Sustainable Technologies
EVALUATION PROGRAM

TECHNICAL BRIEF

Performance Evaluation of a High Rate Treatment Bioretention Filter

This study evaluates a proprietary bioretention filtration system (Filterra®) that treats stormwater runoff from impervious surface areas over 100 times larger than the footprint of the facility. The space efficient unit is designed to be installed as part of a traditional curb and gutter road right of way design and is well suited to retrofit applications. It can function either as a standalone treatment device or as pre-treatment to a downstream detention basin or infiltration system.

Results from a two year study of the system by STEP show low Total Suspended Solids (TSS) effluent concentrations (median of 8.7 mg/L, n=22) and statistically significant reductions of TSS, total phosphorus lead, iron copper and zinc. Outlet concentrations of dissolved nutrients such as ortho-phosphate and total nitrogen were not statistically different than inlet concentrations. Oil and grease was also captured effectively. Unlike underground high treatment filters and sedimentation devices, the Filterra® unit is very easy and affordable to maintain, which is a clear benefit to municipalities intent on keeping maintenance costs low.

Did you know?

The Kortright Centre for Conservation, along with the onsite Earth Rangers Building, is home to many low impact development stormwater management installations. Aside from the Filterra® unit, you can find three permeable pavement sites, three bioretention areas, an infiltration trench, two green roofs and a rainwater harvesting system on the property.

In built up areas, space is often a significant constraint to the implementation of vegetated stormwater management practices such as bioretention or swales. At the same time, stormwater control is even more important in these areas, which are dominated by impervious surfaces. Solutions that can be installed under road ways or shoe horned into small spaces are attractive alternatives in these contexts, particularly when they also serve as an attractive landscape feature.

INTRODUCTION

Conventional bioretention or rain gardens require that approximately 5 – 10% of the total drainage area be set aside to accomodate their footprint. This makes them impractical in highly impervious urban environments that lack space for landscaped features. The Filterra® bioretention system demonstrates how high rate filters can help overcome this limitation by providing treatment in an area that constitutes less than 1% of the drainage area. The proprietary filter media is designed to capture and immobilize pollutants, as well as promote decomposition and biodegradation.

The Filterra® unit differs from standard bioretention in that it does not reduce runoff volumes. If volume control is deemed to be an important stormwater objective for the site, the system would need to drain to an adjacent sub-surface infiltration system such as a stormwater chamber or infiltration trench. The parallel subsurface infiltration system could be installed below roads, parking lots or landscaped surfaces to avoid conflict with other surface uses. Pre-treatment through the filter would enhance longevity of the infiltration system and reduce long term maintenance costs.

STUDY SITE AND FACILITY DESIGN

The Filterra® bioretention system was installed in January 2017 at the entrance to Earth Rangers building at Kortright in Vaughan (Figure 1). The unit is designed to capture stormwater runoff from the adjacent road and filter the water through soil media specially designed for pollutant retention. Normally the unit would be installed in a curb and gutter context, with flows draining along the curb and into the throat inlet of the system. Since a curb was not available at the test site, a 76 m long asphalt gutter was installed adjacent to a 277 m^2 section of road. Runoff from the road and asphalt gutter enters the unit through a large opening on the side (Figure 2). The unit itself is a square concrete box approximately 1.7 m in all dimensions. The inside treatment area surface is 1.2 m x 1.2 m (or 1.44 m^2). Therefore, the drainage area to the unit is roughly 96 times larger than the footprint of the facility and 192 times larger than the filter media surface area.

The surface of the system consists of a 7 cm layer of mulch over 530 cm of Imbrium's engineered biofiltration media and a 152 cm clear stone reservoir. A six inch irrigation port runs vertically through the unit connecting to the perforated underdrain which transitions to solid pipe as it leaves the unit and directs the treated runoff to an outlet. An overflow for the system is provided downstream of the inlet. During large rain events excess ponded runoff is conveyed to the small overflow catchbasin that drains to a location parallel to the normal outlet for the system.

The maximum water quality treatment flow rate for the media is 1 L/s, which corresponds to an infiltration rate of 2500 mm/h over the surface area and a surface loading rate of 42 L/min/m^2. At this infiltration rate, flows would be fully treated at rainfall intensities less than approximately 13 mm/h. Higher intensities may generate overflows.

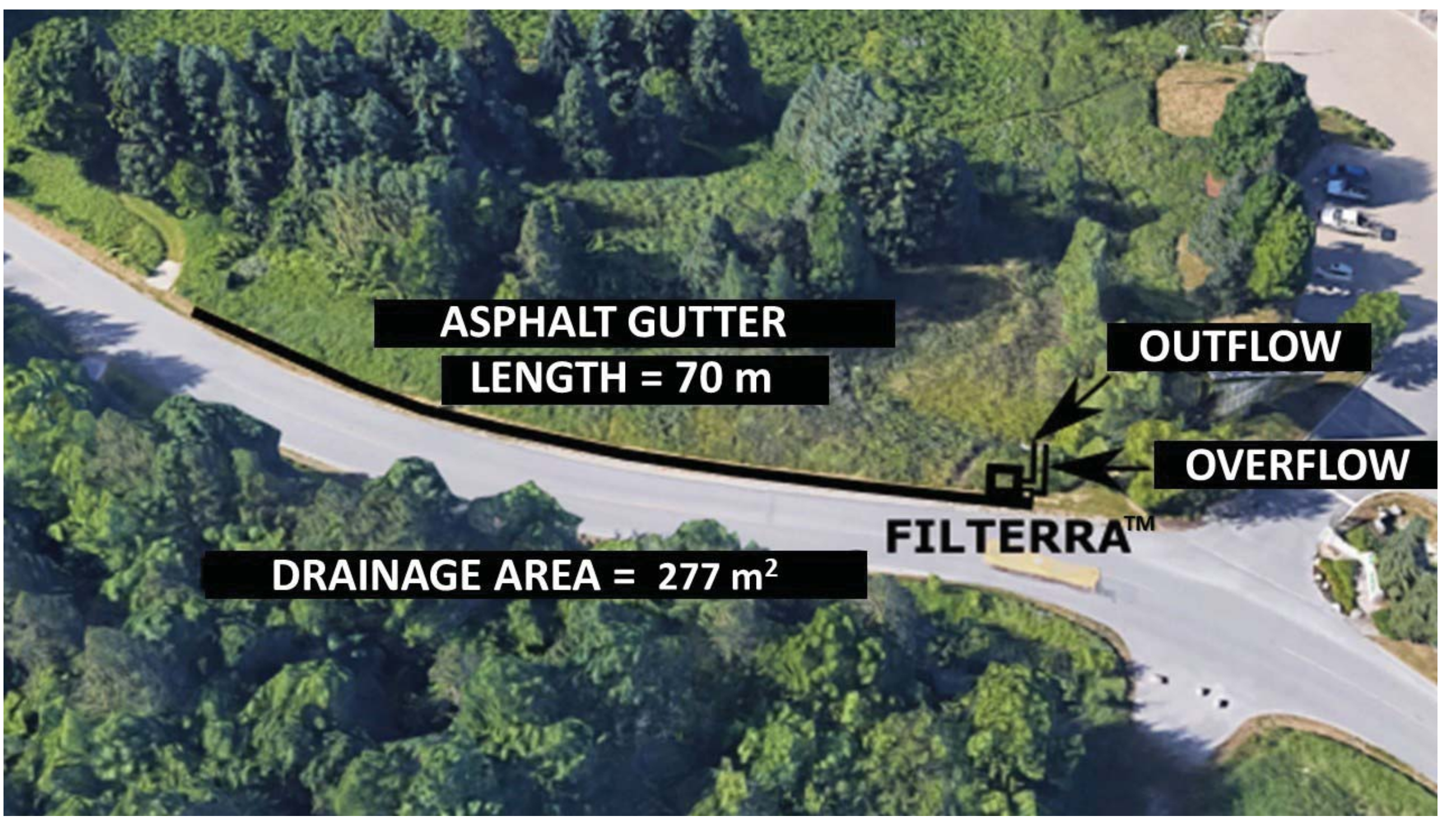

Figure 1. Location of the filtration unit at Kortright

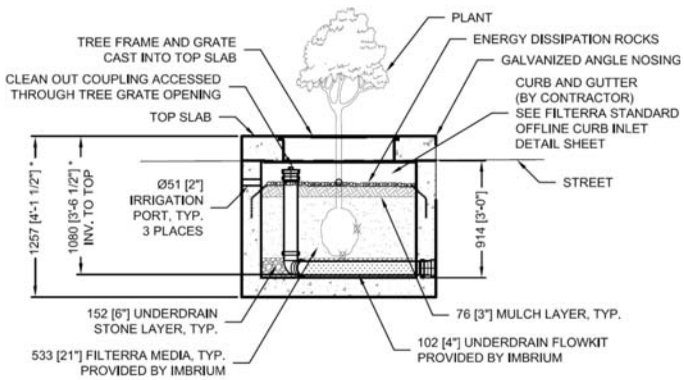

Figure 2. Cross-section of the Filterra® unit showing media layers, outlet and clean-out

Figure 3. Outlet V-notch weir box (top), service berry shrub (2nd from top), inlet gutter & throat with sampler intake and area velocity probe (bottom right), overflow measurement device (bottom left).

APPROACH

The monitoring program was conducted over a 2 year period from mid-June to the first week of November in 2017, and May to November in 2018. Variables measured included precipitation, flow and water quality.

Runoff generated from the road enters the asphalt swale as sheet flow and is directed to the inlet of the Filterra® bioretention system. An area velocity probe at the inlet was used to measure flow and water levels. Outflow from the unit was measured using a 22.5 degree V-notch weir box. Overflow events were measured with a calibrated orifice flow monitoring device downstream of the overflow catchbasin. Inflow volumes determined as the product of rain and drainage area had a close correlation to measured outflow volumes, which was expected given that there is negligible loss of volume through the system due its small size and storage capacity.

Inflow and outflow water quality samples were collected with automated samplers in a small monitoring hut adjacent to the unit. Water quality samples were proportioned according to flow by measuring out a volume of water from each discrete sample bottle proportional to the volume of flow since the previous sample. The inlet samples used water level rather than flow for proportioning as the water depth was often not sufficient to generate accurate velocities for flow measurements. The resulting volume proportioned composite samples for each event were subsequently prepared and delivered to the Ontario Ministry of the Environment Conservation and Parks (MECP) Laboratory in Etobicoke for analysis following MECP lab preparation and submission protocols. Water quality variables analyzed included solids, general chemistry, nutrients and metals.

The capacity of the Filterra® bioretention system to improve water quality was assessed through bootstrap statistical analyses of the quality of the inflow and outflow from the unit. Overflows were infrequent and small (Table 1). They occurred when the diversion structure downstream of the inlet throat was overtopped, rather than due to exceedance of bioretention media infiltration rates. The diversion structure elevation was increased in June 2018 to prevent unnecessary overflow.

Table 1. Treated and overflow volumes during paired sample events

Year	Treated (m^3)	Overflows (m^3)	Percent Treated
2017	21.1	3.6	85%
2018	41.8	0.02	100%
Total	62.8	3.6	95%

STUDY FINDINGS

Flows during high intensity events infiltrated rapidly with limited overflow. The rapid infiltration feature of the unit is evident in the hydrograph in Figure 4, which shows a close match between inflow and outflow rates and timing. The lag between inflow and outflow was approximately 6 to 9 minutes with some runoff absorbed by the media during the first flush. Overflows in 2017 (table 1) occurred due to the physical configuration of the overflow diversion channel rather than due to surface ponding. Reconfiguring the overflow channel in 2018 significantly reduced the incidence of overflows, although small, short duration overflows continued to occur when 5 minute rain intensities exceeded 2 mm (equivalent to 24 mm/h). These may have been prevented with improved flow diversion design, although data were not available to confirm this hypothesis.

Results for Total Suspended Solids (TSS) met the requirements for enhanced level performance established by Washington State for the evaluation of proprietary stormwater management devices. Washington State's TAPE program (Ecology, 2018) is widely recognized as providing the most rigorous criteria for field evaluation of stormwater devices. The TAPE criteria distinguish runoff events by influent TSS event mean concentration (EMC) for the purpose of evaluation, as follows: (i) runoff events with influent EMCs equal to or less than 20 mg/L are considered 'clean' and not included in the performance assessment; (ii) events with influent EMCs between 20 and 100 mg/L are assessed based on an effluent EMC limit of 20 mg/L, and (iii) removal efficiencies are calculated for events with influent EMCs equal to or above 100 mg/L. Data summarized in Table 2 show that the Filterra unit met the established benchmarks over the two year test program. The upper 95% confidence interval of the median TSS effluent EMC for the entire paired dataset (n=22) and all sampled events (n=46) was 11.9 mg/L and 9.9 mg/L, respectively. Box plots for TSS are presented in Figure 5 indicate the general range and percentile concentrations were similar for paired and all sampled events.

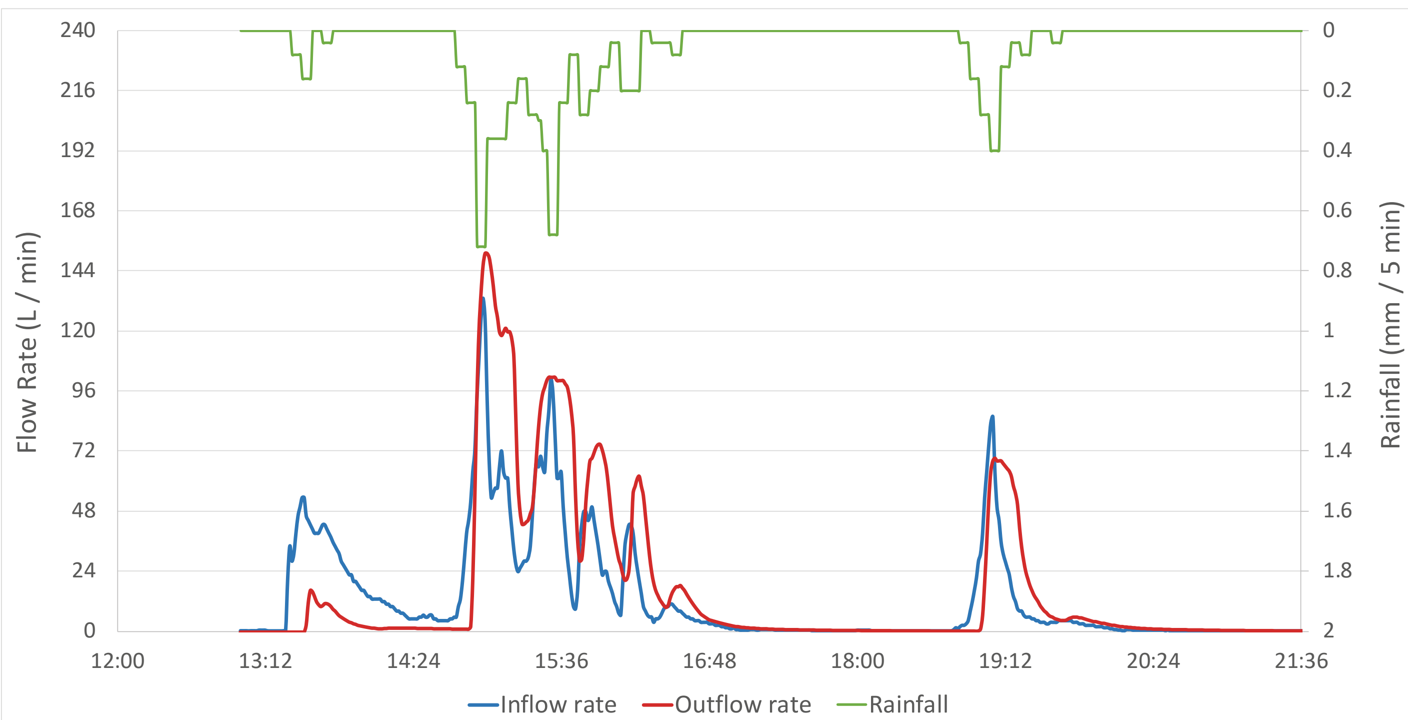

Figure 4. Hydrograph and hyetograph for a 32 mm rain event on July 16th, 2018

Table 2. Study results for treated flows relative to Washington TAPE criteria

Category	Number of Observations	Criteria	Result	Rating
Influent EMC < 20 mg/L	7	Not considered	7 events removed from consideration	Not applicable
Influent EMC between 20 and 100 mg/L	13	Effluent TSS EMC <20 mg/L	12.8 mg/L*	Pass
Influent EMC ≥ 100 mg/L	2	Removal efficiency ≥80%	Mean = 84%	Pass

*Upper 95% confidence interval limit of the median value as determined through bootstrap analysis. EMCs ranged from 3 to 22 mg/L.

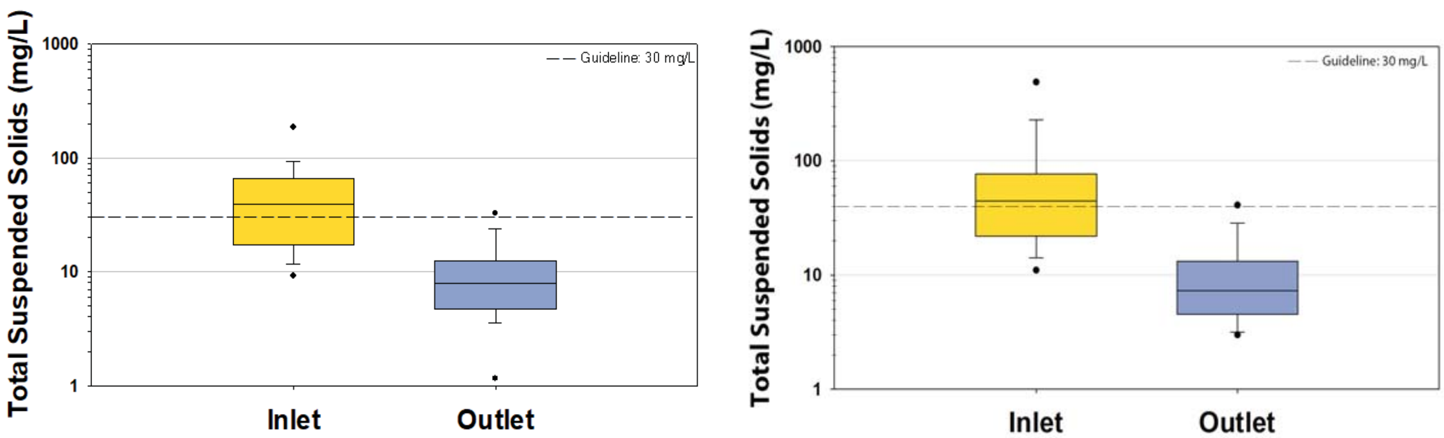

Figure 5. TSS box plots for matched events (left, n=22) and all events (right, inlet: n=37; outlet: n=46)

The Filterra® unit also showed effective treatment of total phosphorus, lead, iron, copper and zinc, but no statistically significant removal of total nitrogen or dissolved phosphorus. Results of the statistical analysis are presented in Table 3. Box plots showing influent and effluent concentrations and relevant receiving water guidelines for each constituent are presented in Figure 6. Low influent concentrations of several contaminants prevented assessment of performance under higher loading conditions. For total phosphorus, the TAPE protocol stipulates a qualifying influent EMC range of between 0.1 and 0.5 mg/L, and a goal of 50% removal. Only 5 paired TP samples in our study met this criterion, and the average removal efficiency for these events was 55%. Oil and grease (solvent extractable) was above laboratory detection limits 42% of the time at the inlet, and was never detected in paired samples at the outlet.

Water quality treatment results shown in this study are comparable to results from other third party studies in Washington and North Carolina using similar monitoring protocols. Both US studies were assessed following ISO 14034:2016 for verification of the Filterra unit in Canada (TRCA and Globe, 2018). The Washington study was conducted according to the Washington TAPE protocol and the North Carolina study used the North Carolina Department

Table 3. Bootstrap statistical analysis of inlet and outlet concentrations of selected variables

Year	TSS	TP	PO_4	TN	Pb	Fe	Cu	Zn
2017	In > Out	Not Sig.	Not Sig.	Not Sig.	In > Out	Not Sig.	Not Sig.	In > Out
2018	In > Out	In > Out	Not Sig.	Not Sig.	In > Out	In > Out	In > Out	In > Out
2017/18	In > Out	In > Out	Not Sig.	Not Sig.	In > Out	In > Out	In > Out	In > Out

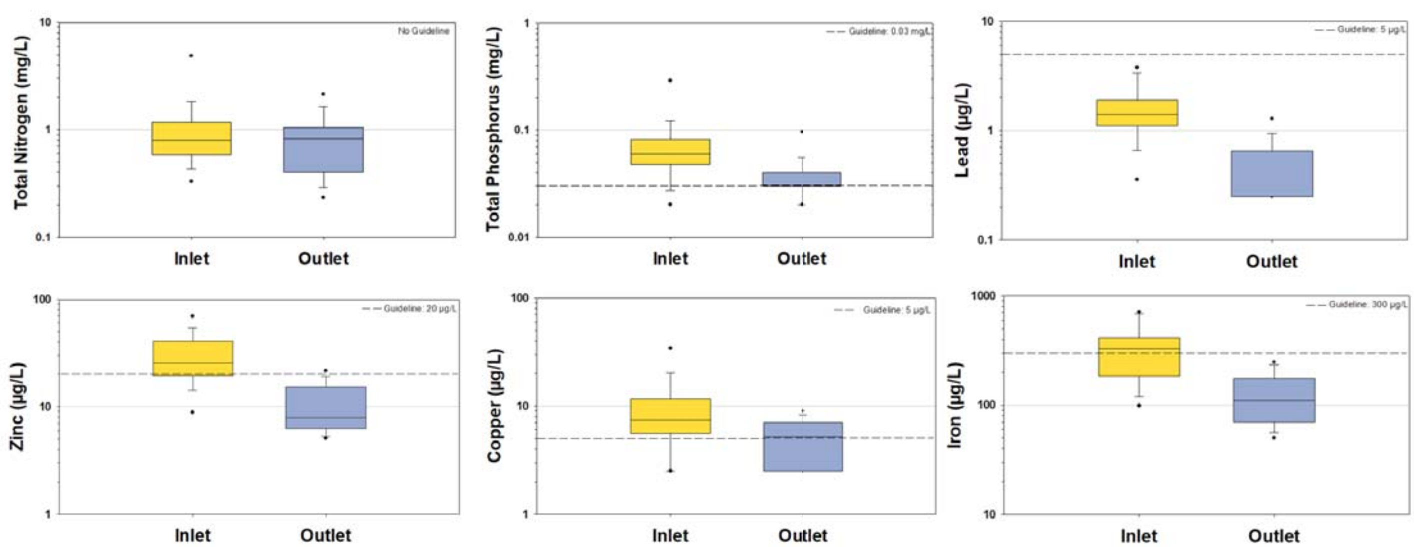

Figure 6. Box plots for selected water quality variables (paired events)

of Environmental Quality procedures. Although the impervious to pervious area ratios for units monitored in the US studies were more than 50% larger than those in this study, the quality of treated runoff was similar across the three studies. Median TSS effluent concentrations were 3.7 mg/L (n=17), 4.0 mg/L (n=28) and 7.3 mg/L (n=46) for the Washington, North Carolina and Ontario studies, respectively. Median total phosphorus effluent concentrations for the same three studies were 0.032 mg/L, 0.040 mg/L, and 0.039 mg/L, respectively. Influent total phosphorus concentrations in our study were the lowest of all studies, with median values of only 0.060 mg/L.

Maintenance on the Filterra® proved to be relatively simple, requiring tools and skill sets that are readily available within any municipality. The maintenance conducted in 2017 and 2018 involved removal of the mulch and accumulated sediment along one edge, and the installation of some stones to dissipate energy along the downstream edge, where most of the sediment was accumulating (Figure 7). The total time for maintenance was under 30 minutes utilizing inexpensive equipment for sediment removal and disposal (e.g. shovel, hoe).

The Service Berry shrub planted in the Filterra® unit has survived well over the three year period since it was planted. The shrub, planted in 2017, was selected because it is native to Ontario and tolerant of drought, periodic inundation and high salt loadings. A recommended plant list is available from the vendor. Larger trees are not suitable for this unit due to the small size of the container.

CONCLUSION

This study evaluated the water quality performance of a high rate treatment stormwater filter. Results showed that the unit achieved expected performance with 80% TSS removal for events with influent TSS concentrations above 100 mg/L, and median concentrations well below the threshold target of 20 mg/L for all events. The system also features good removal of other constituents, such as zinc and iron. Overflows were infrequent and small once the overflow diversion channel was redesigned to prevent unnecessary bypass, which suggests that sizing of the unit for this location was appropriate. An important advantage of the system is its relatively low and inexpensive maintenance requirements. The unit can be installed as a stand alone water quality treatment device, or as pre-treatment to other infiltration facilities to provide added volume and peak flow control benefits.

REFERENCES

Ecology 2018, *Technology Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies*. Technology Assessment Protocol - Ecology (TAPE) Washington State Department of Ecology, Olympia, Washington. Publication. Revision of publication 11-10-061, Publication no. 18-10-038

TRCA and Globe, 2018. *ISO 14034:2016 Verification Statement for the Filterra Bioretention System*. Completed December 1, 2018.

Figure 7. Maintenance of the Filterra® unit

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