Hydrologic Assessment of LID Honda Campus, Markham, ON

TECHNICAL BRIEF

Low Impact Development Series

The 17.9 hectare Honda Canada Campus employs a number of innovative Low Impact Development (LID) technologies to manage stormwater runoff, improve water quality, reduce potable water use and achieve other positive environmental objectives. When it was constructed in 2010, the project was the largest of its type in Ontario to rely solely on landscape-based stormwater management techniques, including a system of biofilters to treat runoff from over ½ million square feet of building area and a parking area accommodating over 1000 vehicles.

Often, over 70% of commercial and industrial properties are covered by impervious pavements, sidewalks and roofs. LID practices help reduce the downstream impacts of this impervious cover by enhancing the natural infiltration and evapotranspiration functions of the landscape that were lost during development.

This study evaluates the effectiveness of meeting provincial and municipal stormwater management and flood control criteria on a commercial property by using a combination of decentralized Low Impact Development (LID) practices as an alternative to sole reliance on centralized stormwater detention facilities. Practices incorporated into the design include biofilters, permeable pavements, swales and rainwater re-use for landscape irrigation. Based on a combination of monitoring and modeling, results show that, relative to a conventional stormwater approach without LID, runoff was reduced over the study period by between 30 and 35% for the entire site, and by between 58 and 62% in the catchment with a higher density of LID practices. Peak flows were also reduced by 65 to 79%. In the Northeast catchment, 20% of rainfall harvested from the roof was stored and reused for irrigation during the summer months. This reuse volume represented 6% of total site rainfall over 8 months. A hydrologic model calibrated using monitored data showed that the stormwater management system met the design objective of providing quantity control for the post development 100 year storm.

INTRODUCTION

A growing number of property owners and developers are choosing to use LID approaches to manage stormwater and mitigate runoff impacts on downstream infrastructure, watercourses and aquatic communities. These approaches offer unique aesthetic benefits that can improve employee satisfaction and generate significant savings over conventional stormwater management techniques, particularly if they replace or reduce the need for end-of-pipe detention facilities.

This study evaluates the hydrologic effectiveness of low impact development (LID) practices applied across a large commercial site owned by Honda Canada (Figure 1). The monitoring and modelling assessment focussed primarily on runoff rates and volumes, in recognition that the key benefits of LID are largely achieved though their ability to reduce the volume of stormwater runoff by means of detention, reuse, infiltration and evapotranspiration. Challenges and costs associated with adopting this innovative approach to stormwater management are also discussed. The purpose of the project was to assess actual performance relative to design objectives and share information and experiences that other property owners considering a similar approach to runoff management can use to improve their projects.

Figure 1. From left to right: Drainage swale and fitness path, biofilter stone trench, permeable surfaces in outdoor eating areas, rainwater cistern, native plantings , vegetated biofilter

STUDY SITE

The Honda Campus is located at 180 Honda Boulevard, Markham, Ontario and incorporates a number of low impact development stormwater management practices, including an extensive system of biofilters that drain a 1000 car parking lot and other paved surfaces within the development (Figure 2). The LEED Gold certified building and site reflect Honda's vision for sustainability and a clean, minimalist aesthetic.

Runoff from the 17.9 ha Honda Canada Campus drains to three outlets (Figure2 and Table 1). The northeast catchment (5.4 ha) includes a 636 m^3 rainwater cistern that receives runoff from the 2.6 hectare roof of the Production Distribution Centre. The cistern supplies rainwater for automated irrigation of the adjacent field and landscaped areas. Overflows from the cistern and adjacent biofilters are directed to a small dry pond that temporarily stores runoff prior to releasing it to the municipal sewer. Runoff from the service road north of the building drains to stone-filled infiltration trenches surfaced with planting beds containing tall grasses, herbaceous plants and trees (referred to here as biofilters). The stone biofilter trenches are typically 2 m deep and 2 m wide at the bottom, drained by a 200 mm diameter perforated pipe raised above the native soil by approximately 0.15 m (Figure 3).

The southeast (6.3 ha) and west (6.2 ha) catchment outlets drain runoff from the parking lot, the remaining roofs and rear loading areas (Table 1). Permeable pavers in the forecourt roundabout and parking lot, as well as sheet drainage to landscaped areas, provide

Table 1. Sub-catchment land cover areas and runoff coefficients as provided in the original design brief.

Sub-Catchment	Area (ha.)				Percent Impervious	Runoff Coefficient
	Total	Grass	Building	Pavement		
West	6.2	2.9	1.2	2.0	53	0.57
Northeast	5.4	2.5	2.6	0.4	55	0.58
Southeast	6.3	1.1	0.0	5.2	83	0.78
Total Area	17.9	6.4	3.8	7.6	64	0.65

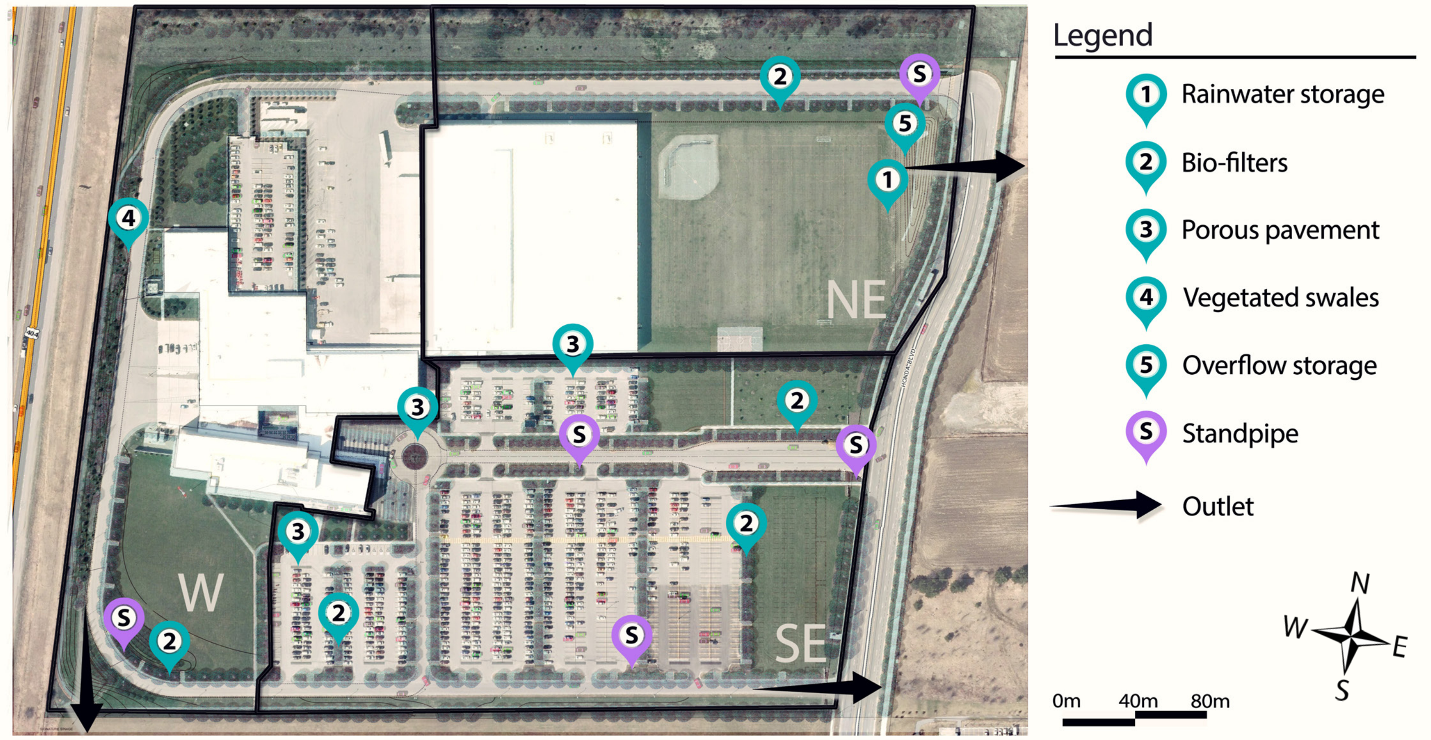

Figure 2. Locations of LID features within the Honda Canada Head Office study site in Markham, Ontario. Water levels were monitored at the standpipe locations and flow rates were measured at the outlets to the northeast (NE), southeast (SE) and west (W) catchments.

some infiltration, but the majority of runoff is directed to the vegetated biofilters along the roads and within the parking lot.

Table 2 expresses infiltration areas as a ratio of impervious cover for each catchment. The southeast catchment has the largest impervious area but the lowest ratio of impervious cover to infiltration area (Table 2). The west and northeast have similar impervious-to-infiltration area ratios, but the northeast catchment includes the added benefit of the cistern, which is connected to an automated irrigation system. This helps to maintain healthy vegetation while reducing water bills and increasing evapotranspiration from the site.

Native soils consist of low permeability silty clay glacial till that are common within the Greater Toronto Area. Studies at other sites with similar soil texture have shown that underground infiltration practices typically drain at rates between 1 and 5 mm/h on fine-textured glacial till soil (Young et al, 2013). These rates are higher than native subsoil infiltration rates under natural conditions because LID installations enhance drainage through evapotranspiration and the built-up of hydraulic head through temporary water storage.

Table 2. Summary of sub-catchment pervious and impervious areas.

Parameter	Sub-catchments			Total Area
	West	Northeast	Southeast	
Impervious area	32,710	29,560	52,349	114,619
Infiltration area (m^2)	940	977	6,272	8,189
Cistern re-use volume capacity (m^3)		636		636
Ratio of infiltration area to impervious area	1:35	1:30	1:8	1:14

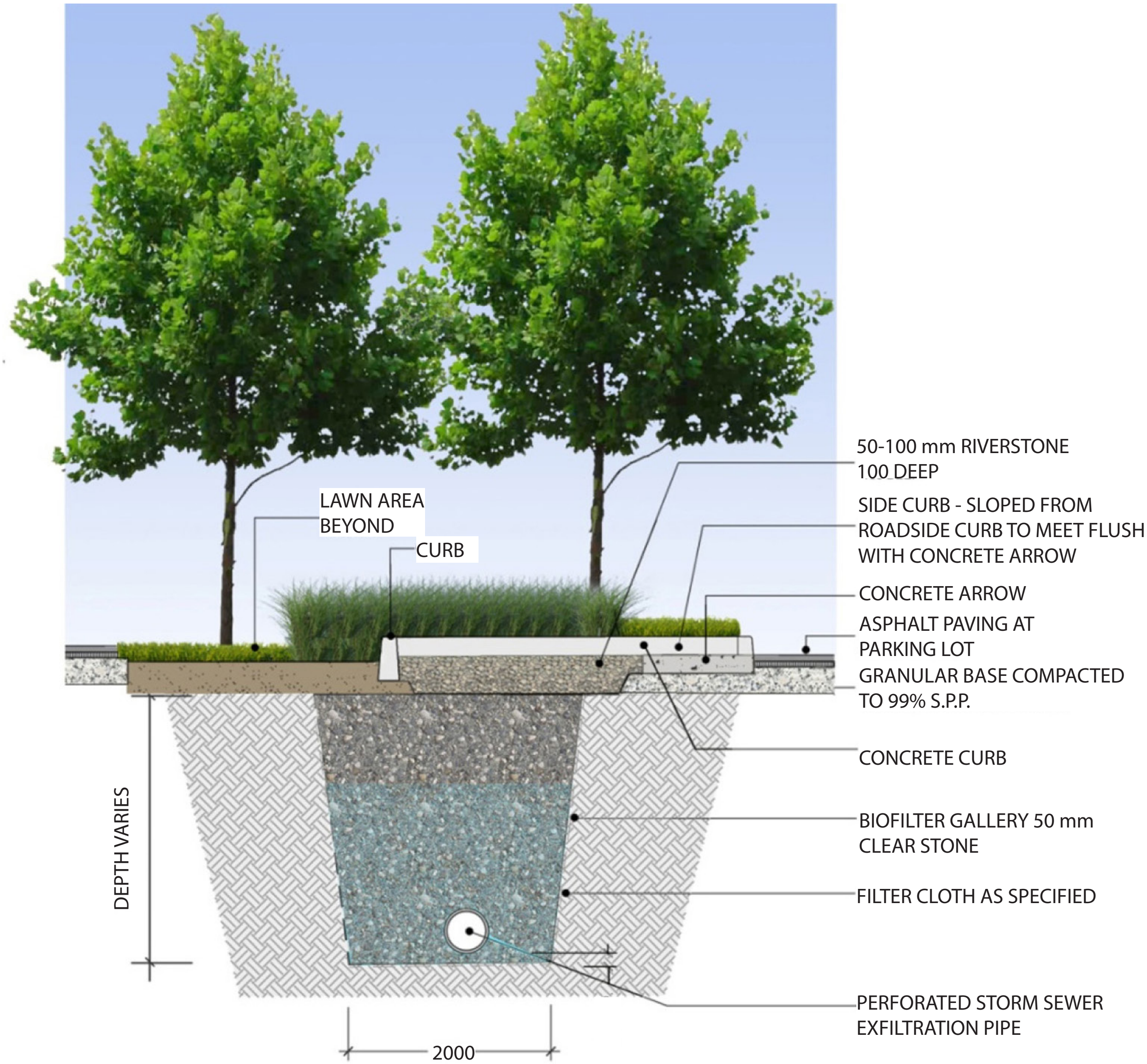

Figure 3. Cross section of a biofilter. (Image courtesy of Schollen & Company Inc.)

APPROACH

The methods used to evaluate the stormwater management benefits of the innovative approach used on this site included a combination of field monitoring and hydrologic modelling. Monitoring of the site occurred between June 2012 to August 2013. Flow rates and volumes were monitored using area-velocity probes at the three outlets. Water levels in the biofilters were monitored using pressure transducers in standpipes located in each of the catchments (Figure 2). A tipping bucket rain gauge was installed on-site to measure rainfall. A second back-up rain gauge was located within 10 km of the site.

Modelling was conducted using SWMM software, developed by the US Environmental Protection Agency. Three models were created for this task, and are summarized in an earlier paper (Tiveron, 2014). Each of the models, of varying complexity, was analyzed against observed data to provide improved guidance on the efficacy of different LID modelling approaches. The models also provided the basis for assessment of how the stormwater management system would function for events larger than those observed during the monitoring period, and allowed performance to be compared to the original hydrologic targets for the site. These site targets included a unit release rate of 180 L/s/ha and 100 year post development flood control (SKA, 2008).

Table 3. Summary of results from Method 1 (hydrologic model) and Method 2 (calculated from runoff coefficients) for the investigated sub-catchments.

Parameter	Sub-catchments			Total Area
	West	Northeast	Southeast	
Method 1: Hydrologic Model				
No LID total runoff volume (m^3)	27,894	25,008	37,564	90,465
Observed runoff volume (m^3)	28,443	19,002	15,723	63,168
Runoff Reduction (%)	-2	24	58	30
Method 2: Calculated from runoff coefficients				
No LID total runoff volume (m^3)	29,580	26,459	41,379	97,418
Observed runoff volume (m^3)	28,443	19,002	15,723	63,168
Runoff Reduction (%)	4	28	62	35

Analysis of monitoring data was conducted for each rainfall event between 9 July to 12 November 2012 and 8 April to 8 July 2013. Winter data (December to March) were not included in the analysis. The performance of LIDs was assessed relative to a conventional catchment without stormwater management by comparing a 'no LID' control scenario with monitored data. The 'no LID' flow volumes were estimated using two methods. The first method determined runoff rates and volumes from a version of the calibrated SWMM model without the LID features (referred to as the calibrated model with no LID). The second method was simpler, and did not use the hydrologic model. Instead, estimates of storm event volumes were calculated using the runoff coefficients provided in the original design report for each of the catchments. Both 'no LID' scenarios maintained the same surface features currently on the site, but runoff was routed directly to sewers rather than to the orifice controlled perforated underdrains. Using these methods, event based runoff reduction rates were estimated for each of the three catchments, and for the site as a whole.

FINDINGS

Comparison of monitored flow and simulated flow without LID controls showed that the LID features reduced outflow volumes from the site by 30 to 35% during the eight month study period through a combination of infiltration, evapotranspiration and water reuse. Runoff reductions varied across the site, ranging from 58 to 62% in the southeast catchment

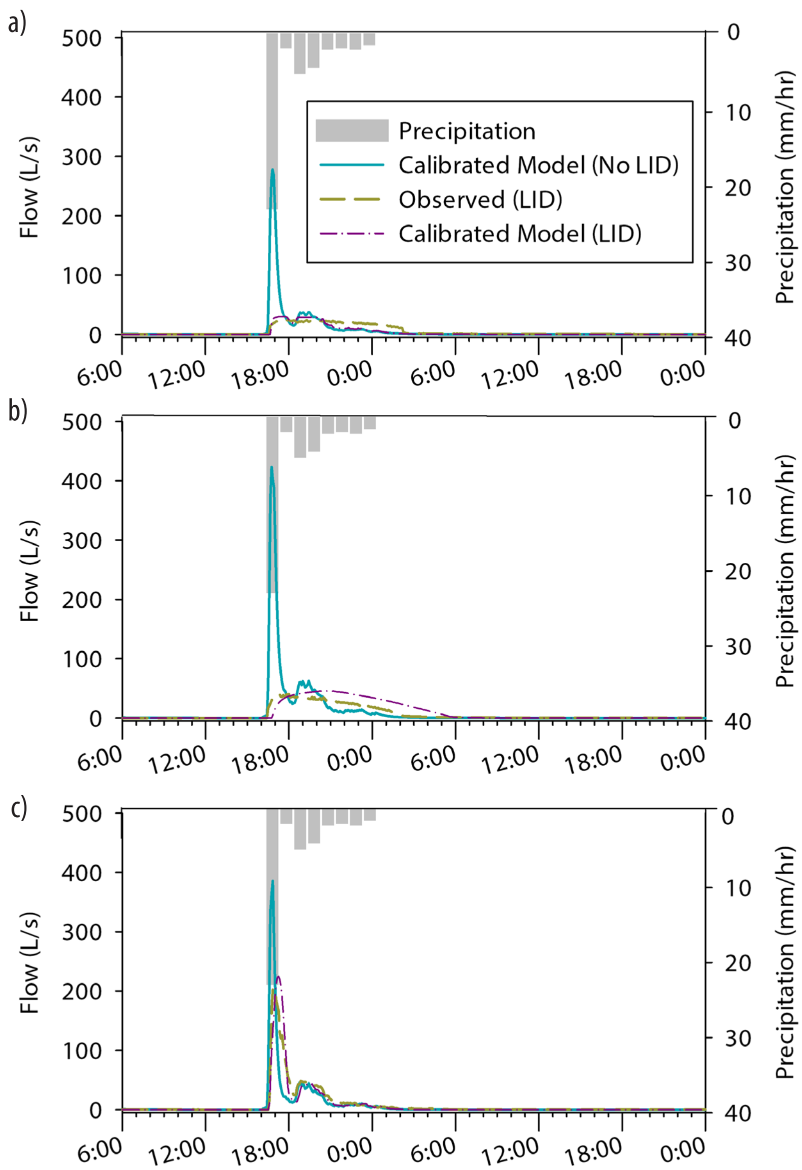

Figure 4. Event hydrographs from the a) Northeast; b) Southeast; and c) West catchments. The rain event took place on July 8-9, 2013.

to only negligible reductions in the west catchment (Table 3). These differences can be largely explained by differences in the catchment impervious cover-to-infiltration area ratios presented in Table 2. In the southeast catchment, the area available for infiltration of runoff from impervious surfaces was over 4 times that of the west catchment on a unit area basis. The northeast catchment had higher runoff reduction rates than the west catchment (Table 3), primarily due to water re-use from the 636 m^3 cistern (see discussion below). It should be noted that the calculated runoff reduction rates are likely conservative estimates of actual runoff reduction. This became evident during successive autumn rain events, when available storage for infiltration and re-use had been fully utilized, and measured runoff volumes from the NE and W catchments were slightly greater than predicted by the models without LID practices. Overall, the estimates show that the LID approaches have been effective in reducing the volume of water discharged from the site, and thereby have helped to provide cleaner and more controlled flows that are critical to protecting sensitive aquatic life in headwater streams.

Peak flow rates were significantly reduced by the LID controls and were maintained below design thresholds during the study period. This was expected as on-site post development water quantity controls are provided for the 100 year storm through orifice tubes that restrict the rate of flow to a unit release rate of no more than 180 L/s/ha (SKA, 2008). Hence, flow rates increase rapidly until the pipe capacity is reached, at which point the rate of flow levels off as water builds up in the stone trenches (see SE and NE catchments in Figure 4). Overall peak flow reductions ranged from 65 to 79 % in the West and Southeast catchments respectively (Table 4). Peak flows observed during the field monitoring period were 93, 82, and 92% less than the maximum allowable flow rates for the NE, W and SE catchments, respectively.

Approximately 20% of rainfall on the northeastern catchment was stored and reused for grounds irrigation over an eight month period. This represents 9,019 cubic meters of water, or roughly 6% of rainfall over the entire site during the same period. Most of this volume was used for irrigation from June to September

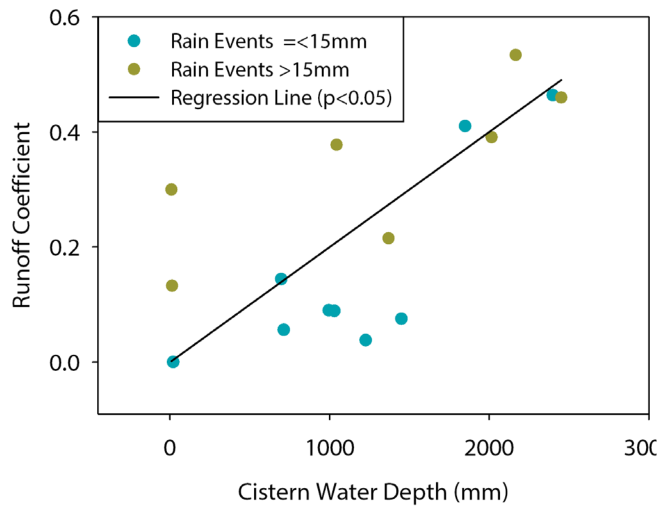

Figure 5. Relationship between the catchment runoff coefficient and rainwater cistern water levels prior to rain events.

when the lawns and vegetated areas were most in need of water. Figure 5 shows the relation between available storage in the cistern and the catchment runoff coefficient. The runoff coefficient represents the proportion of rain that is converted to runoff during storm events. As expected, higher runoff coefficients were observed during storm events that occurred when the cistern was still partially full of water (i.e. less available storage capacity), confirming that runoff from the roof is the primary source of discharge from the NE catchment. In fact, less than one third of the runoff reduced over the study period in the NE catchment could be attributed to the biofilters. Exceptions occur during large events when cistern storage represents a small component of total runoff volumes.

Water budget analysis showed that the LID practices dramatically altered the proportion of water allocated to evapotranspiration and runoff, without significantly changing land cover or buildable area. This is shown in Figure 6, where the outer circle represents land cover, and the inner circle represents the water budget. As discussed earlier, the proportion of water discharged from the site as runoff declined significantly;

Table 4. Summary of flow results from observed values and no LID model from July 9-November 12, 2012 and April 8-July 8, 2013.

Sub-catchments	Maximum allowable flow rates (m^3/s)	Peak Flows (m^3/s)		Peak flow reduction (%)
		No LID model	Observed	
West	1.10	0.59	0.20	65
Northeast	0.97	0.28	0.07	74
Southeast	1.14	0.42	0.09	79

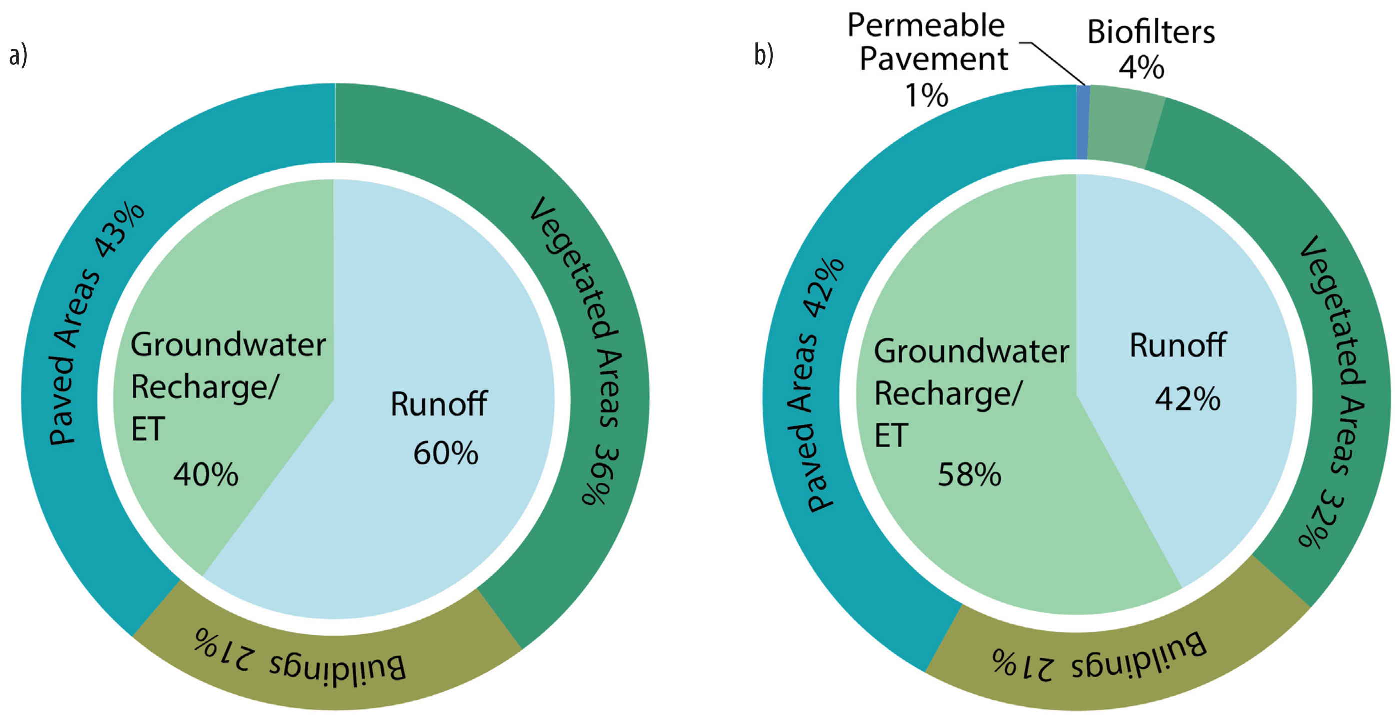

Figure 6. Study site land cover (outer ring) and water balance (inner ring) for a) no LID model and b) observed values.

hence more water was apportioned to groundwater recharge and evapotranspiration. Approximately 6% of total precipitation was re-used for irrigation, most of which would have been returned to the atmosphere as evapotranspiration. These changes in the water balance occurred despite the presence of very low permeability silty clay soils, demonstrating that even under challenging conditions, substantial modifications to the water balance are achievable through the use of LID practices.

Model Simulations showed that the biofilters met the design objective of providing water quantity control for the post development 100 year storm. This was a unique feature of the stormwater management design, as LID technologies are rarely designed to provide control for flood flows. In the northeast and west catchments, there was even some underutilized biofilter storage. Scenario analysis showed that in these catchments the orifices could be further reduced by 10 – 20% to improve peak flow control and further enhance infiltration (Tiveron, 2013). Alternatively, the unused storage could be reduced by raising the perforated pipe further in the cross section. This would enhance infiltration, but peak flows under this scenario would remain unchanged. In the southeast catchment, the storage volume was fully utilized during the modeled storm, indicating that there was little room for further reductions in peak flow through orifice control.

Development and calibration of three stormwater management models for simulating LID performance and function showed that calibrations improved with increasing model complexity. Calibration with observed data was essential to accurately model the general features of LIDs (i.e., immediate routing of runoff from the surface into the storage layer) but it could not simulate intricate processes such as the exfiltration of runoff from the perforated underdrain into the storage layer. While simpler SWMM models were characterized as insufficient for design purposes, the complex model requires considerably more parameterization that may be difficult to satisfy in the design phase (Tiveron, 2013).

Implementation of new approaches rarely occurs without challenges, and this site was no exception. For instance, the permeable pavers in the parking lot were designed to include underdrains to prevent frost damage to adjacent asphalt pavements, but the underdrains were not installed as detailed on the drawings, resulting in damage that later needed to be repaired. The original drainage plan with stone filters conveying parking lot runoff into the biofilter trenches was also modified during the review process. This resulted in catchbasins being installed to convey minor system flows to the biofilters, while the stone trench filters were maintained to convey larger event surface runoff when the catchbasins surcharged. Pretreatment of runoff flowing into the stone trenches is generally considered to be preferable to direct discharge through catchbasins.

The use of LID for stormwater control was initially priced at a 10% premium to a conventional stormwater management approach, but when factoring in the value of the land where the pond would have been located, the scheme generated a 5% net savings. Besides saving on costs, the LID approach also produced a more visually appealing aesthetic and helped reduce impacts on downstream infrastructure and receiving water systems. Further savings were realized through the re-use of roof runoff for irrigation. If Honda had paid for this water, it would have cost roughly $27,643 over the June to September 2012 growing season based on the Town of Markham's water rate of $3.0649/1000 L.

CONCLUSIONS

The Honda Campus stormwater management system provides a combination of on-site water balance, water quality and flood control through various LID practices. Results showed that, relative to a no-LID modeled scenario, the infiltration and water re-use practices reduced runoff and increased evapotranspiration and groundwater recharge by between 30 and 35%. Runoff was also released more slowly with peak flows approximately 65 to 79% lower than a conventionally sewered development with the same landcover. Approximately 6% of precipitation over the entire site was re-used for grounds irrigation during the summer months.

A key feature of the stormwater management plan was the provision of flood control for storms up to the 100 year return period event. Modelling showed that there was more than enough storage within the biofilter trenches to meet this requirement. In two of the three catchments, flow rates could have been further restricted to slow the rate of stormwater release while still providing adequate active storage for flood control. This could be achieved by reducing the size of the outlet orifice. Alternatively the perforated pipe could have been raised further in the cross section to provide a larger sump for infiltration. This would have maintained existing peak flows but provided greater groundwater recharge and runoff reduction benefits.

REFERENCES

Sabourin Kimble and Associates Ltd (2008) Stormwater Management Design Brief - Honda Canada Inc. Lands. Markham, Ontario.
Tiveron, Thomas (2013) Modelling Guidance for Low Impact Development Practices. Master of Applied Science, Ryerson University.
Young D, Van Seters T, Graham C (2013) Evaluation of Underground Stormwater Infiltration Systems. TRCA's Sustainable Technologies Evaluation Program, Toronto.

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