◆ Verification Statement ◆ Verification Statement ◆ Verification Statement ◆

VERIFICATION STATEMENT

GLOBE Performance Solutions

Verifies the performance of

Filterra® Bioretention System

Distributed and marketed by Imbrium Systems, Inc.
Whitby, Ontario, Canada

Registration: GPS-ETV_VR2024-12-15_Imbrium-FB

In accordance with

ISO 14034:2016

Environmental Management —
Environmental Technology Verification (ETV)

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Vancouver, BC, Canada

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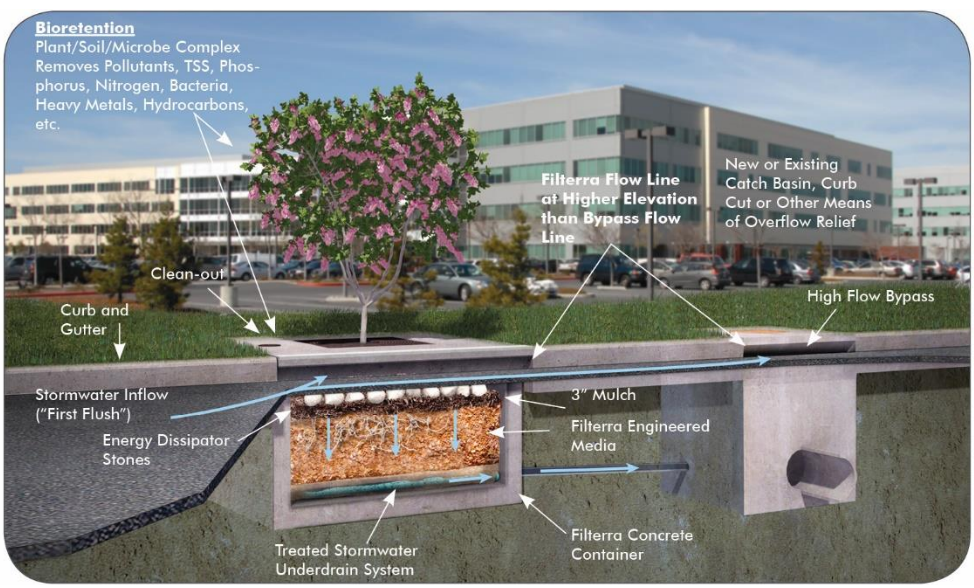
Technology description and application

The Filterra® stormwater bioretention system consists of a prefabricated concrete structure with mulch, soil media, plants and drainage infrastructure found in conventional bioretention (Figure 1). The media is specially formulated to remove suspended solids, nutrients, heavy metals and oil and grease from stormwater runoff, while retaining a high flow through capacity that minimizes the surface footprint area required for installation. The system is typically applied for the treatment of runoff from small catchments such as roads and parking lots.

The concrete container comes in various sizes ranging from 1.2 by 1.2 meters (4 x 4 feet) to 1.8 by 3.6 meters (6 by 12 feet). The top slab is fitted with a decorative tree gate. The schematic of the system in Figure 1 shows the function of the system. Runoff enters the unit along the curb through a 10 to 15 cm (4 to 6 inch) high curb inlet throat. Runoff bypassing the inlet during high flows is directed to a catchbasin inlet or other form of drainage infrastructure downstream of the unit. Devices with internal bypasses are also available.

Flows entering the inlet are dispersed across the top surface mulch layer. Freeboard depth of approximately 23 cm (9 inches) between the media layer and the system bypass is typically provided for temporary storage to promote settling. The 8 cm (3 inch) mulch layer is underlain by approximately 56 cm (22 inches) of engineered filter media with a specified gradation and organic matter content to ensure consistent and dependable hydraulic functionality and fertility. A perforated 10 to 15 cm (4 to 6 inch) underdrain wrapped in a fiberglass mesh and surrounded by 15 cm of gravel is placed along the concrete floor for rapid drainage of filtered runoff. Planting material may include flowers, grasses, shrubs or small trees, varying based on site specific climate and aesthetic considerations.

Various configurations of the device are available including those that infiltrate directly through the bottom of the unit and/or drain treated water to a neighbouring trench or chamber system that reduces runoff volumes through infiltration into the surrounding soils. This verification was conducted on the non-infiltrating configuration of the technology.



Performance conditions

The data and results published in this Verification Statement were obtained primarily from two third-party field studies conducted on a railway parking lot in Fayetteville, North Carolina and on a residential road in the City of Bellingham, Washington. The Filterra® units used in the two studies were 1.2 x 1.8 meters (4 x 6 feet) and 1.2 x 2.0 meters (4 x 6.5 feet), with media depths between 53 and 56 cm (21 and 22 inches), respectively. Ponding depths above the media were a minimum of 23 cm (0.75 feet). Testing was completed by researchers from North Carolina State University in accordance with the North Carolina Department of Environmental Quality standards, and by Herrera Environmental Consultants in Seattle Washington in accordance with Washington State Department of Ecology TAPE protocol. In the North Carolina study, the impervious drainage area for the Filterra® system was 1,012 m^2 (0.25 acres), the design infiltration rate was 3,556 mm/hour (140 inches/hour), and the unit was monitored during 125 rain events (3 to 125 mm) over a 22 month period. In the Washington study, the impervious drainage area and design infiltration was 1619 m^2 (0.4 acres) and 2,540 mm/hour (100 inches/hour), respectively, and the unit was monitored during 59 TAPE qualifying events (5 to 36 mm) over a 7 month period. In the North Carolina and Washington studies, flow proportioned water quality samples were collected during 32 and 17 of the events, and flows bypassing the unit during these events accounted for 30% and 1% of all treated flows, respectively.

Table 1 shows the specified and achieved criteria for storm selection and sampling. **Table 2** shows the observed ranges of operational conditions that occurred over the testing period.

Table 1. Specified and achieved criteria for storm selection and sampling

Description	TAPE Criteria Value	North Carolina Department of Environmental Quality Criteria Value	Achieved Value	
			Fayetteville, North Carolina	Bellingham, Washington
Minimum storm depth	≥ 3.81 mm (0.15 in)	> 2.5 mm (0.1 in)	> 2.5 mm (0.1 in)	≥ 4.5 mm (0.18 in)
Minimum inter-event period	6 hrs	6 hrs	6.2 hrs	6.9 hrs
Minimum flow-weighted composite sample storm coverage	75% including as much of the first 20% of the storm	≥70%	70%	73%
Minimum influent/effluent samples	12, but a minimum of 10 subsamples for composite samples	10	Minimum of 10 sub-samples for composite samples	Minimum of 10 sub-samples for composite samples
Number of storms	Minimum 12	Minimum 10	32	17

Table 2. Observed operational conditions for events sampled over the study period

	Observed range	
Operational condition	**North Carolina study**	**Washington Study**
Storm durations	0.1 to 48.1 hours	5.9 to 27.5
Antecedent dry days	0.26 to 13.4 days	0.3 to 13.0
Rainfall depth	3 to 50 mm	5 to 36 mm
Effluent volume	288 m3	192 m3
Bypass volume	86.7 m3	2.0 m3
Peak rainfall intensity	56 mm/hr	1.9 mm/hr*
Median peak flow rate**	9.91 L/s (SD = 8.21)	1.38 L/s (SD = 1.02)

* Peak rainfall intensity for all events, including those not sampled, was 9.1 mm/h, which generated a peak flow rate of 9.5 L/s through the unit.
** NC peak flow rate is for the catchment (including bypass), whereas Washington peak flow is measured at the outlet after flow has passed through the media. Median bypass peak flow in the Washington study was 0.11 L/s, with a maximum of 23.2 L/s.

Performance claims

Filterra® Bioretention System, when designed for a stormwater infiltration rate ranging from 2,540 mm/hour (100 inches/hour) to 3,556 mm/hour (140 inches/hour), and based on data generated in two third-party field monitoring studies of commercial installations (one study conducted in accordance with the Washington State Department of Ecology TAPE protocol and a second study conducted to meet North Carolina Department of Environmental Quality requirements), provides removal efficiencies *for treated flows*[1] of at least 89% for Total Suspended Solids (TSS) and at least 52% for Total Phosphorus (TP) when TSS and TP influent concentrations are above 20 mg/L and 0.1 mg/L, respectively.[2]

Performance results

The cumulative frequency of rainfall depths monitored during the two studies study is presented in **Figure 2**. The median and 90th percentile rainfall depths were 15/31 mm and 11/15 mm for the NC and WA studies, respectively. These values represent the depth of rainfall that is not exceeded in 50 and 90 percent of the monitored rainfall events.

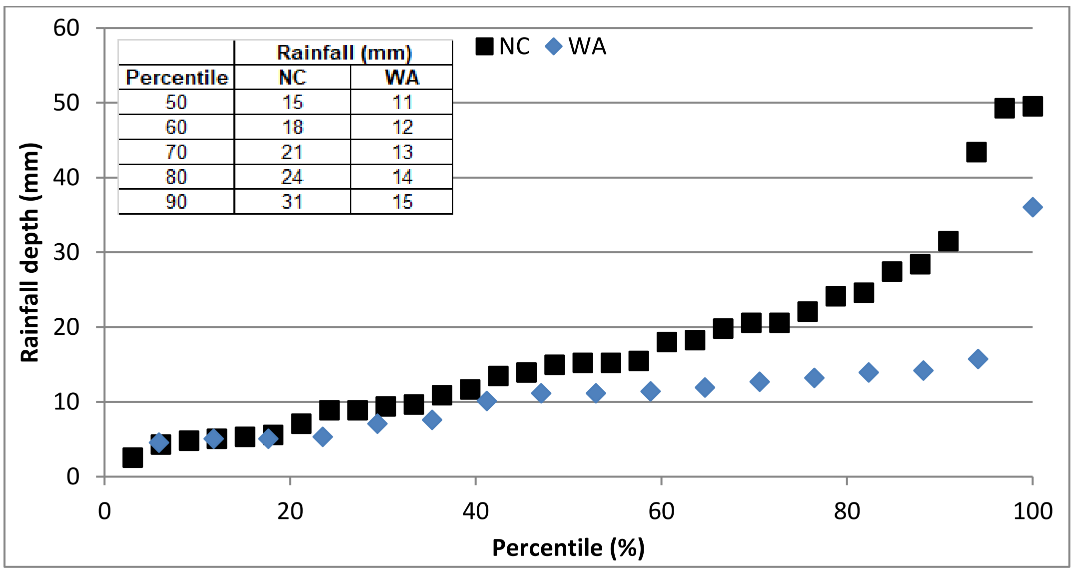


Figure 2. Rainfall depth frequency curves

The Filterra® unit tested in Washington was sized using state specified modelling software to treat 91% of the annual stormwater runoff volume. The Filterra® unit tested in North Carolina was sized for the 25 mm (1 inch) design storm water quality volume based on sizing charts developed through engineering analysis for North Carolina districts that stipulate the maximum size impervious drainage area for different unit sizes. Elevation survey measurements of the drainage area for the Filterra® unit after installation showed that the system was undersized because a portion of the upstream impervious area (roughly 16% of the total) not previously accounted for was in fact draining to the unit. This meant that the actual drainage area of 1012 m^2 (0.25 acres) was appreciably larger than the maximum drainage area

[1] These removal rates represent the lower 95% confidence interval values for treated flows only, not including high flows that bypassed the units. Bypass reduces the system removal efficiency below those stated in this performance claim. Bypass is a key component of the Filterra® Bioretention System that cannot be omitted. Lowering the potential for bypass to a small fraction of average annual flows (e.g. <2%) will require close adherence to vendor recommendations for system inspection and maintenance, and an increase in filter surface area per vendor or approval agency sizing recommendations. See Table 4 and text for more information on removal efficiency calculations with bypass.

[2] The claim may be applied to other units of different dimensions than the tested unit as long as the provisions for scaling detailed in section 5 of the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device* (January 25, 2013) are followed.

(850 m² or 0.21 acres) specified in the sizing charts for a 4 x 6 foot Filterra® unit in this part of North Carolina.

Performance of the Filterra® Bioretention System was achieved in both studies by measuring flows and on-site rainfall continuously, and collecting flow proportioned water quality samples (minimum of 10 sample aliquots). The North Carolina study used a combination of weirs and an area velocity probe to measure inflows and outflows. Bypass flows were measured in a plastic pipe using a bubbler for water level, which was converted to flow using Manning's equation for open channel flow. Automated samplers were used in conjunction with flow measurements at the inlet and outlet to collect flow proportioned samples.

In the Washington study, effluent flows were continuously monitored with an area velocity probe and bypass flows were monitored with a bubbler level sensor and H-flume. For safety reasons, influent flows could not be measured in the road right-of-way. Therefore, effluent flow data were used to represent both influent and effluent flows for the purpose of sample flow proportioning. Data was presented from earlier studies of the Filterra® device showing close tracking of influent and effluent flows, which indicated that the monitoring approach was reasonable. It is recognized, however, that the time offset between inlet and outlet hydrographs introduces an error in sample flow proportioning which for some events may have resulted in incomplete capture of the first flush. This typically translates to lower influent concentrations than would have been the case had the flow proportioning been conducted on actual influent flows because a high proportion of sediment deposited on road surfaces during the interevent period is washed off the road during the first 10 to 15 minutes of surface flow.

Sampling of flows into and out of the Filterra® unit over the testing period showed statistically significant reductions ($p < 0.001$; Wilcoxon signed-rank test) in influent event mean concentrations for Total Suspended solids (TSS) and Total Phosphorus (TP) (**Table 3** and **Figures 3a and 3b**). Effluent event mean TSS concentrations during qualifying events were below 17 mg/L and 10 mg/L in the North Carolina (n = 28) and Washington (n = 17) studies, respectively. Based on a subset of the sampled events, the d50 particle size (i.e. median particle size) of influent total suspended solids was 147 microns in the North Carolina study (n = 15) and approximately 55 microns in the Washington study (n = 4). In both studies, there were no statistically significant monotonic correlations ($p < 0.01$, Spearman's rank correlation test) between influent and effluent concentrations of TSS, indicating that variations in TSS influent concentrations did not have a strong influence on the concentrations of TSS discharged from the Filterra® system. Effluent concentrations of TSS were also not sensitive to changes in peak flow rate or volume, the latter of which varied over a much larger range than observed effluent concentrations.

Table 3. Summary statistics for influent and effluent event mean concentrations for TSS and TP

Study Location	Water Quality Variable	N	Sampling Location	Min	Max	Median	Mean	SD	Mean 95% confidence interval - lower limit	Mean 95% confidence interval - upper limit
Bellingham, Washington	TSS	17	Influent (mg/L)	7.5	107	49	47.2	29.7	33.8	61.0
		17	Effluent (mg/L)	1.8	9.5	3.7	4.1	2	3.3	5.1
	TP	17	Influent (mg/L)	0.03	0.52	0.090	0.13	0.12	0.08	0.19
		17	Effluent (mg/L)	0.02	0.06	0.032	0.03	0.01	0.03	0.04
Fayetteville, North Carolina	TSS	28	Influent (mg/L)	20.00	730	67	120.6	139	75	174
		28	Effluent (mg/L)	1.2	16	4	5.4	3.7	4.1	6.9
	TP	32	Influent (mg/L)	0.03	0.59	0.095	0.13	0.12	0.09	0.17
		32	Effluent (mg/L)	0.012	0.14	0.040	0.05	0.03	0.03	0.06

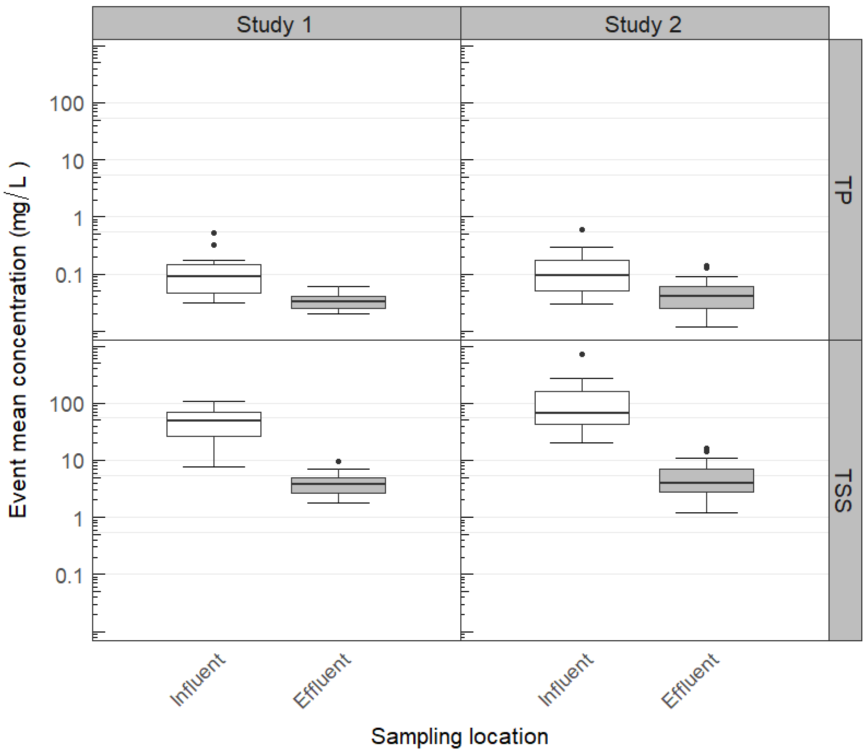


Figure 3a. Boxplots showing influent/effluent Event Mean Concentrations (EMC) for TSS and TP for each study.

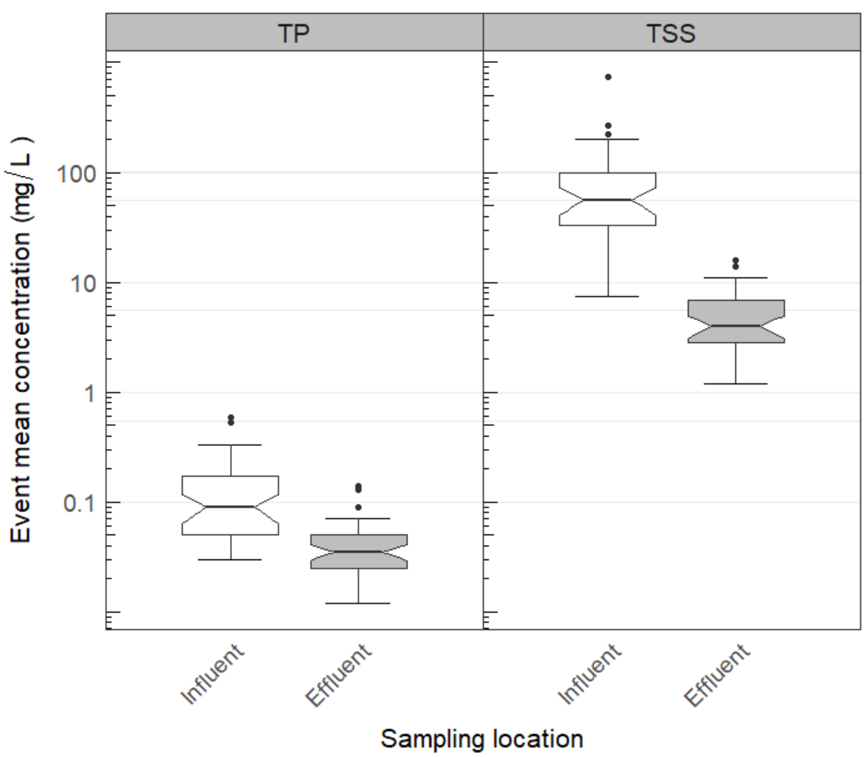


Figure 3b. Boxplots showing influent/effluent Event Mean Concentrations (EMC) for TSS and TP combined for both study locations.

Table 4 shows removal efficiencies for treated flows and for both treated and bypass flows. In the calculation with bypass flows, the concentration of bypass flows are assumed to be the same as measured influent concentrations (i.e. no treatment is provided). Upper and lower confidence intervals were calculated based on a bootstrap analysis. Since both sites reported similar effluent concentration ranges and medians, the difference in concentration based removal efficiencies for treated flows can be largely attributed to differences in influent concentrations.

As expected, pollutant removal efficiencies fell considerably when untreated bypass volumes were incorporated into the removal efficiency calculation. In the Washington study, the bypass volumes were relatively small, at only one percent of measured outflows for qualifying water quality events. This was in part because the system was slightly oversized. In the North Carolina study, the bypass volumes were much more significant, particularly in year two of the study. The higher bypass volumes and lower flow rates triggering bypass in year two were largely attributed to clogging of the system due to a reduction in maintenance frequency. The vendor recommends bi-annual cleaning, but maintenance occurred only once in year two. Higher bypasses were also a result of the unit being undersized, as indicated above.

Table 4. Summary statistics for concentration based TSS and TP removal efficiencies (%) for treated flows and treated and bypass flows

Study Location	Water Quality Variable	Flow Stream	N	Min	Max	Median	Mean	SD	Median 95% confidence interval - lower limit	Median 95% confidence interval - upper limit
Bellingham, Washington	TSS	Treated flows	13	76.7	96.8	93.8	91.2	5.5	89.2	94.6
		Treated and bypass flows	13	74.7	96.5	93.6	90.7	6.1	87.3	94.6
	TP	Treated flows	8	45.7	90.5	78.3	75.3	14.3	68.3	85.5
		Treated and bypass flows	8	45.7	90.2	76.7	74.9	14.3	68.3	88.2
Fayetteville, North Carolina	TSS	Treated flows	27	74.1	98.8	94.9	92.6	6.3	90.6	96.6
		Treated and bypass flows	27	27.0	100	75.4	77.8	15.9	71.8	90.6
	TP	Treated flows	15	18.2	91.5	66.7	64.0	18.3	51.9	75.0
		Treated and bypass flows	15	12.9	91.5	54.0	54.2	21.7	47.4	70.3

Removal efficiencies with influent TSS concentrations below 20 mg/L and influent TP concentrations below 0.1 mg/L were omitted, as per TAPE requirements.

Sources of error

1. In the North Carolina study, inflows through the Filterra® unit were measured with a sharp crested compound v-notch plus rectangular weir. On several occasions runoff volumes exceeded the capacity of the weir, necessitating the use of the Curve Number method for influent volume estimation and the Rational Method for influent peak flow estimation. These relatively crude estimation methods reduced the reliability of the influent flow data and may have introduced some bias into the influent sample flow proportioning results. The influent flow errors were not critical in this verification because removal efficiencies were based on treated water quality concentrations rather than loads. The use of concentrations rather than loads was a reasonable approach given that the verification is based on treated flows only, and flow

volumes entering and exiting the unit over the two study periods would be almost identical, with only minor losses through evapotranspiration.

2. In the Washington study, influent samples were flow proportioned based on effluent rather than influent flows. Data from previous studies of the Filterra® system show influent and effluent hydrographs to have a very similar shape, with lag times typically less than 20 minutes. While the close tracking of influent and effluent flows suggests that the monitoring approach was reasonable given site constraints, the flow sampling delay introduces potential bias in the estimation of influent concentrations. This bias likely resulted in underestimation of influent concentrations as the first flush may not have been adequately captured in some instances. Since, for a given effluent concentration, removal efficiencies would be lower as influent concentrations decline, the error is likely to have introduced a bias that is conservative (i.e. does not bias data in favour of meeting the performance claim).

Verification

The verification was completed by the Verification Expert, Toronto and Region Conservation Authority, contracted by GLOBE Performance Solutions, using the International Standard ***ISO 14034:2016 Environmental management -- Environmental technology verification (ETV)***. Data and information provided by Imbrium Systems to support the performance claim included a performance monitoring report prepared by researchers from North Carolina State University in accordance with the North Carolina Department of Environmental Quality standards, and by Herrera Environmental Consultants in Seattle Washington in accordance with Washington State Department of Ecology TAPE protocol.

What is ISO14034:2016 Environmental management – Environmental technology verification (ETV)?

ISO 14034:2016 specifies principles, procedures and requirements for environmental technology verification (ETV) and was developed and published by the *International Organization for Standardization (ISO)*. The objective of ETV is to provide credible, reliable and independent verification of the performance of environmental technologies. An environmental technology is a technology that either results in an environmental added value or measures parameters that indicate an environmental impact. Such technologies have an increasingly important role in addressing environmental challenges and achieving sustainable development.

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