Controlled Full-Scale Field Testing of an Up-Flow Filtration Device

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ABSTRACT
The objective of this research is to examine the removal capacities of a recently developed stormwater filtration device, in part developed by engineers at the University of Alabama through a Small Business Innovative Research (SBIR) grant from the U.S. Environmental Protection Agency. The UpFlo™ Filter is an efficient high-rate stormwater filtration technology designed for the removal of trash, sediments, nutrients, metals and hydrocarbons from stormwater runoff. Compared with the traditional downflow filtration treatment, the upflow filtration method reduces clogging and was developed to remove a broad range of stormwater pollutants, especially those associated with particulates. The high flow rate capacities of the upflow filter are accomplished through controlled fluidization of the filtration media, while still capturing very small particulates through a flexible, but constraining, media container. The upflow filter also drains down between rain events which minimizes anaerobic conditions in the media and which also partially flushes captured particulates from the media to the storage sump, decreasing clogging and increasing run times between maintenance. Gross floatables are captured through the use of an angled screen before the media and a hood on the overflow siphon, while the sump captures bed load particulates.

INTRODUCTION
Many types of stormwater controls are available, but most are relatively large or insufficient in their treatment capacity. Adequate treatment of runoff requires the removal of many types of pollutants as well as large amounts of debris and floatable materials, over a wide range of flows. Traditional downflow filters, which can provide high levels of treatment, can quickly clog, reducing their treatment flow rate and overall treatment capacity. They also usually operate at a low treatment flow rate requiring a large area to treat substantial portions of the runoff from a site. The UpFlo filter is designed to treat stormwater runoff from critical source areas that discharge especially high levels of pollutants. The commercialized UpFlo filter minimizes clogging and was developed to remove a broad range of stormwater pollutants at a relatively high rate, and can be retrofitted into existing stormwater drainage. This presentation will present the results from a controlled full-scale field evaluation located at a parking lot in Tuscaloosa, AL. Treatment flow rates, particle size controls, and SSC reductions will be stressed in this presentation.

LOCATION AND SIZE OF FILTER

A 7-foot tall 4-foot diameter standard inlet containing a six module UpFlo™ Filter has been installed at the Riverwalk parking lot near the Bama Belle on the Black Warrior River in Tuscaloosa, Alabama. The chamber is a conventional concrete manhole with a sump, with the UpFlo™ filter components installed. The filter receives surface runoff from a parking lot, road, sidewalks, and a small landscaped area, as shown in Table 1. The total drainage area tributary to the device is approximately 0.9 acres. Figure 1 shows the drainage area and the location of the test site.

Table 1. Drainage Area Land Use

Land Use	Area (ft^2)	Area (acre)	% of Land Use
Parking Area	11,800	0.27	30.5
Other Paved	1,300	0.03	3.4
Side Walks	2,100	0.05	5.4
Entrance Road	10,990	0.25	28. 5
Green Space	12,400	0.29	32.2
Total	**38,610**	**0.89**	**100.0**

Figure 1. Site map and drainage area.

DESCRIPTION OF FILTER

The full-scale filter system (having a full complement of 6 filter modules) was installed and is being tested to confirm laboratory and the initial pilot-scale test results under actual rain conditions. Hydraulic capacity and pollutant removal capabilities in the full-scale field installation are being monitored under both controlled and actual runoff conditions. Figure 2 shows the main features of the UpFlo™ filter, while Figure 3 shows the installation of the full-scale test filter at Tuscaloosa. Depending on the selected media, the filtration treatment flow rate varies from 15 to 25 gal/min/ft^2. With 6 modules, each having about 1ft^2 of filter surface, the total treatment flow rate for this installation is expected to be at least 100 gallons/minute.

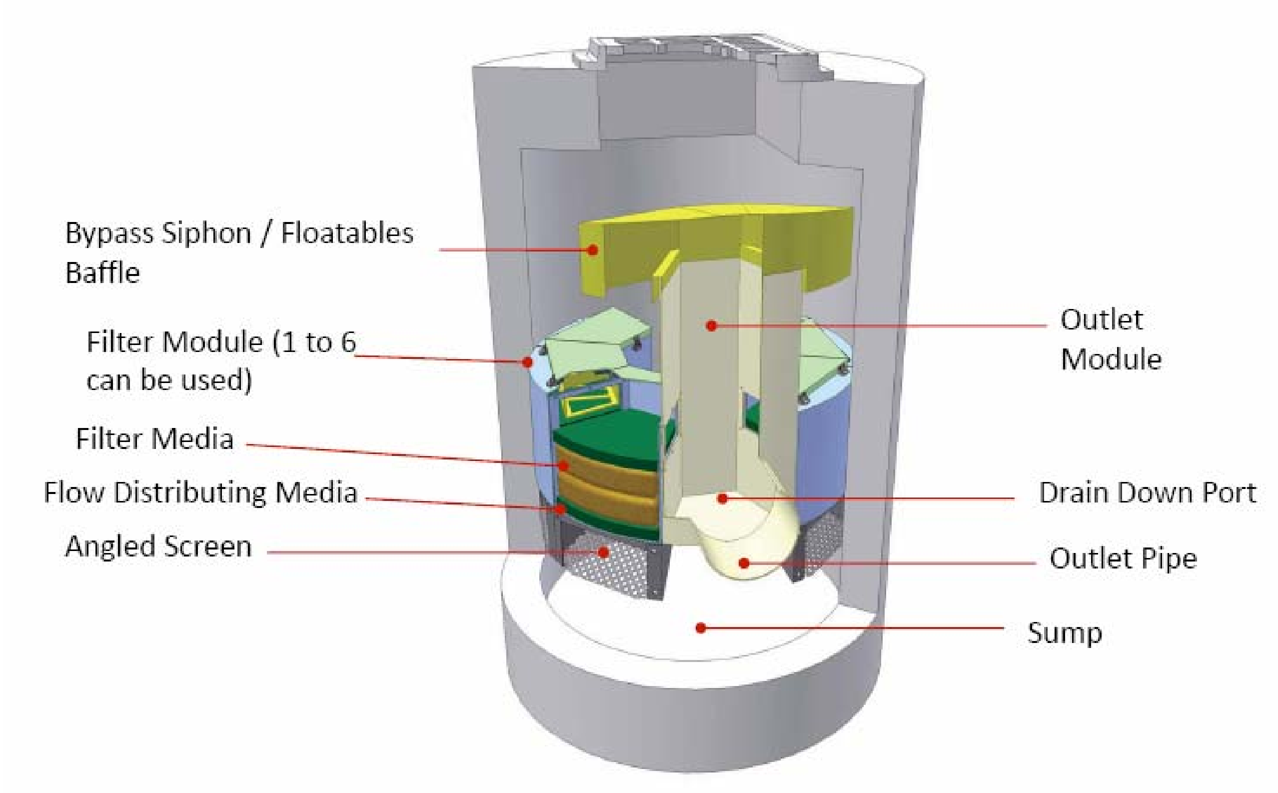


Figure 2. UpFlo™ Filter components.

Figure 3. Installation of Tuscaloosa UpFlo™ filter.

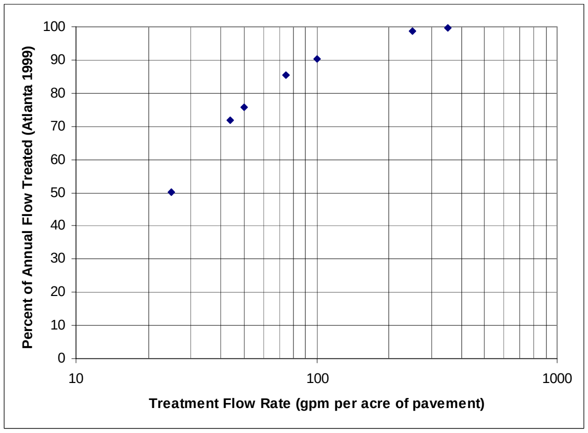


Figure 4. Treatment flow rate requirements for southeast US paved conditions (Example shown for continuous simulation results for Atlanta, GA).

Figure 4 shows the treatment flow rate requirements for typical southeastern US conditions, based on continuous simulations (Pitt and Khambhammettu 2006). The 100 gal/min for the test site is expected to treat about 90 percent of the annual flow for a typical rain year, with about 10 percent of the annual flow bypassing filtration.

CONTROLLED FLOW TEST & CONTROLLED PARTICLE CAPTURE TEST

This paper describes the initial controlled performance monitoring that is being conducted at the Riverwalk parking lot near the Bama Belle in Tuscaloosa, Alabama. The first flow test was conducted for the purpose of determining the hydraulic capacity and the pollutant removal capabilities in a full-scale field installation under controlled conditions. In the test, the filtration rate of the CPZ Mix™ filter media, a proprietary mixture of bone char activated carbon, peat moss, and manganese coated zeolite was evaluated. Based on results of prior lab scale testing, the mixed media is expected to have high pollutant removal at relatively high filtration rates. The UpFlo™ Filter was fitted with two media bags in each of the 6 chambers, for a total of 12 bags, as well as the flow distribution material placed above and below the media bags.

METHODOLOGY FOR THE EVALUATION OF FILTRATION RATE

Flow tests were conducted in the field with the cooperation of the Tuscaloosa Department of Transportation by using a pump to deliver river water to a flow splitter/flow controlling barrel. The water flow rate was measured by measuring the time needed to fill a measured volume (Figure 5). When the rate was established, the volume tray was removed, directing the known and steady flow to the gutter immediately above the Up-Flo intake. For each flow rate, measurements were taken of the steady-stage water depth in the filter and the reported flow rate from the area-velocity sensor that will be used to monitor the flow during rain events. The measurements were repeated 5 times for each flow to reduce the errors. Figure 6 shows an example flow vs. head graph developed during these tests.

Figure 5. Pumped River water is discharged from splitter barrel to the 11 gallon plastic tray.

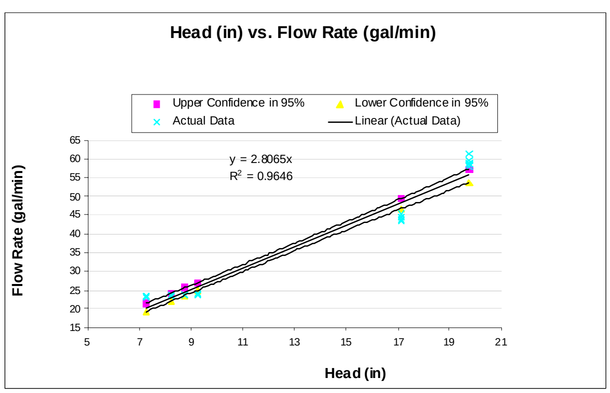


Figure 6. Example flow vs. head graph for mixed media, showing highly repeatable measurements.

PARTICLE SIZE DISTRIBUTION OF TESTED MEDIA AND TEST SEDIMENT

The test sediment in the stormwater stimulant used a mixture Sil-Co-Sil 250, Sil-Co-Sil 106 (both from U.S. Silica Co.), and coarse and fine concrete sands. The mixture was made by mixing the four components with different ratios to obtain a relatively even particle size distribution representing the complete range from about 20 to 2,000µm. This mixture was not intended to represent actual stormwater (which usually has a smaller median size), but to ensure sufficient amounts of large particles so they could be accurately monitored to quantify their removal. As shown later, all of the results of these controlled tests were presented based on many narrow particle size ranges so they could be applied to any expected particle size distribution of the flowing water. Since the samples were all analyzed using sieves and a Coulter Counter, the results are much more useful than if individual SSC analyses were conducted representing all sizes combined. If a single analysis was conducted, then the psd of the challenge water would have to match the stormwater psd, a difficult objective given the highly variable particle size characteristics of stormwater. Figure 7 shows the particle size distributions of two test mixtures that were used during the tests.

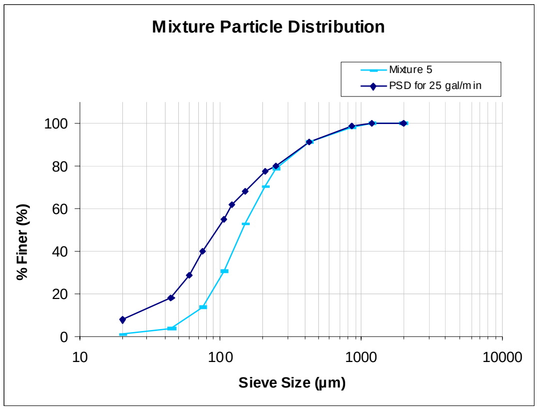


Figure 7. Particle size distribution of mixture used for the flow test.

Figure 8. Sediment mixture was manually and consistently added to the influent water over the 30 minute test period.

TEST METHODOLOGY FOR CONTROLLED SEDIMENT CAPTURE TESTS

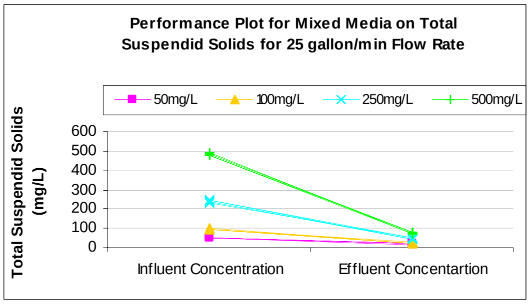
The test described below used several known concentrations of particulate solids over a wide range of particle sizes and an influent flow rate that averaged 24 gallon per minute (having a standard deviation of 0.3 gpm). Each experiment was conducted for 30 minutes, during which time measured aliquots of the dry sediment were constantly poured into the pumped influent "river flow" from the Black Warrior River. River water was also collected before any sediment was added to measure the background solids in the test water to determine the background conditions. Effluent samples were collected using a dipper grab sampler every 1 minutes and composited in a churn sample splitter during the 30 minutes test period. The effluent was sampled at a completely mixed cascading flow exiting the filter in a specially constructed sampling chamber. Using the churn splitter, two samples of 1000 mL each were placed in sample bottles for duplicate laboratory analyses for each test.

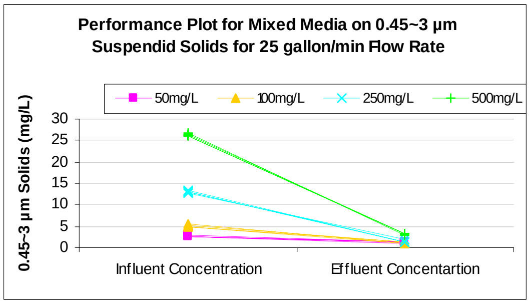
In preparation for the tests, test sediment portions were pre-weighted in many 50 mL polyethylene bottles. The sediment was manually feed into the influent water over the whole period of each experiment, according to the desired particulate solids concentration for the specific flow rate for each test (Figure 8). This method ensured that all of the sediment and all particle sizes entered the test chamber. Depth readings of the water levels were also taken during each experiment to determine the head loss during the Up-Flo™ Filter operation. Also, after completion of each experiment, additional multiple flow and depth readings were taken to determine the final flow rate and available head to detect any change in filtration rate during the test.

During these tests, four different influent sediment concentrations were tested: 50mg/L, 100mg/L, 250mg/L, and 500mg/L.

INITIAL CONTROLLED TEST RESULT OF FILTER

Controlled tests can measure the filter behavior under known conditions. Mixtures of ground silica available from U.S.Silica Co. were used for these initial tests, reflecting filter performance for a variety of particle sizes. Figure 9 shows the influent and effluent concentrations during tests using 50 to 500 mg/L influent conditions. Further controlled tests are being conducted, along with measurements conducted during actual rain conditions.





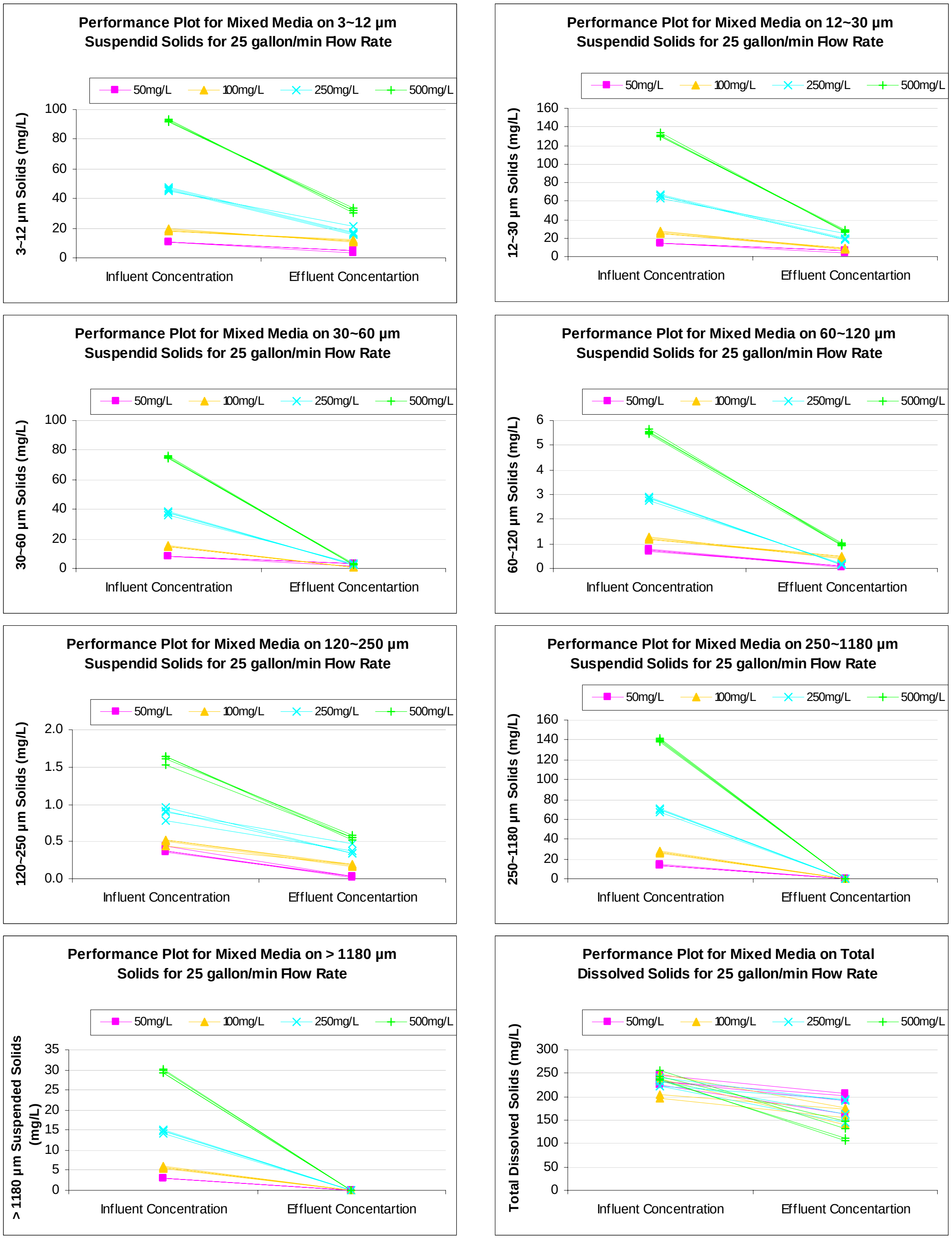


Figure 9. Controlled test results for different particle sizes.

Table 2 summarizes the average influent and effluent concentrations, along with the percentage reductions for 100 and 500 mg/L influent conditions (including river water additions). Table 3 shows the average influent and effluent concentration of TDS concentrations.

Table 2. Average Influent and Effluent Concentration

25 gallon/min Flow Rate and 100 mg/L Concentration			
Particle Size (µm)	Average Influent Concentration (mg/L)	Average Effluent Concentration (mg/L)	Average Reduction (%)
< 0.45	220	160	27
0.45 to 3	5.2	1.1	78
3 to 12	19	11	38
12 to 30	26	8.3	68
30 to 120	16	1.3	92
120 to 1180	28	0.18	99
> 1180	5.7	0	100
sum >0.45 µm	99	21.9	78

25 gallon/min Flow Rate and 500 mg/L Concentration			
Particle Size (µm)	Average Influent Concentration (mg/L)	Average Effluent Concentration (mg/L)	Average Reduction (%)
< 0.45	240	120	49
0.45 to 3	26	3.2	88
3 to 12	92	32	65
12 to 30	130	28	79
30 to 120	81	3.9	95
120 to 1180	142	0.55	100
> 1180	30	0	100
sum >0.45 µm	500	67.7	86

Table 3. Average Influent and Effluent Concentration for TDS

25 gallon/min Flow Rate and TDS Concentration					
Concentration (mg/L)	Average Influent Concentration (mg/L)	Average Effluent Concentration (mg/L)	Average Reduction (%)	Maximum Reduction (%)	Minimum Reduction (%)
50	230	190	19	28	13
100	220	160	27	42	15
250	230	170	25	35	13
500	240	120	49	55	39

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