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Drainage Flow and Backflow Testing of JET Filter System's 3-, 4-, and 6-inch Filter and Drainage Units

TRI ENVIRONMENTAL

TRI-MAPP Report

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Final Report

Submitted to:

JET Filter System LLC
Post Office Box 31
Casey, IL 62420, USA

Attn: Mr. David Heilman
dheilman@jetfiltersystem.com

Submitted by:

TRI Environmental, Inc.
9306 Bee Cave Rd.
Austin, TX 78733

Prepared by:

C. Joel Sprague, P.E.
Technical Director – TRI South Carolina
(864) 346-3107
jsprague@tri-env.com

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REPORT: **Drainage Flow Rate and Backflow Testing of Jet Filter Units**

This testing program quantified the drainage flow rate vs. pressure characteristics of Open-End JET Filter units and the drainage flow rate vs. pressure and backflow rate vs. pressure characteristics of Closed-End JET Filter units. The following performance characteristics were established for the tested material at 2.5 psi:

JET Filter Unit & Weep Hole Diameter	Open-End Design		Closed-End
	Standard Open-End w/Face Plate	+Louvered Vent	+ Backflow Prevention Valve
3 in.	52.2	42.1	Not Tested
4 in.	100.0	47.0	35.0
6 in.	> 256.5	256.5	50.0

This report contains additional results for drainage flow rates and backflow rates at multiple pressures using a variety of assemblies and components. All tests were conducted with standard components based on the bill of materials for each model size. All applied pressures were unrestricted by opposing pressure. All tests were conducted using clean recirculating water.

C. Joel Sprague, P.E.
Technical Director
TRI-South Carolina

James E. (Jay) Sprague, CPESC
Laboratory Director
TRI-South Carolina

TEST REPORT

Drainage Flow and Backflow Testing of JET Filter System's 3-, 4-, and 6-inch Filter and Drainage Units

OVERVIEW

Lack of proper drainage is the most common cause of failures in earth retaining structures, such as retaining wall, seawalls, flood control channels and others. Properly designed earth retaining structure drainage systems serve two functions: they efficiently drain the water from behind the wall and they stop soil from being washed out from behind the wall. In other words, properly designed drainage systems must provide sufficient long-term flow capacity while simultaneously providing in-situ soil retention. Over time, the drainage performance of all drainage systems will decrease as the soil filtration components becomes clogged. This results in excessive water (hydrostatic) pressures on the retaining wall leading to wall distress or allowing the drainage systems to wash soil from behind the wall leaving voids and sink holes in the backfill.

JET Filter System. LLC has developed a system of maintainable weep hole filters (aka JET Filters) that can be installed during initial construction or retrofitted to existing retaining wall to provide drainage and soil filtration. These maintainable weep hole filters can be used with a range of wall types, including cast-in-place and precast concrete, sheet pile (steel, vinyl, aluminum, composite, etc), mechanically stabilized earth (MSE), and wooden retaining walls.

JET Filter System has commissioned the testing reported herein to define performance specifications for the JET Filter maintainable weep hole filters and to gather data intended to verify the product's design and fabrication. The four primary goals of TRI testing are to:

1) Identify the drainage flow rates of various JET Filter configurations, including 3", 4" & 6" diameters and a multitude of accessories.
2) Compare the drainage flow data between traditional weep hole drainage system with geotextile filter fabric behind the wall verses JET Filter's conical shaped technology with the same hole diameter but greater geotextile surface area.
3) Study the backflow prevention valve's ability to reduce reverse flow rates in JET Filter's Closed-End Units.
4) Confirm that JET Filter's configuration maintains the geotextile manufacturer's flow specifications using various geotextiles.

TEST PROGRAM OUTLINE

This testing program focused on the drainage capacity of JET Filter System units commonly used in drainage flowing one-way (unidirectional) from behind a wall, such as with a typical retaining wall. These units are referred to as “Open-End” units. Additional testing was done on JET Filter units outfitted with a backflow prevention valve that are exposed to hydrostatic pressure to assess not only the primary drainage flow capacity but also the ability of the unit to minimize backflow into the backfill behind a wall, such as with a seawall. These units are referred to as “Closed-End” units.

The drainage flow testing characterized the flow rate versus the associated hydrostatic pressure by introducing a controlled flow out of the backfill side of the unit. The backflow flow rate testing introduced flow under pressure from the face plate / backflow valve side of the device to establish the assembly’s ability to resist backflow back into the unit. The backflow rate test only tested the pressure from the outside/wall front. This test did not incorporate off-setting water pressures coming from the backfill side of the wall.

Testing was carried out in October of 2019 and July/August of 2020.

TESTING EQUIPMENT AND PROCEDURES

Overview of Test and Apparatus

The testing reported herein was performed at TRI Environmental, Inc.'s (TRI's) hydraulics testing facility located at the Roads to Rivers Research Institute (3RI) in Greenville, SC. PVC pipe, fittings, and valves were assembled into a system able to expose the JET Filter units to stable, controlled flow and pressure. Pictures of the test setup used in testing in October 2019 and in July 2020 are shown in Figures 1 and 2, respectively.

Figure 1. Outdoor testing in October 2019

Figure 2. Indoor testing in July 2020

Tested Products

The products tested were 3-, 4-, and 6-inch diameter JET Filter units and associated accessories (the unit diameter represents the diameter of a cored weep hole). Some of the tested assemblies were representative of those used only for drainage flow. Other assemblies were representative of units that are used when it is important to minimize backflow due to intermittent high water or wave action on the front side. Figures 3 and 4 show the 4-inch and 6-inch components incorporated into the testing.

Figure 3. 4-inch components incorporated into the testing

Figure 4. 6-inch components incorporated into the testing

Product Assembly

A typical assembled JET Filter unit for drainage flow (Open-End) incorporates a housing, a filter cartridge, a face plate, and an optional louver cover. When backflow is to be prevented, a valve is also incorporated into the assembly with a required louver cover. A close-up of these various components is shown in Figure 5. Figures 6 and 7 show which components are included (6-inch size shown) for "Open-End" Drainage Flow Testing and "Closed-End" Drainage Flow and Backflow Testing, respectively.

Figure 5. Close-up of Components (L to R):
Housing, Filter Cartridge, Face Plate, Louvered Cover, Back-flow Prevention Valve

Figure 6. "Open-End" Component Assembly for Drainage Flow Testing Only

Figure 7. "Closed-End" Component Assembly for Reverse Flow Testing includes a Back-flow Prevention Valve

Specific Test Procedure

Drainage flow rate vs pressure testing:
The objective of these tests was to establish the maximum flow rate passing through the various assemblies at various hydrostatic pressure levels. This test was run on a range of sizes and component assemblies to develop an understanding of the contribution the different components make to restricting flow. Component assemblies included:

1) Housing and Filter Cartridge only
2) Housing, Filter Cartridge + Face Plate
3) Housing, Filter Cartridge, Face Plate + Louvered Cover
4) Housing, Filter Cartridge, Face Plate, Louvered Cover + Backflow Prevention Valve

Additionally, a circular specimen of only the filter fabric matching the diameter of the test pipe, representing the diameter of a weep hole, was also tested to provide a comparison between the 3-dimenstional conically shaped filter cartridge and a traditional 2-dimensional weep hole with the same filter fabric.

In all test runs, the flow was set at a given pressure and allowed to stabilize before reading the water level upstream of the measuring weir and calculating the flow rate. The pressure would then be increased and the flow allowed to once again stabilize before measuring the water level in the weir box.

Backflow rate vs. pressure testing:
The objective of these tests was to establish the maximum flow rate passing through the full "Closed-End" assembly of each size JET Filter at various hydrostatic pressure levels from the front face of the filter. Component assemblies included only:

5) Housing, Filter Cartridge, Face Plate, Louvered Cover + Backflow Prevention Valve

In all test runs, the flow was set and the resulting upstream pressure was allowed to stabilize before catching the backflow through the assembly in a small bucket while timing with a stopwatch. The bucket would then be weighed and the results converted to a flow per time. Multiple timed catches at each pressure were performed and averaged. The pressure would then be increased, and allowed to once again stabilize before once again performing a timed catch and weighing of the backflow to determine the backflow rate. Pictures of typical drainage flow and backflow testing are shown in Figures 8 and 9, respectively.

TEST RESULTS

Tables 1 and 2 present the flow test data collected during testing in 2019 and 2020, respectively. Tables 3 and 4 present the backflow test data collected. The data is presented in flow vs. pressure graphs in Figures 10 thru 14.

Figure 8. Typical Drainage Flow Test

Figure 9. Typical Reverse Flow Test

Table 1. Drainage Flow Testing Data – October 2019

Test #	Diameter, in.	Filter Fabric	Face Plate	Back-Flow Prev. Valve	Louver Cover	Pressure, psi	Water Level, ft	Water Depth, ft	Weir-based Flow, gpm	Catch-based Flow, gpm	Average Flow, gpm	Comments
1	4	FW300	16 hole	No	No	1.5	3.430	0.500	59.8	66.6	63.2	4", FW300 cone, 16-hole face plate
						2.0	3.500	0.570	82.9	86.4	84.7	
						3.0	3.580	0.650	115.2	111.2	113.2	
2	4	FW300	16 hole	No	Yes	2.0	3.335	0.405	35.3	37.8	36.5	4", FW300 cone, 16-hole face plate, louver cover
						4.0	3.470	0.540	72.4	74.6	73.5	
						7.5	3.590	0.660	119.6	121.5	120.6	
3	4	FW300	16 hole	Yes	Yes	2.0	3.310	0.380	30.1	31.1	30.6	4", FW300 cone, Std valve, 16-hole face plate, louver cover
						4.0	3.365	0.435	42.2	46.2	44.2	
						17.0	3.540	0.610	98.3	96.6	97.4	
4	4	FW300	none	No	No	2.5	3.595	0.665	121.9	n/a	121.9	4", FW300 3-dimensional cone only
5	4	FW700	none	NO	No	2.5	3.290	0.360	26.3	27.8	27.0	4", FW700 3-dimensional cone only
6	4	FW402	none	No	No	2.5	3.595	0.665	121.9	n/a	121.9	4", FW402 3-dimensional cone only
7	4	FW404	none	No	No	2.5	3.490	0.560	79.3	79.4	79.4	4", FW404 3-dimensional Cone only
8	4	FW300	None	No	No	2.5	3.445	0.515	64.4	62.6	63.5	4", FW300 2-dimensional circle

Table 2. Drainage Flow Testing Data – July/August 2020

Test #	Diameter, in.	Filter Fabric	Face Plate	Back Flow Prev. Valve	Louver Cover	Pressure, psi	Water Level, ft	Water Depth, ft	Weir-based Flow, gpm	Catch-based Flow, gpm	Average Flow, gpm	Comments
9	3	FW300	none	No	No	2.5	3.250	0.515	57.7	60.8	59.3	3", FW300 3-dimensional cone only
10	3	FW300	8 hole	No	No	2.5	3.225	0.490	51.0	53.3	52.2	3", FW300 cone, 8-hole face plate
11	3	FW300	8 hole	No	Yes	1.0	3.050	0.315	16.9		16.9	3", FW300 cone, 8-hole face plate, louver cover
	3	FW300	8 hole	No	Yes	2.5	3.175	0.440	39.0	45.3	42.1	
	3	FW300	8 hole	No	Yes	5.0	3.300	0.565	72.8		72.8	
12	3	FW300	none	No	No	2.5	3.170	0.435	37.9	39.4	38.6	3", FW300 2-dimensional circle
13	6	FW300	none	No	No	2.5	3.470	0.735	140.5		140.5	6", FW300 2-dimensional circle
14	6	FW300	24 hole	Yes	Yes	1.0	3.175	0.440	39.0		39.0	6", FW300 cone, 24-hole face plate, Std Valve, louver cover
						2.5	3.220	0.485	49.7		49.7	
						5.0	3.275	0.540	65.0		65.0	
15	6	FW300	24 hole	No	Yes	0.5	3.560	0.825	187.6		187.6	6", FW300 cone, 24-hole face plate, louver cover
						2.5	3.680	0.945	263.4		263.4	
16	6	FW300	72 hole	No	Yes	0.5	3.570	0.835	193.3		193.3	6", FW300 cone, 72-hole face plate, louver cover (Note: Geotextile separated from cone during highest pressure test.)
						2.5	3.670	0.935	256.5		256.5	
						3.7	3.710	0.975	284.8		284.8	

Table 3. Backflow Testing Data – October 2019

Test #	Diameter, in.	Filter Fabric	Face Plate	Back-Flow Prev. Valve	Louver Cover	Pressure (psi)	Weight, grams	Time, minutes	Catch-based Flow, oz/min	Catch-based Flow, gph	Comments
1	4	FW300	16 hole	Yes	No	2	82.58	5.0	0.583	0.005	4", FW300 cone, Std Valve, 16 hole face plate, No cover
						5	85.31	5.0	0.602	0.005	
						10	188.36	5.0	1.329	0.010	
						15	118.39	2.0	2.088	0.016	
						20	535.85	2.0	9.451	0.074	

Table 4. Backflow Testing Data – July/August 2020

Test #	Diameter, in.	Filter Fabric	Face Plate	Back Flow Prev. Valve	Louver Cover	Pressure (psi)	Weight, grams	Time, minutes	Catch-based Flow, oz/min	Catch-based Flow, gpm	Comments
2	3	FW300	8 hole	Yes	Yes	2.5	0	5.0	0.000	0.00	3", FW300 cone, Std Valve, 8-hole face plate, louver cover
						5.0	933	5.0	6.582	0.05	
3	4	FW300	16 hole	Yes	Yes	2.5	208	6.0	1.223	0.01	4", FW300 cone, Std Valve, 16-hole face plate, louver cover
						5.0	91	5.0	0.642	0.01	
						7.5	42	5.0	0.296	0.00	
						10.0	94	5.0	0.663	0.01	
						15.0	106	2.5	1.496	0.01	
						20.0	450	2.0	7.937	0.06	
4	6	FW300	72 hole	Std	Yes	0.5	935	1.75	18.846	0.15	6", FW300 cone, Std Valve, 72-hole face plate, louver cover
						1.0	1089	1.50	25.608	0.20	
						2.5	987	1.0	34.815	0.27	

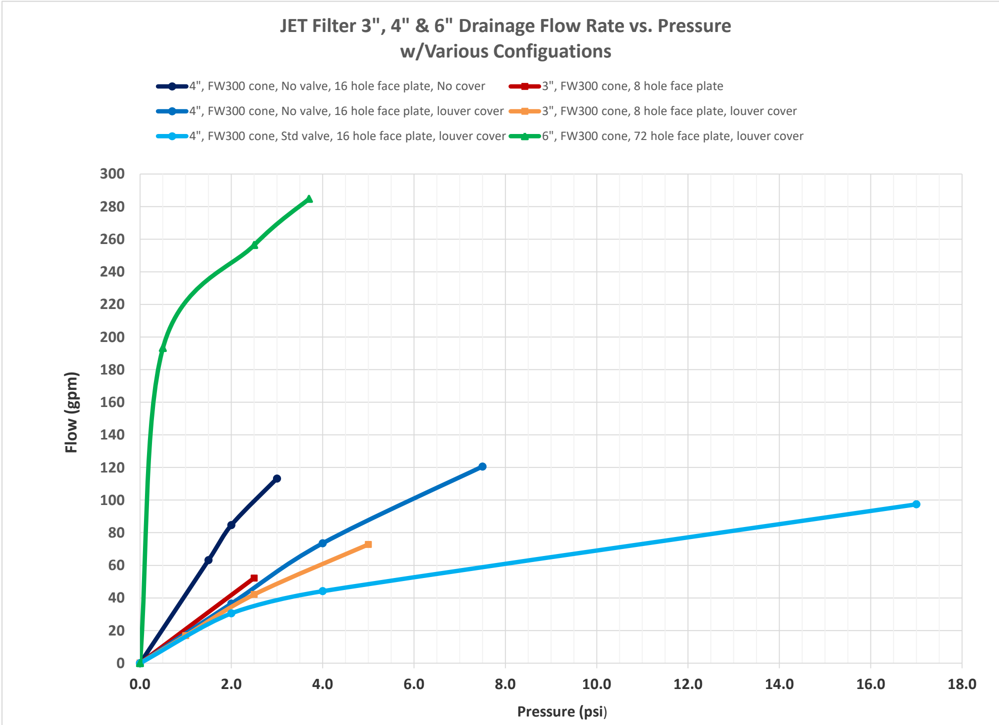

Figure 10. Full Pressure Range of Drainage Flow Tests

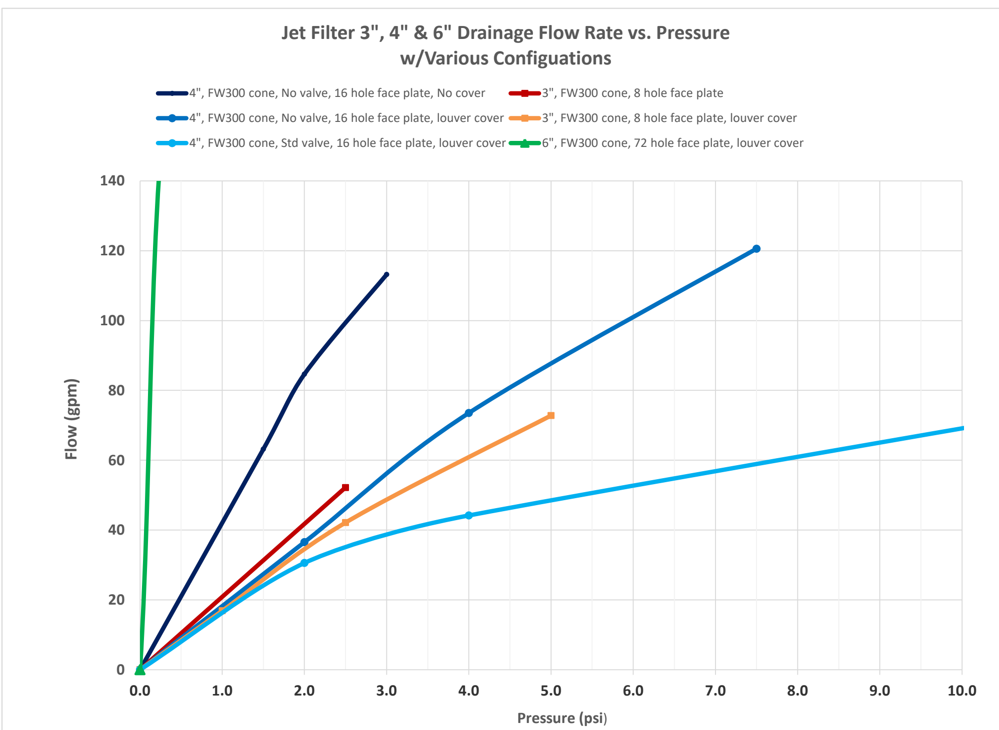

Figure 11. Mid-Pressure Range of Drainage Flow Tests

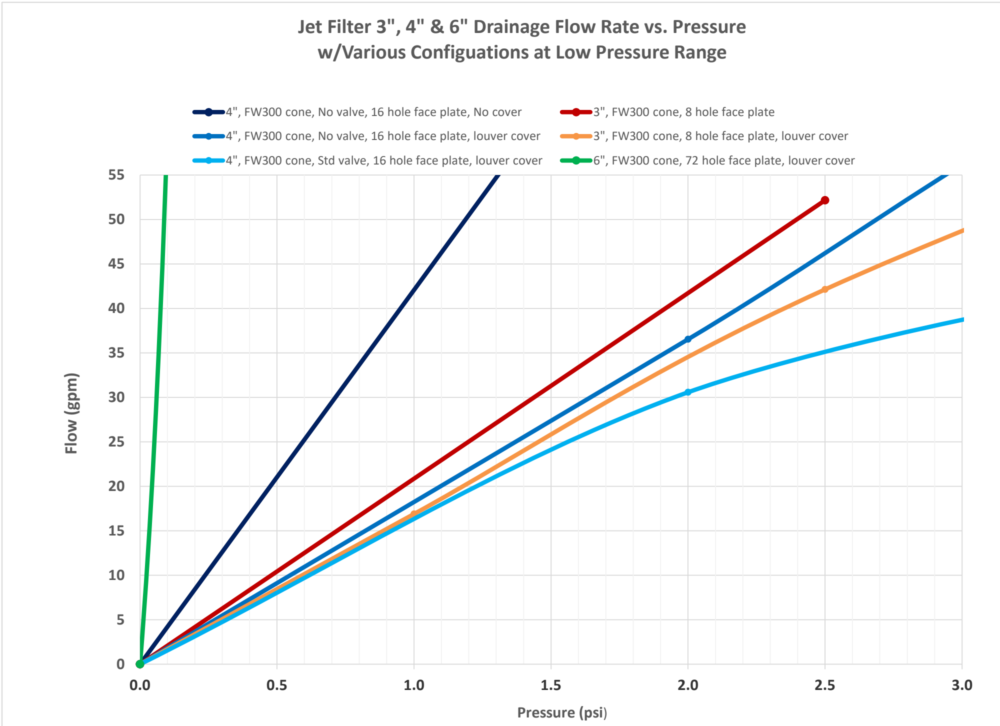

Figure 12. Low Pressure Range of Drainage Flow Tests

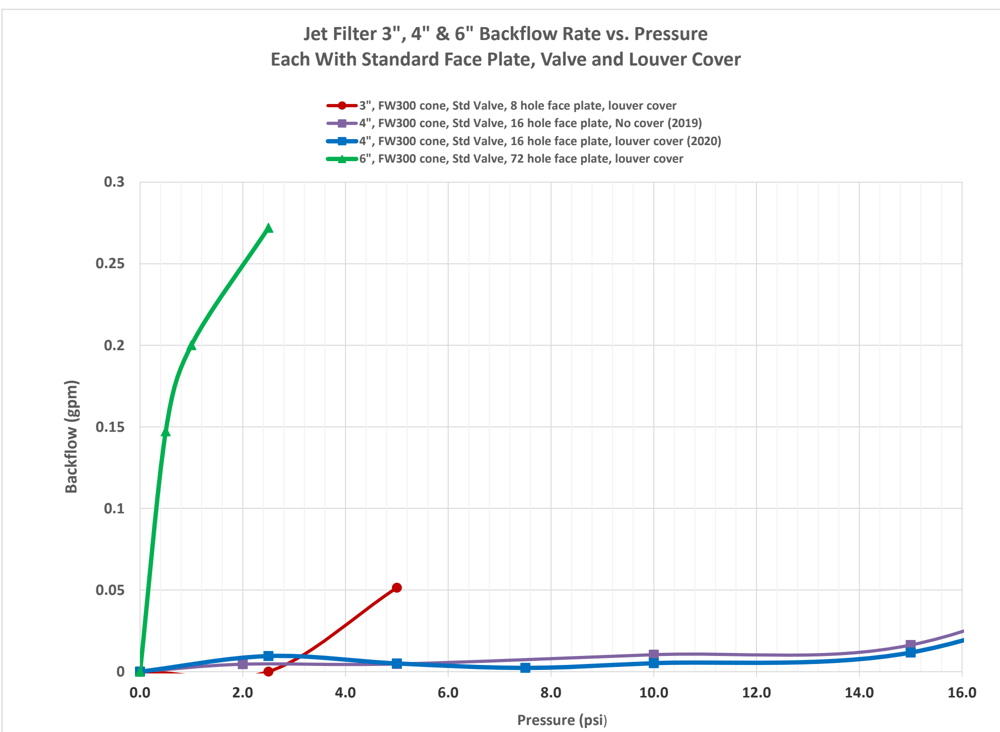

Figure 13. Full Pressure Range of Backflow Tests

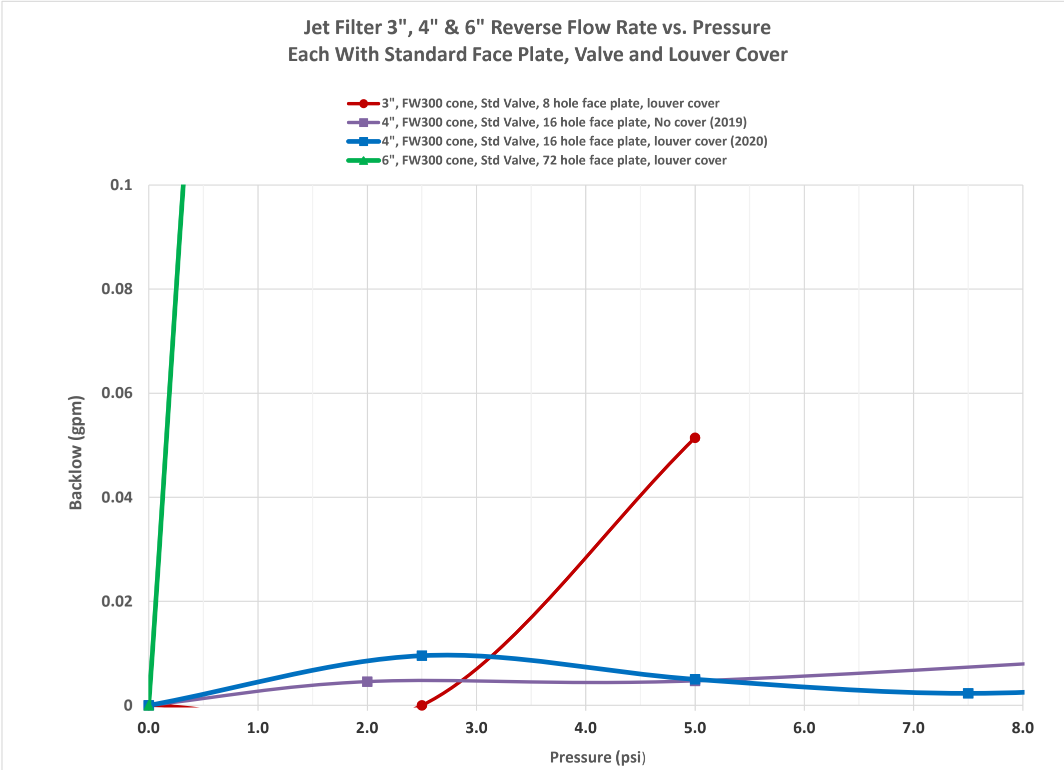

Figure 14. Low and Mid-Pressure Range of Backflow Tests

Observations and Discussion

Drainage flow rates and backflow rates determined from full-scale testing have been summarized in Tables 1 through 4 and Figures 10 through 14. Some important observations can be made by examining the data and comparing results from different sizes and configurations developed at the same pressure head. Following are some observations based on results at 2.5 psi (approx. 70 inch head).

1) Drainage flow rate capacity of JET Filter products is dependent on both the unit's size and the accessories that are added to the standard product. The larger the JET Filter product diameter the greater the product surface area and the greater the flow capacity. As expected, adding additional components reduces the total drainage flow rate. It should be noted that all the measured drainage flow rates are significantly greater than common backfill soil permeabilities and associated groundwater flow rates. Table 5 provides drainage flow rates for various sizes and configurations of JET Filters.

Table 5. Drainage Flow Capacity of Various JET Filter Sizes and Configurations

JET Filter Unit & Weep Hole Diameter	Open-End Design		Closed-End
	Standard Open-End w/Face Plate	+Louvered Vent	+ Backflow Prevention Valve
3 in.	52.2	42.1	Not Tested
4 in.	100.0	47.0	35.0
6 in.	> 256.5[2]	256.5	50.0[1]

[1] 6" test with backflow valve was conducted on a 24-hole face plate. [2] Based on testing that included a louvered vent.

2) Table 6 and Figure 15 provide comparative flow data between traditional weep hole drainage systems and the JET Filter System's conical shaped products. A traditional weep hole with a geotextile behind the wall has a flow capacity limited by the two-dimensional surface area of geotextile covering the circular cored hole. The conical JET Filter presents a three-dimensional "face" to the soil backfill which provides a much larger geotextile surface area through which the flow can pass.

Table 6. 2-Dimensional Geotextile vs. 3-Dimensional Filter Cone

Drainage Flow Rate Capacity (gpm @2.5 psi) Traditional 2D vs. Jet Filter 3D Technology				
Weep Hole Diameter	Surface Area of Conical Geotextile	Traditional 2D Weep Hole w/Geotextile	Jet Filter Conical 3D (Housing & Filter Cartridge	Percent Improved Flow Rate
3"	17.4 in^2	38.6	59.3	154%
4"	26.0 in^2	63.5	121.9	192%
6"	76.5 in^2	140.5	263+[1]	187+%[1]

1. The 6"- 3D Conical Jet Filter exceeded testing limits and is estimated to be much greater than the 263+ gpm measured in the test with the 24 hole face plate & louver cover (Test #15)

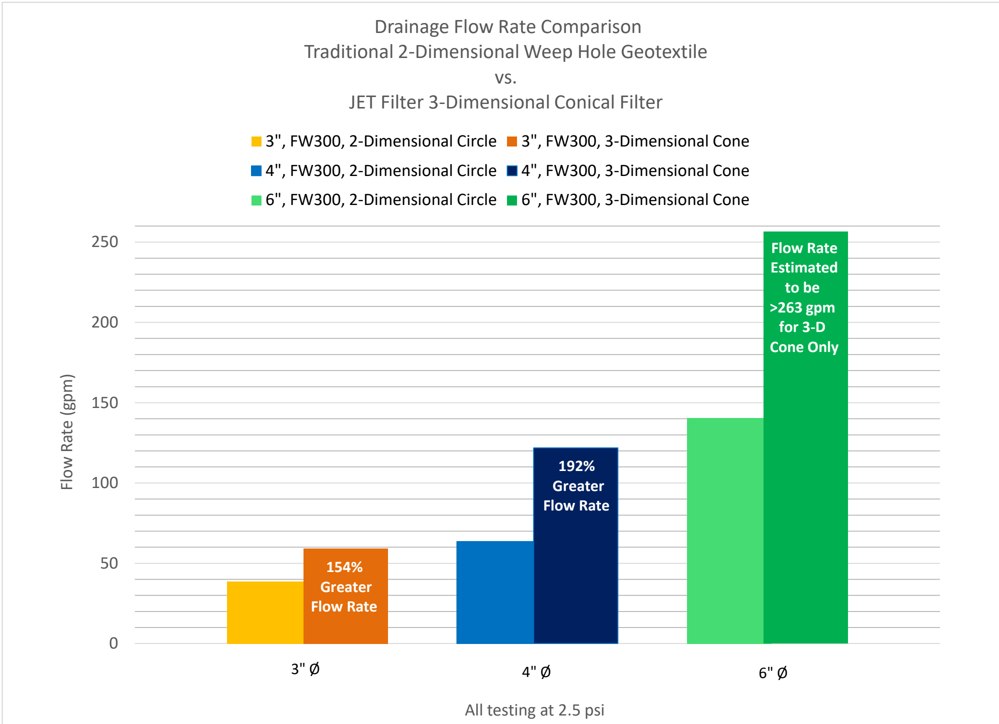

Figure 15. 2-Dimensional Circle vs. 3-Dimensional Cone

3) Backflow testing of JET Filter System's standard backflow prevention valves confirmed that the valves are effective in minimizing backflow into the core of the JET Filter, especially in the smaller diameter units.

Table 7. JET Filter Backflow Rates

Backflow Rate with Backflow Prevention Valve @2.5 psi	
Unit Size	Gallons / Minute
3"	0.000
4"	0.010
6"	0.272

4) The flow characteristics of the geotextile significantly influence the drainage flow capacity of the JET Filter unit. Geotextile manufacturers publish flow rate values for their products that are determined in accordance with ASTM D4491 as a part of their manufacturing quality control programs. Figure 16 shows the influence of the type of geotextile on the flow capacity of 4" JET Filter units. Table 8 presents the geotextile manufacturer's published values for these same geotextiles along with the JET Filter flow results from testing. Figure 17 shows the strong relationship between JET Filter flow capacity at 2.5 psi and the geotextile manufacturer's published flow data, though it appears that the maximum flow capacity of the 4-inch

JET Filter is limited by the cone structure as shown by the flow capacity peaking at 121.9 gpm for both FW300 and FW402 even though the FW 402 has a higher flow capacity.

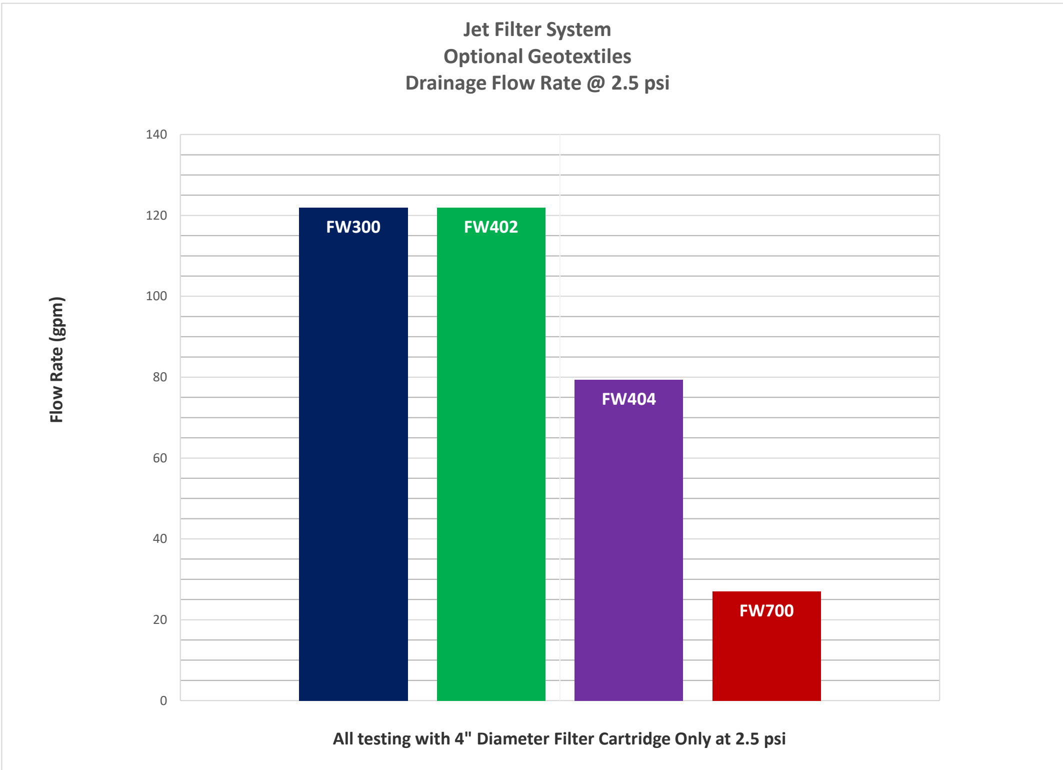

Figure 16. Drainage Flow Rate of Various Geotextiles

Table 8. Comparison of Published Geotextile Flow Properties vs.
JET Filter 4" Units Tested Flow Rate

Data Source	FW300	FW402	FW404	FW700
JET Filter Tested Flow Rate (gpm)	121.9	121.9	79.4	27
Manufacturer's Published Flow Rate (gpm/ft^2)	115	145	70	18
Manufacturer's Published Permittivity (sec.$^{-1}$)	1.5	2.1	0.9	0.28

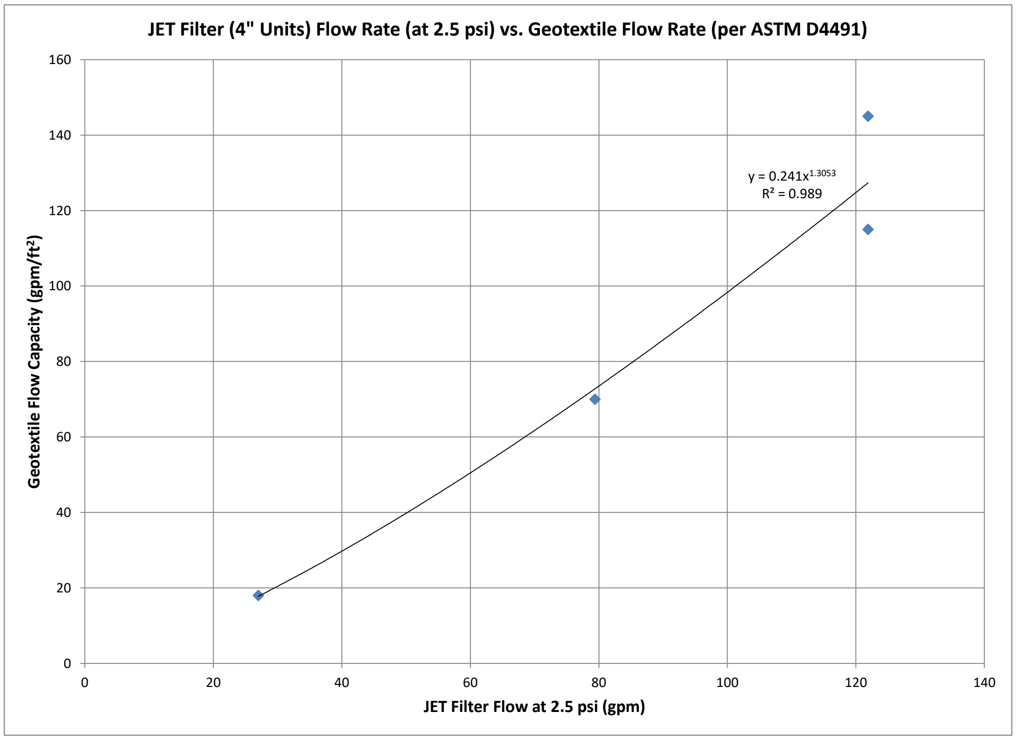

Figure 17. JET Filter Flow Rate vs. Geotextile Flow Rate

Conclusions

This testing program quantified the drainage flow rate vs. pressure characteristics of Open-End JET Filter units and the drainage flow rate vs. pressure and backflow rate vs. pressure characteristics of Closed-End JET Filter units. The testing established the performance characteristics of a range of JET Filter sizes and configurations. All tests were conducted with standard components based on the bill of materials for each model size. All applied pressures were unrestricted by opposing pressure. All tests were conducted using clean recirculating water.