Data-based Headworks Design – The Value of Field Test Data for Screening Design

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ABSTRACT
To support the upgrade and replacement of existing coarse and fine mechanical screens at a large wastewater treatment facility treating a combined sewer system, field data was collected to analyze the solids capture effectiveness of different screen size and type combinations. Each facility's wastewater influent is different, and different types of screens perform differently at different facilities. This paper shows the value of collecting screen performance field data to better inform screening facility equipment upgrade decisions.

KEYWORDS
Headworks design, fine screens, coarse screening, screen capture testing

BACKGROUND
Alexandria Renew Enterprises (AlexRenew) is the public wastewater agency in Alexandria, Virginia. AlexRenew's 54 MGD WRRF treats over 13 billion gallons of wastewater annually from Alexandria and portions of Fairfax County. In 2020, AlexRenew commissioned a study to improve the performance, operability, maintainability, and redundancy of the WRRF's preliminary and primary treatment systems. A key part of this effort was an evaluation of the coarse and fine screening systems which protect the facility from debris entering the plant from the combined sewer system.

The AlexRenew WRRF accepts wastewater from a combined sewer system that includes various debris. The existing coarse screens provide the first line of defense to the treatment facility equipment particularly the Raw Sewage Pump Station (RSPS). The current coarse screens are mechanical climber type raked bar screens with 2-5/8" clear opening between bars, each rated for 60 MGD. The discharge conduits from the RSPS convey flow to the fine screens. The existing fine screening system includes four 40 MGD continuous self-cleaning moving media fine screens with ¼ inch openings, four associated screening washer/compactors, and two shaftless screw screening conveyors.

Both sets of screens were installed in 2005 and are nearing the end of their useful life. Although the coarse screens have served to protect the influent pumps from significant clogging problems, the limited screenings capture by the large bar opening size has resulted in most of the leaves, rags, and other debris in the influent passing downstream to the fine screens. The plant staff has observed a significant amount of screenable material passing through the screens and into the downstream grit removal system and primary settling tanks. These materials cause clogging of the grit and primary sludge pumps, buildup of floatable solids in the scum removal system, and buildup of rags in the gravity thickeners as shown in Figure 1.

Figure 1 ***Materials Passing Downstream of the Screens***

APPROACH

Available plant data was reviewed to analyze the performance of the existing screening systems. Figure 2 shows the historical coarse screen removal quantities vs. influent flow.

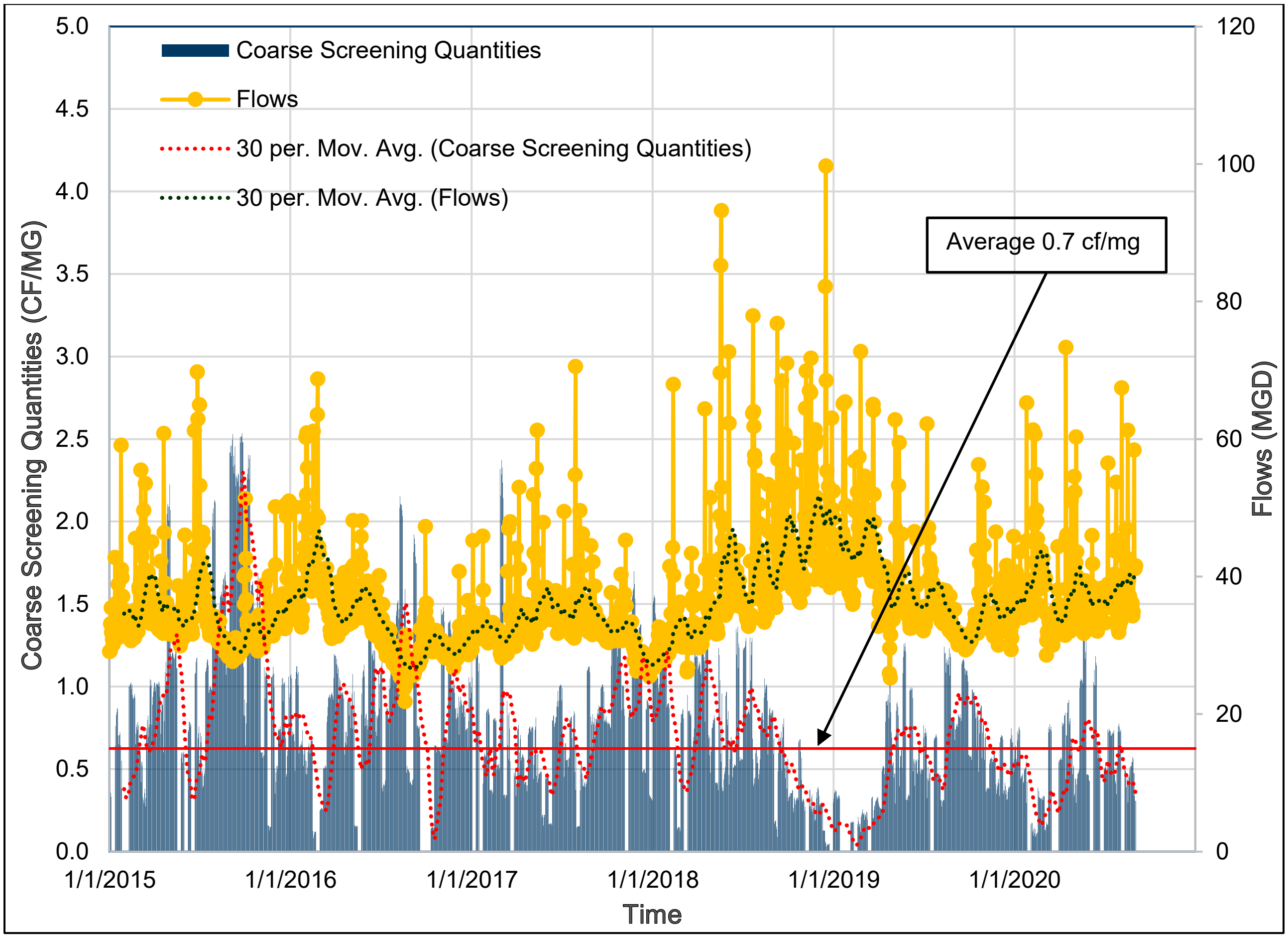


Figure 2 ***Historical Coarse Screening Removal***

The data indicates that the average coarse screening removal rate ranges from 0.2 to 2.5 cubic feet per million gallons (CF/MG), with an average of 0.7 CF/MG. This is comparable to the average coarse screening removal rate for a 50 mm (2") screen of 0.8 CF/MG shown published in industry standard reference documents as shown in Table 1.

Table 1 ***Typical Screen Removal Rates***[1]

Screen Opening Size	Volume of Screening Removed (CF/MG) – Range	Volume of Screenings Removed (CF/MG) – Average
6 mm (1/4")	7-13.5	9.5
12.5 mm (1/2")	5-10	7.0
25 mm (1")	2-5	3.0
37.5 mm (1.5")	1-2	1.5
50 mm (2")	0.5-1.5	0.8

Note:
1. From Metcalf & Eddy Wastewater Engineering, 5th Edition, Table 5-2.

Historical data for the fine screens was also reviewed. However, AlexRenew measures the combined tonnage of grit, fine screenings, and thickened grease hauled by a contractor. Due to combined material data, an accurate measurement of the fine screenings removed from the system cannot be determined.

To obtain better data to serve as the basis for design for a proposed screening upgrade project, Hammerhead Onsite Screen Sizing (H.O.S.S.) testing was performed to measure the quantity of screenings captured and screenings escaped per volume treated for different combinations of coarse and fine sieve alternatives in series. Coarse test sieves included those with smaller opening sizes (i.e., 25 mm (1”), 19 mm (3/4”), and 12 mm (1/2”)) than the existing 2-5/8”, slotted screen. Fine test sieves included those with the same opening size and geometry as the existing fine screens (6 mm (1/4”), slotted) as well as sieves with smaller opening sizes and/or another geometry (i.e., 6 mm (1/4”) perforated plate and 4 mm (3/16”) perforated plate).

Testing occurred over the course of two days and was conducted by placing a submersible pump upstream of the coarse screen in the influent channel, approximately 2/3 of the channel depth (4’ deep in the existing 6’ deep channel) and at the approximate center of the channel, to pump wastewater through a series of coarse and fine sieve alternatives in series and discharge back into the channel.

The testing apparatus consists of a solids handling pump, piping, flow meter, pressure sensors, a sieve (i.e., screen) assembly, and a Programmable Logic Controller (PLC). As shown in Figure 3, the sieve assembly allows for two screens, a coarse screen and fine screen, to be tested in series to mimic dual screening operations.

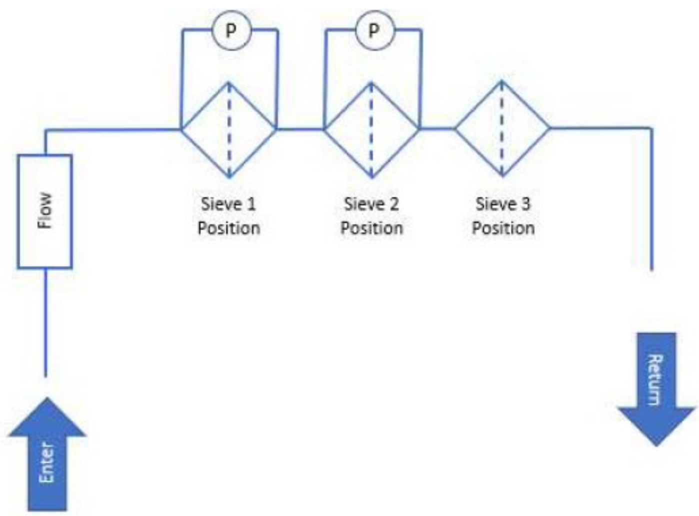


Figure 3 ***Testing Equipment Setup Schematic (courtesy Hydro-Dyne Engineering, Inc.)***

Prior to each test, the screen grid type (slotted or perforated plate), opening size, test duration, and maximum differential pressure are programmed into the PLC. Each test runs for a prescribed test time, or until the maximum pressure is reached for the selected screen grid and opening size. The PLC collects the test duration, flow rate through the testing apparatus, and differential pressure across each of the sieves. Once the test is complete, the sieves are removed from the sieve assembly, where the collected material is visually examined, photographed, and then cleared from the screen panels for the captured material to be weighed.

Several combinations of sieve assemblies were tested at the AlexRenew WRRF. As mentioned previously, coarse screen tests included 25 mm, 19 mm, and 12 mm slotted sieves, and no sieve to mimic the existing coarse screen. The fine screen tests included 6 mm slotted, 6 mm perforated plate, and 4 mm perforated plate sieves. The witness sieve, shown as sieve 3 position in Figure 3, is a 2 mm perforated plate sieve for each test run to establish the performance of the various size combinations against the consistent 2 mm perforated plate sieve. Table 2 presents the various sieve combinations and the associated test group. There was a total of 12 test groups and each test group was tested four times for a total of 48 test runs.

Table 2 ***Sieve Combination Test Groups***

Coarse Screen Sieve 1 Position	**Fine Screen Sieve 2 Position**			**Witness Sieve 3 Position**
	6 mm Slotted	6 mm Perforated Plate	4 mm Perforated Plate	
25 mm Slotted	**A**	**B**	**C**	2 mm Perforated Plate
19 mm Slotted	**D**	**E**	**F**	
12 mm Slotted	**G**	**H**	**I**	
None	**J**	**K**	**L**	

RESULTS

Test data is compiled for each test including photos of each sieve used, and mass of screenings weighed. Photographs from two of the testing runs are shown in Figure 4 and Figure 5 as a visual example of some of the test data collected. The PLC recorded the differential pressure across the screen grids and the flow through the equipment. The data obtained was used to calculate a screen capture ratio, evaluate a screen blinding rate, and determine the appropriate screening opening size and grid type.

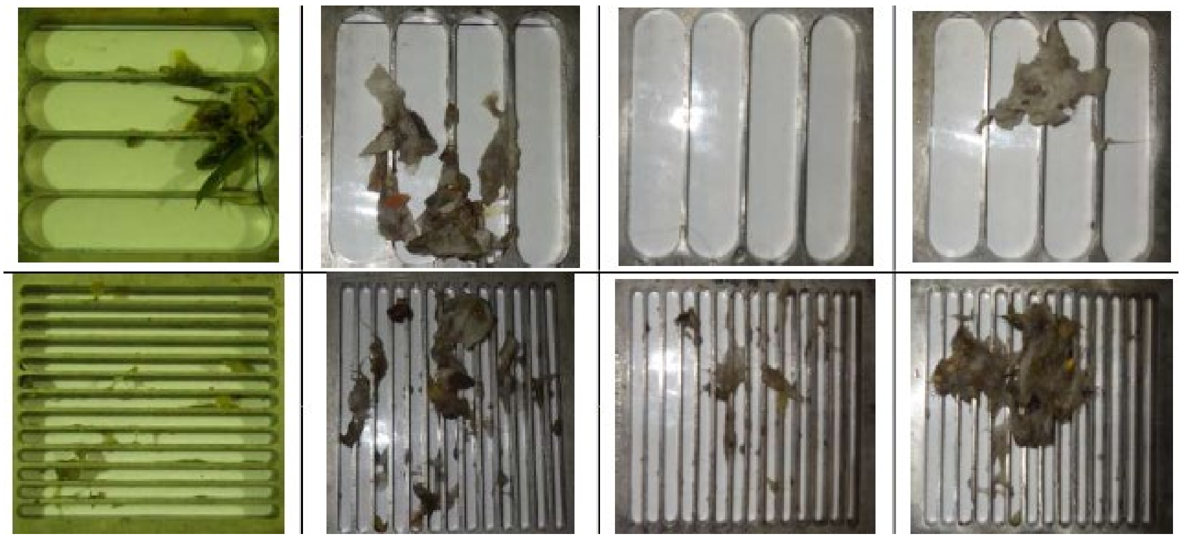


Figure 4 Example of test results for 25 mm (1") slotted coarse screen followed by 6 mm (1/4") slotted fine screen

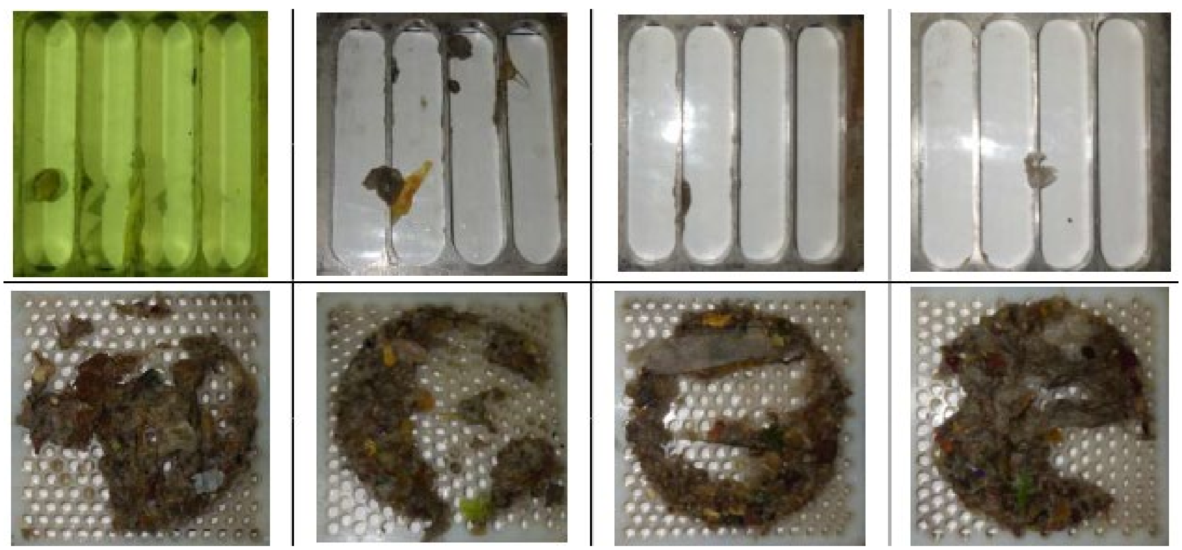


Figure 5 Example of test results for 25 mm (1") slotted coarse screen followed by 6 mm (1/4") perforated plate fine screen

Table 3 shows the screenings quantities captured and escaped for the coarse screen options tested. Each coarse screen opening size and type was tested 12 times, four runs per test group and three different combinations of the succeeding fine screen per test group.

Table 3 Screenings Quantities Captured and Escaped for the Coarse Screen Options Tested [1]

Screen Opening Size and Type	Screening Capture Rate (g/gallon)	Screening Capture Rate (CF/MG) [2]	Screening Escaped Rate (g/gallon) [3]
25 mm (1") – Slotted	0.03	1.21	0.39
19 mm (3/4") – Slotted	0.05	2.06	0.41
12 mm (1/2") – Slotted	0.07	2.73	0.42

Notes:
1. Based on Hammerhead Onsite Screen Sizing (H.O.S.S.) testing conducted by Hydro-Dyne Engineering, Inc., December 13 and 14, 2021.

2. Based on national average screening density of 55 lb/cf per WEF Manual of Practice No. 8 6th Edition, page 11-7.
3. Screenings that passed through the upstream sieve combinations and were captured on the downstream 2 mm perforated plate witness sieve

Coarse screening capture rates from the testing were compared to the historical screening capture rate for the current 2-5/8" coarse screen of 0.7 CF/MG. Based on the testing, a 1" coarse screen is predicted to remove 1.7 times more screenings than the current screen, while a ¾" coarse screen is predicted to remove 2.9 times more material than the current screen. The screenings escaped are the screenings that passed through the upstream sieve combinations and were captured on the downstream 2 mm perforated plate witness sieve. The screening capture rate is compared against the screening escaped rate to determine the performance of the screen opening size and type.

Table 4 shows the screenings quantities captured and escaped for the specific fine screen grid types and opening sizes tested. Each fine screen opening size and type was tested 16 times, four runs per test group and four different combinations of the preceding coarse screen per test group.

Table 4 ***Screenings Quantities Captured and Escaped for the Fine Screen Options Tested [1]***

Screen Opening Size and Type	Screening Capture Rate (g/gallon)	Screening Capture Rate (CF/MG) [2]	Screening Escaped Rate (g/gallon)
6 mm (1/4") – Slotted	0.10	3.99	0.27
6 mm (1/4") – Perforated Plate	0.24	9.70	0.22
4 mm (1/6") – Perforated Plate	0.36	14.49	0.16

Notes:
1. Based on Hammerhead Onsite Screen Sizing (H.O.S.S.) testing conducted by Hydro-Dyne Engineering, Inc., December 13 and 14, 2021.
2. Based on national average screening density of 55 lb/cf per WEF Manual of Practice No. 8 6th Edition, page 11-7.

Average screening capture rates recorded during the testing for the 6 mm slotted screen were much lower than the reported national average of 9.5 CF/MG for a 6 mm screen reported in Metcalf & Eddy Wastewater Engineering, 5th Edition, Table 5-2. The reason for this difference is likely related to the significant variation of screenings capture rate observed on the 6 mm slotted screen during the testing, which ranged from 0.03 to 0.15 g/gallon across the four test groups. With the larger screen openings, a single large object captured during one of the test runs can have a significant impact on the average recorded screening removal. The screens with smaller opening sizes exhibited much more consistency during the testing – for example the 6 mm perforated plate screen data measured the same 0.23 g/gallon in 3 of the 4 test groups and only slightly more (0.29 g/gallon) in the fourth test group.

It should be noted that the 9.7 CF/MG capture rate observed during the testing for the 6 mm perforated plate screen is very close to the reported national average of 9.5 CF/MG for a 6 mm screen reported in Metcalf & Eddy Wastewater Engineering, 5th Edition, Table 5-2.

Compared to the measured 3.99 CF/MG fine screen capture rate for the current 6 mm slotted screen, the 6 mm perforated plate is predicted to remove 2.4 times more material, while the 4 mm perforated plate is predicted to remove 3.6 times more material. Despite the improved capture ratio, a significant amount of potentially screenable material still passed through the 4 mm perforated plate screen. However, the potential high headloss associated with the finer screen openings, particularly under peak flows and fall leaf loadings, made fine screen openings smaller than 6 mm undesirable for this facility.

Keep in mind the screenings testing was performed under average dry weather flow conditions. Screenings capture rates during a high flow event, particularly one in the fall which may receive high volume of leaves entering into combined sewer inlets, would be expected to be much higher. The screening testing conducted at the AlexRenew WRRF required a significant amount of advance planning and coordination so it was not possible to conduct the screening testing during the worst case scenario, which would be a large storm occurring in the fall at the same time there is a large amount of debris buildup in the collection system and a significant amount of leaves on the streets in the combined sewer service area.

The amount of screenings passing through the screens (which is defined as the amount of material captured by a 2 mm perforated plate screen) is consistently high for all coarse screen opening sizes, indicating that most screenable material will still pass through the screens even if a finer coarse screen is installed. The on-site screen testing was not able to capture leaf removal efficiency, but it would be expected that a finer coarse screen size and perforated plate type fine screen would remove a significantly greater percentage of leaves than the current coarse screens, which would help off-load the fine screens during a fall storm event with significant quantities of leaves in the wastewater flow.

Slug samples were also collected from the fine screens washer/compactor units to determine the volume and density of the washed and compacted material. Table 5 presents an overview of the fine screen washer/compactor samples collected.

Table 5 Fine Screen Washer/Compactor Slug Samples

Sample Number	Weight (lbs)	Diameter (in)	Length (in)	Density (lb/CF)
1	15.3	12	9	26
2	14.5	12	8	28
3	3.1	12	2	24
4	4.5	12	3	23

The observed density of the compacted fine screenings at AlexRenew is less than the reported national average of 55 lb/cf (WEF Manual of Practice No. 8 6th Edition, page 11-73). The washer/compactor samples collected concluded that the existing washer/compactor units are dewatering and compressing the screening slugs, however they are not removing the organic material or optimally conditioning the slugs. Improved washing and compaction of the fine screenings would reduce the organic content and moisture content in screenings conveyed to the disposal trailers.

RECOMMENDATIONS

Based on the screen testing, a ¾” flex-rake mechanical coarse screen followed by a 6 mm perforated plate center flow band fine screen was recommended for AlexRenew. This combination of coarse and fine screening is expected to provide the best screenings capture performance at this facility while minimizing the risk of excessive blinding of the screens during peak flow events with heavy screenable solids loadings. The ¾” coarse screen will provide increased screenings capture compared to the current 2-5/8” screen while still being robust enough to handle large objects from the combined sewer system, while the 6 mm perforated plate center flow band fine screen will provide significantly more capture of screenable material without unintentional screenings carryover from the screen cleaning mechanism compared to the current 6 mm slotted fine screen. The new equipment should reduce downstream clogging issues observed in the grit removal, primary sludge and scum pumping systems, and gravity thickeners associated with debris passing through the existing screens. Improved washing/compaction was also recommended to reduce the organic and moisture content of the dewatered screenings and increase dewatered screenings density.

Based on field testing results, the following dry-weather screen performance was measured for the recommended screen combination. Figure 6 presents the screenings captured on each screen for the combination of a ¾” slotted coarse screen and a 6 mm perforated plate fine screen along with the screenings escaped through the sieve combination on the 2 mm perforated plate witness sieve. The 19 mm slotted coarse screen captures some screenings material and will prevent large debris from passing through to downstream equipment. The 6 mm perforated plate fine screen captures much more material than the upstream coarse screen. This will allow the screen to capture smaller particles and prevent material carryover to downstream unit processes. The material observed on the 2 mm perforated plate witness sieve consists predominantly of -organic and some inorganic particles. The inorganic particles consisted of bits of wipes and fibrous material. There were only a few instances of inorganics found on the 2mm perforated sieve.

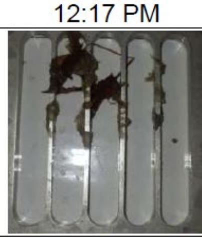
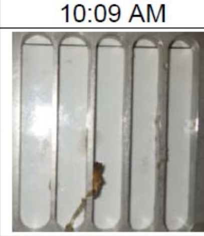
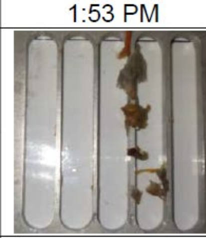
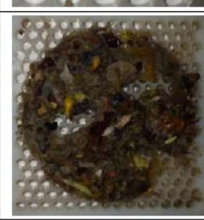
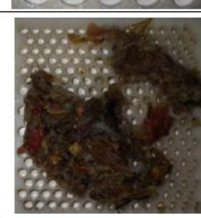
Table E: 19S-6P	Test 6	Test 19	Test 33	Test 46
Time	12:17 PM	2:46 PM	10:09 AM	1:53 PM
Coarse Sieve - a: 19mm Slot				
Fine Sieve - b: 6mm Perf				
Witness Sieve - c: 2mm perforated				

Figure 6 Images of Test Group E Results - 19 mm Slotted Coarse Screen and 6 mm Perforated Plate Fine Screen

Table 6 outlines the field testing results of the ¾” slotted coarse screen and a 6 mm perforated plate fine screen combination. The percentages of screenings captured in this test group ranged from 42%-59%, with an average screenings capture of 52%.

Table 6 Test Group E Results by Screening Opening Size and Type

	Test 6		Test 19		Test 33		Test 46	
Screen Opening Size and Type	**Screening Capture Rate (g/gallon)**	**Screening Capture Rate (CF/MG) [2]**	**Screening Capture Rate (g/gallon)**	**Screening Capture Rate (CF/MG) [2]**	**Screening Capture Rate (g/gallon)**	**Screening Capture Rate (CF/MG) [2]**	**Screening Capture Rate (g/gallon)**	**Screening Capture Rate (CF/MG) [2]**
Coarse Sieve A: 19 mm Slotted	0.035	1.414	0.031	1.242	0.004	0.161	0.018	0.731
Fine Sieve B: 6 mm Perforated Plate	0.210	8.404	0.184	7.360	0.201	8.035	0.261	10.450
Witness Sieve C: 2 mm Perforated Plate	0.345	13.824	0.210	8.415	0.157	6.308	0.191	7.663
Total Screenings Captured	0.245	9.818	0.215	8.602	0.205	8.196	0.279	11.181
Total Screenings Escaped	0.345	13.824	0.210	8.415	0.157	6.308	0.191	7.663
Screenings Captured (%)	42%		51%		57%		59%	

Notes:
1. Based on Hammerhead Onsite Screen Sizing (H.O.S.S.) testing conducted by Hydro-Dyne Engineering, Inc., December 13 and 14, 2021.
2. Based on national average screening density of 55 lb/cf per WEF Manual of Practice No. 8 6th Edition, page 11-7.

During each test period, the differential pressure across the sieves and the flow rate were recorded. Evaluation of the pressure gradients is important in selecting the correct screen combination. High differential pressures indicate high pressure across the screening surface which will create high head loss through the screen and reduce capture rates by pushing screenings through the surface. A rapidly increasing pressure curve illustrates a screen that is experiencing high pressures across the screening surface and is therefore too small resulting in the material matting and blinding the screen surface. In contrast, a slow increasing pressure curve or flat curve indicates that the screen opening size is too large and results in material carryover to downstream unit processes. Figure 7 presents the differential pressure of each screen opening size and type from Test Group E.

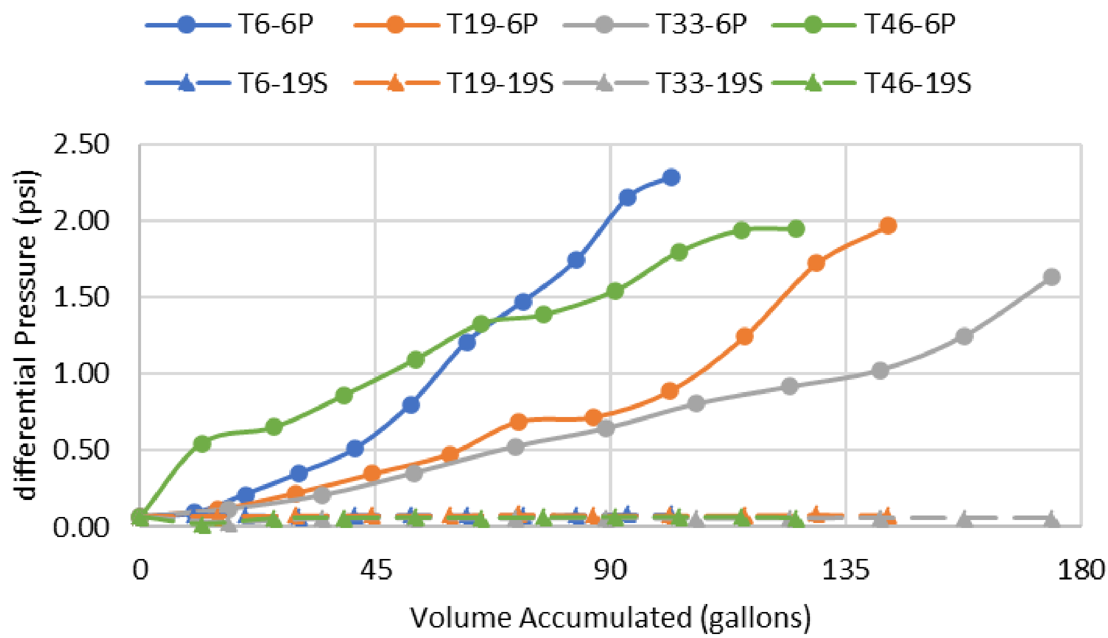


Figure 7 Test Group E (i.e., T- Test; #, Test number) Screen Size (in mm) and Opening Type (P-Perforated, S-Slotted) Headloss Curves

The gradual pressure curves of the 6 mm perforated plate fine screen in Figure 7 indicate it is an adequate fine screen selection that will capture screenings while minimizing the risk of excessively blinding the screen surface. The 19 mm slotted coarse screen shows a very flat pressure curve which indicates that the large screen opening size had limited solids capture under the test conditions. However, the goal of the coarse screening system at AlexRenew is to prevent large debris from passing through to downstream equipment and remove some screenings to reduce the load on the fine screens during high loading events. The 19 mm slotted coarse screen will provide increased screenings capture compared to the current 2-5/8” (67 mm) screen while still being robust enough to handle large objects from the combined sewer system.