purposeful design objective of water efficient plants, reduced the need for garden watering.

It is postulated that if a means of using rainwater from the barrels that was more convenient than filling watering cans had been put in place (e.g. soaker hose draining to the garden or lawn, submersible pump and pressure sprayer) more rainwater may have been used, resulting in greater water utility bill savings and improved runoff capture performance of the rain garden.

6. Conclusions

In conclusion, both the rain garden and sideyard soakaway features are effective in fully capturing runoff from rain events up to 13.2 mm in depth which represents 54% of average annual rainfall depth in this area. This result is conservative due to the wetter than average conditions that occurred during the monitoring period.

The rain garden's design provides desired drainage times and storage capacity. Its effectiveness could be further enhanced if the surface ponding area was larger or deeper. The sideyard soakaway is very effective at reducing roof runoff and is well suited for the relatively underutilized spaces between driveways. Future soakaway applications in this neighbourhood or on similar, fine-textured glacial till soil, should be installed deeper (i.e. stacked on top of one another instead of beside one another) to increase drainage rates and improve runoff capture performance.

The rain barrel provided limited runoff reduction and municipal water conservation benefits, due to limited use, coupled with the low demand for landscape watering that occurred over the much wetter than normal monitoring period. The addition of more convenient means of using the rainwater and draining the rain barrel between storm events, such as a submersible pump and pressure sprayer or soaker hose attachment, could increase rainwater use, conserve more municipal water and further reduce lot runoff.

7. References

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