NJCAT TECHNOLOGY VERIFICATION

Kraken® Membrane Filtration System

Bio Clean Environmental Services, Inc.

(With April 2016 Addendum and February 2022 Round Kraken Filter Models)

February 2016

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1. Description of Technology

The Kraken® Filter is an engineered storm water quality treatment device utilizing a reusable membrane filter designed to remove high levels of TSS, hydrocarbons, and particulate bound metals and nutrients found in contaminated storm water. Each filter contains a large surface area which is designed to deal with high TSS concentrations.

The Kraken® Filter has sedimentation chambers that are utilized as a form of pre-treatment for floatables, oils, coarser sediments and other suspended particulates. Once the water exits the pre-treatment chamber, it passes through the filter chamber orifices and into the filtration chambers where the membrane filters are located.

The membrane filters are used to filter out finer micron sediments and particulate bound contaminants. The filter's efficiency is controlled by an internal riser tube so the filters will only begin to process and discharge once the water level has reached to the top of the filter column, close to the maximum hydraulic grade line in the filtration chamber. The riser tubes control the flow rate to a level substantially less than the flow capacity of the membrane filters and ensure that the sediment loading is evenly distributed along the full height of the cartridge.

Each filter chamber includes one drain down cartridge which has an additional small drain orifice at the bottom of the tube to allow the chambers to drain dry after each storm event. Since the standard cartridges have risers, there is no positive pressure on the influent side of the filter membrane during the drain down period, thereby allowing sediment which has accumulated on the surface of the membrane to be flushed off.

The Kraken® Filter is also designed with an internal bypass weir. The bypass weir is located at the effluent end of the pre-treatment chamber and allows runoff to pass directly from pre-treatment chamber to discharge chamber without passing through the filtration chambers. Water passes over the bypass weir once incoming flow exceeds the system's treatment capacity. This prevents scouring of fine sediment captured in the filtration chambers.

Figure 1 shows a cut-away view of the system's pre-treatment, filtration, and discharge chambers.

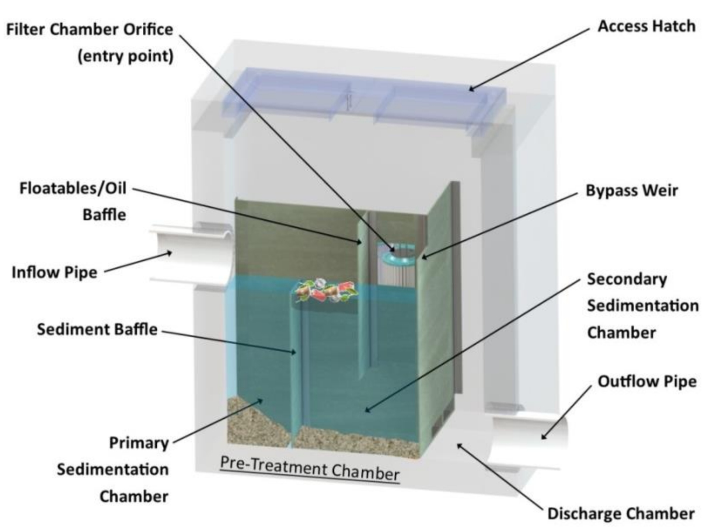


Figure 1 Kraken® Design

2. Laboratory Testing

The test program was conducted by Good Harbour Laboratories, an independent water technology testing lab, at their site in Mississauga, Ontario. Testing occurred during the month of August, 2015. The Kraken® Filter that was tested in the laboratory was identical to a commercially available unit with the exception that it did not have a concrete top that would be associated with a unit installed below grade. For lab testing there was no need for a concrete top as it would inhibit access to the unit. There was no effect on testing by not having a top on the unit.

Laboratory testing was done in accordance with the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January, 2013)*. Prior to starting the performance testing program, a quality assurance project plan (QAPP) was submitted to and approved by the New Jersey Corporation for Advanced Technology (NJCAT).

2.1 Test Setup

The Kraken® Filter tested was a commercially available Membrane Filtration System, model KF-4-4, dimensional details are provided in **Figure 2**. This unit has a total sedimentation area of 11.72 ft^2 and 16 filters, providing an effective filtration treatment area of 2720 ft^2. The KF-4-4 model enables the results to be scaled to all other Kraken® Filter Models (**Table A-3).**

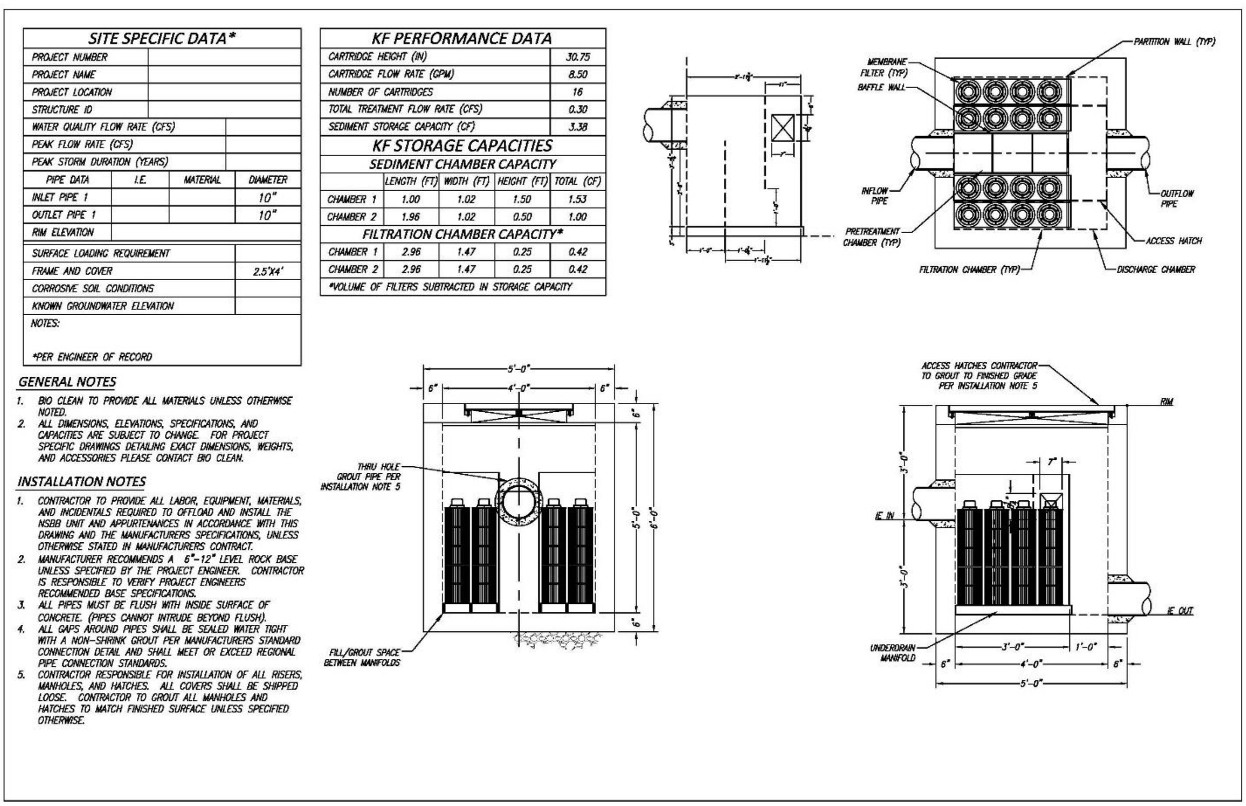


Figure 2 Kraken® Filter KF-4-4

The laboratory test setup was a water flow loop filled with potable water. The loop was comprised of water reservoirs, pumps, stand pipe, receiving tank and flow meters, in addition to the Kraken®

Filter. The total water capacity of the system was approximately 10,000 gallons. The test flow loop is illustrated in **Figure 3** and **Figure 4**.

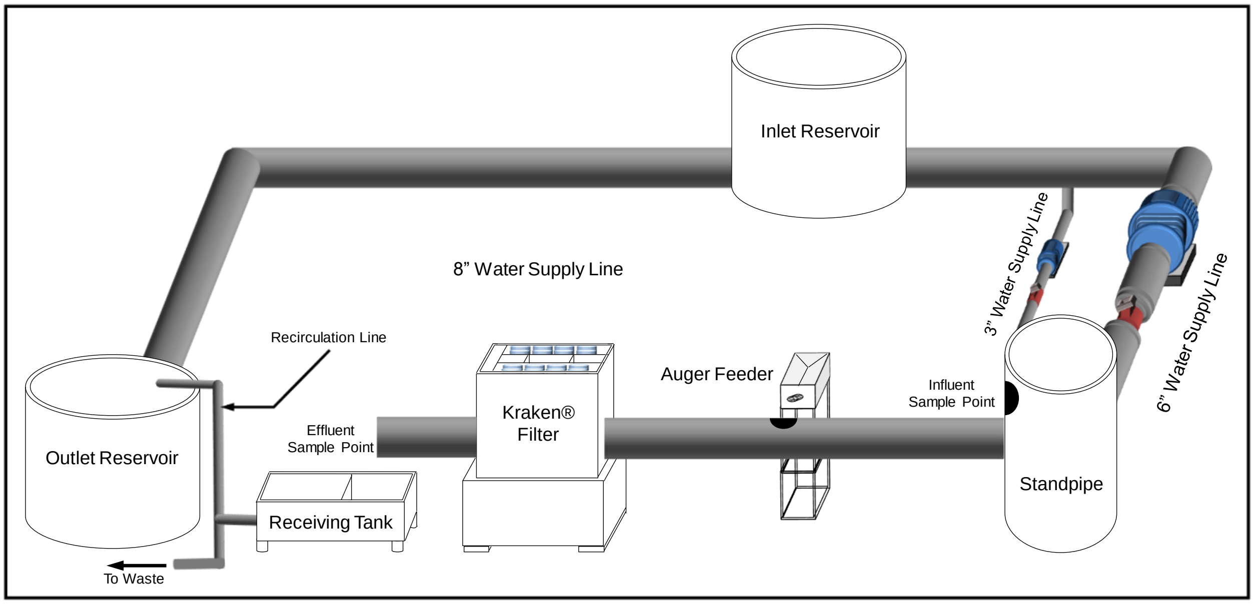


Figure 3 Test Flow Loop

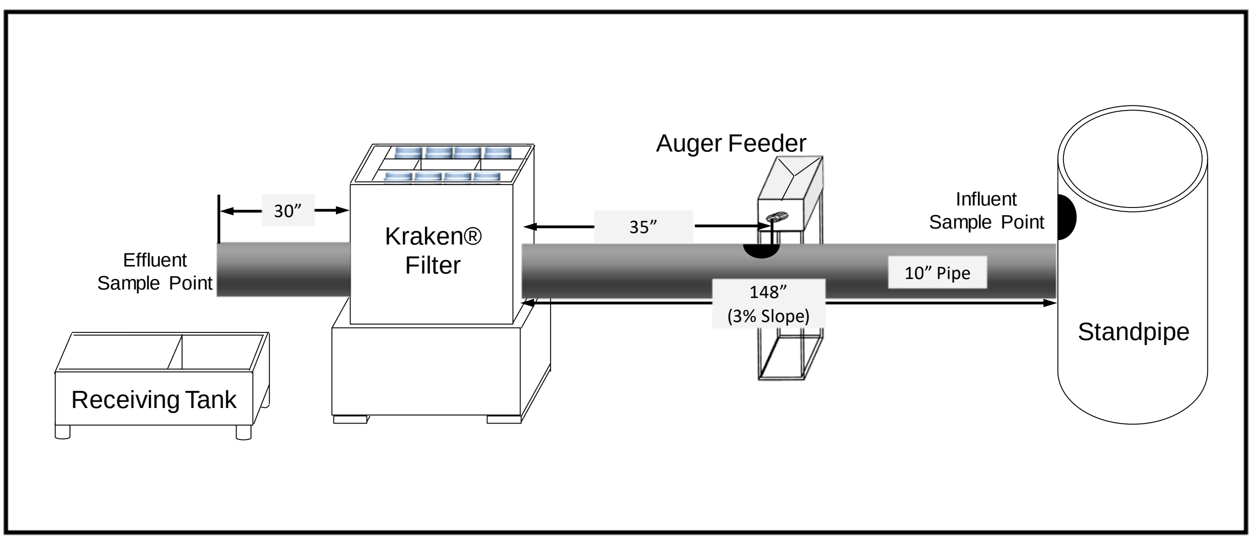


Figure 4 Test Flow Loop Detail

Water Flow and Measurement

From the inlet reservoir, water was pumped using a WEG Model FC00312 centrifugal pump through a 3″ PVC line to the standpipe. Flow measurement was done using a Toshiba Model GF630 mag-type flow meter and a MadgeTech Process 101A data logger. The data logger was configured to record a flow measurement every minute.

From the standpipe, water flowed by gravity through a 10″ inlet pipe to the Kraken® Filter. The influent pipe was 148 inches long with a slope of 3%. Water flow exited the Kraken® Filter through a 10″ pipe stub (30 inches long) and terminated with a free-fall into the Receiving Tank. From the Receiving Tank, water was either pumped to waste or into the Outlet Reservoir.

Sample Collection

Background water samples were grabbed by hand by submerging a 1L sample jar beneath the surface of the water in the stand pipe, at the mouth of the influent feed line **(Figure 5).**

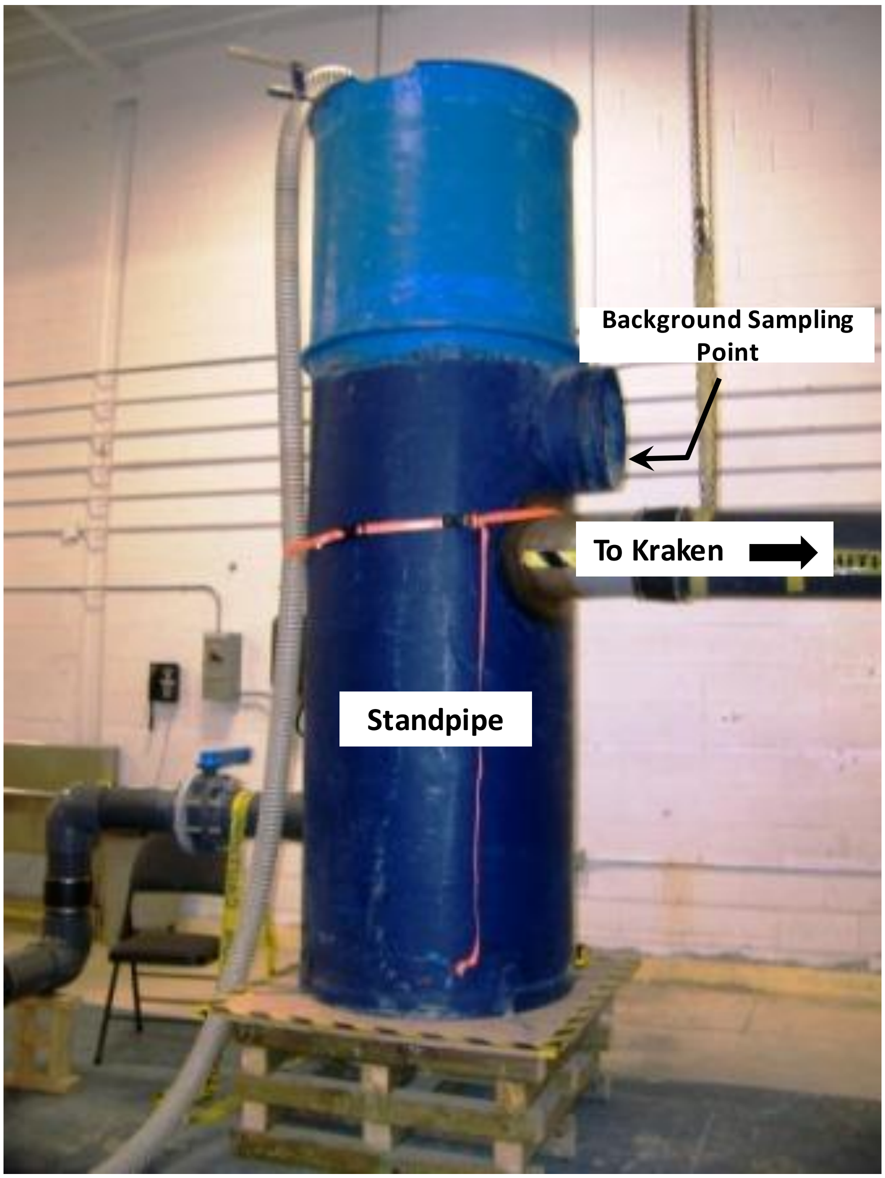


Figure 5 Background Sampling Point

Effluent samples for the Removal Efficiency and Sediment Mass Loading tests were also grabbed by hand. The effluent pipe drained freely into the Receiving Tank and the effluent sample was taken at that point (**Figure 6**). The sampling technique was to take the grab sample by sweeping a wide-mouth 1L jar through the entire stream such that the sample jar was full after a single pass.

Figure 6 Effluent Sampling – Removal Efficiency Test

Other Instrumentation and Measurement

Effluent water temperature was taken at the end of the effluent pipe, as the flow discharged into the Receiving Tank, using a Kangaroo Model 21800-68 digital thermometer.

The water level in the Kraken® Filter during the run was taken in the Secondary Sedimentation Chamber against the baffle wall, next to the bypass weir. Measurements were taken using a yard stick with 1/8″ resolution. A second yard stick was also set up in one of the filtration chambers to allow for the calculation of the water volume during drain down.

Run and sampling times were measured using a stopwatch (Control Company Model X4C50200C).

Sediment addition occurred through the crown of the inlet pipe, 35 inches (3.5 pipe diameters) from the Kraken® Filter inlet (**Figure 7**). The sediment feeder was an Auger Feeders Model VF-1 volumetric screw feeder with a 5/8″ or 7/8″ auger, spout attachment and 1.5 cubic foot hopper. The sediment feed samples that were taken during the run were collected in 500 mL jars and weighed on an analytical balance (Mettler Toledo Model AB204-S).

Figure 7 Sediment Addition Point

2.2 Test Sediment

The test sediment used for this study was a custom blend of two commercially available silica sediments. The blend ratio was determined such that the particle size distribution of the resulting blended sediment would meet the specification for the Filter Test Protocol. The sediment was blended using a small cement mixer in nine batches. Following each batch, 2 X 30 mL sediment samples were placed in each of three 1 L jars, the samples were taken from random positions throughout the cement mixer. When blending was complete, each sample jar contained 540 mL of sediment. The blended sediment was stored in sealed plastic-lined fiber drums until needed.

The three sediment samples were sent to Maxxam Analytical in Mississauga ON for particle size analysis using the methodology of ASTM method D422-63. The test results are summarized in **Table 1** and shown graphically in **Figure 8**.

Table 1 Particle Size Distribution of Test Sediment

Particle Size (µm)	Test Sediment Particle size (%passing)				NJDEP Specification (minimum % Passing)
	Sample 1	Sample 2	Sample 3	Average	
1000	98.5	98.3	98.0	98	98
500	95.0	94.9	94.2	95	93
250	89.8	90.3	88.5	90	88
150	79.9	79.2	78.0	79	73
100	65.2	65.9	66.8	66	58
75	58.8	58.2	70.9	63	48
50	47.3	48.7	51.7	49	43
20	34.4	36.5	38.0	36	33
8	18.0	18.1	18.9	18	18
5	11.8	12.4	13.0	12	8
2	6.8	6.8	7.1	7	3

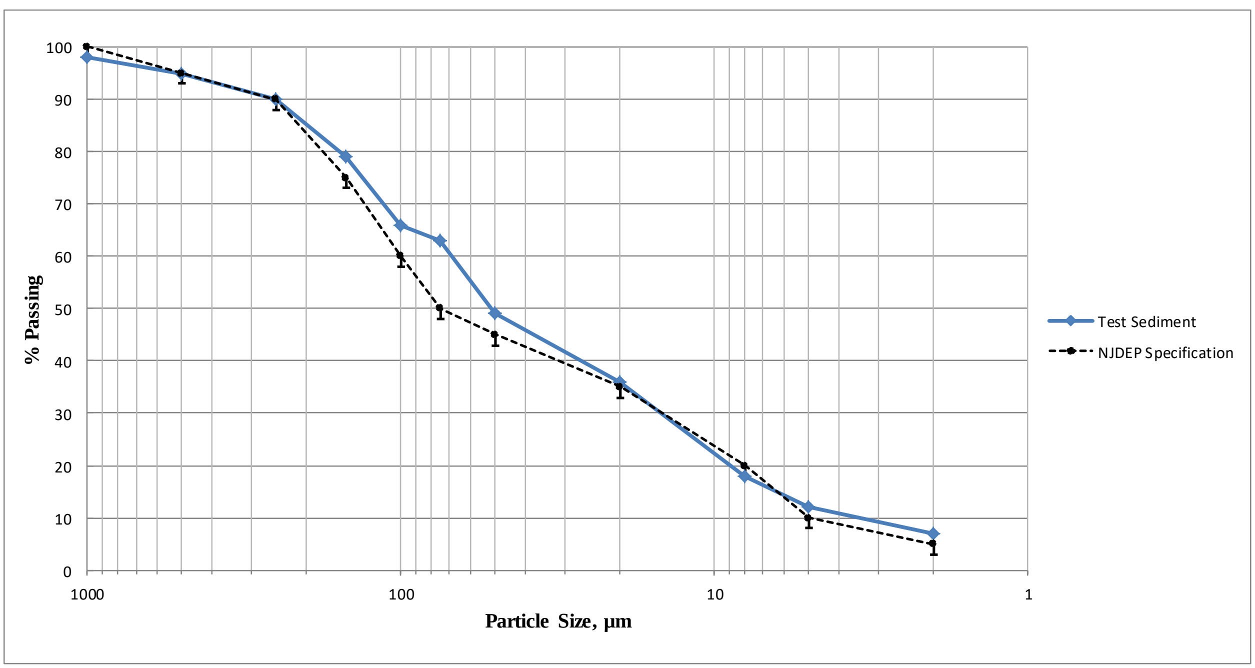


Figure 8 Average Particle Size Distribution of Test Sediment

In addition to particle size distribution, Maxxam Analytics also performed a moisture analysis of the test sediment and determined the water content to be < 0.30%, the method detection limit.

The blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. With a d_{50} of 52 µm, the test sediment was slightly finer than the sediment required by the NJDEP test protocol.

2.3 Removal Efficiency Testing

Removal Efficiency Testing was conducted in accordance with Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. Testing was completed at a flow rate of 0.303 cfs (136 gpm) and a target sediment concentration of 200 mg/L.

Effluent grab sampling was performed 5 times per run (at evenly spaced intervals), with each run lasting 45 minutes in duration followed by a drain down period. In addition to the effluent samples, 3 background water samples were taken with every odd-numbered effluent sample (1st, 3rd and 5th). In all cases, effluent sampling did not start until the filtration MTD had been in operation for a minimum of three detention times (5.4 minutes). When the test sediment feed was interrupted for measurement, the next effluent sample was collected following a minimum of three detention times. Sampling times for Removal Efficiency testing are summarized in **Table 2**. Effluent and background water samples were collected in clean 1L wide-mouth jars.

The test sediment was sampled 3 times per run to confirm the sediment feed rate, one sample at the start of dosing, one sample in the middle of the test run and one sample just prior to the conclusion of dosing. Each sediment feed rate sample was a minimum of 100 mL and collected in a clean 500 mL jar. Sediment sampling was timed to the nearest 1/100th of a second using a calibrated stop watch and samples were weighed to the nearest 0.1 mg.

It was originally proposed that the water flow through the system would be a closed loop; the water would be recirculated from the Receiving Tank back into the Outlet Reservoir. However after the initial two runs of the Removal Efficiency Test, a concern arose over maintaining the background sediment concentration below 20 mg/L. Therefore, the system was modified so that the effluent was pumped from the Receiving Tank to waste and fresh potable make-up water was added to maintain the water level in the system. The water temperature was measured as the effluent exited the Kraken® Filter with a calibrated thermometer to the nearest 0.1 °C.

Table 2 Removal Efficiency Sampling Frequency

Sample/ Measurement Taken	Run Time (min.)											
	0	1	9	18	19	27	36	37	45	END of RUN	50	55
Sediment		X			X			X				
Effluent			X	X		X	X		X			
Background			X			X			X			
Drain down											X	X

The drain down sample was collected at the end of each removal efficiency run, after the pump had been switched off and the sediment feed stopped. On a clean filter, the drain down period lasted 15 minutes and sampling occurred at 5 and 10 minutes into the drain down period. However, as sediment accumulated in the filtration chambers, the drain down period was extended. Therefore the sampling period was also adjusted, gradually increasing to 10 and 20 minutes after the pump and sediment feed had stopped.

2.4 Sediment Mass Loading Capacity

The sediment mass loading capacity of the Kraken® Filter was determined as a continuation of the Removal Efficiency Testing. All aspects of the test procedure remained the same except that the influent sediment concentration was increased from 200 to 400 mg/L. Sediment Mass loading began after 16 runs of removal efficiency had been completed.

2.5 Scour Testing

At this time the Kraken® Filter System is being submitted for approval for off-line testing; therefore no scour test data was provided.

3. Performance Claims

Per the NJDEP verification procedure, the following are the performance claims made by Bio Clean Environmental Services, Inc. and/or established via the laboratory testing conducted for the Kraken® Filter.

Verified Total Suspended Solids (TSS) Removal Rate

Based on the laboratory testing conducted, the Kraken® Filter achieved greater than 80% removal efficiency of TSS. In accordance with the NJDEP process for obtaining approval of a stormwater treatment device from NJCAT (Procedure; NJDEP 2013) the TSS removal efficiency is rounded down to 80%.

Maximum Treatment Flow Rate (MTFR) and maximum drain down cartridge flow.

The MTFR increases with the Kraken® Filter model size and the number of filtration cartridges. For the tested unit, the Kraken® Filter model KF-4-4, the MTFR was 0.303 cfs (136 gpm) which corresponds to a MTFR to filtration treatment area ratio of 1.11×10^{-4} cfs/ft^2 (0.05 gpm/ft^2).

Each Kraken® Filter is designed so that there is 1 drain down cartridge for every 7 filter cartridges. The drain down flow is regulated by a drain down orifice, sized so that a clean filter drains down in 15 minutes. The drain down flow rate is expected to decrease as the filters ripen.

Maximum Sediment Storage Depth and Volume

The sedimentation and treatment volume varies with the Kraken® Filter model size. For the KF-4-4, the total storage capacity is 4.5 ft^3 (as determined during this laboratory testing), which includes the Primary Sedimentation, Secondary Sedimentation and two Filter chambers.

Effective Treatment/Sedimentation Area

The Effective Treatment and Sedimentation areas are the same for the Kraken® Filter and will increase with increasing model size. For the Kraken® Filter KF-4-4, the effective treatment/sedimentation area is the combined area of all the chambers, 11.72 ft^2.

Detention Time and Wet Volume

The Kraken® Filter detention time and wet volume will vary with model size. The unit tested had a wet volume of 32 ft^3 which corresponded to a detention time of 1.8 minutes at the test flow rate of 0.303 cfs.

Effective Filtration Area

The effective filtration area varies with the number of cartridges installed in the Kraken® Filter unit. The KF-4-4 has 16 filters with a total effective filtration area of 2,720 ft^2.

Sediment Mass Loading Capacity

The sedimentation mass loading capacity varies with the Kraken® Filter model size. Based on the laboratory testing results, the KF-4-4 has a mass loading capacity of 434 lbs. (4.5 ft^3).

Maximum Allowable Inflow Drainage Area

Based on the results from the laboratory testing, approximately 434 pounds of sediment (27.1 lbs/cartridge AND/OR 37 lbs/ft^2 of effective treatment/sedimentation area) can be loaded into the KF-4-4, while maintaining an overall 89% removal efficiency. Based on the protocol requirements for "Maximum Allowable Inflow Drainage Area" the KF-4-4 can effectively treat 0.723 acres based on a load of 600 lbs per acre of drainage area annually per the protocol. It should be noted that at 434 pounds of sediment loading the system did not go into bypass. The water level in the system was still several inches from the bypass weir, indicating the system could continue to effectively treat runoff at 0.303 cfs for an extended period of time.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report.

4.1 Removal Efficiency Testing

A total of 16 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 136 gpm and 200 mg/L respectively. The results from all 16 runs were used to calculate the overall removal efficiency of the Kraken® Filter KF-4-4.

Flow Rate

The flow rate was measured using an electromagnetic-type flow meter and data logger configured to take a reading every minute. The run was started as soon as water was observed to be exiting from the Kraken® Filter. For each run, the flow rate was to be maintained within 10% of the target flow with a COV (coefficient of variation) of 0.03. The flow data has been summarized in **Table 3**, including the compliance to the QA/QC acceptance criteria.

The average flow for all removal efficiency runs was 136.0 gpm.

Sediment Addition

The target sediment concentration was 200 ± 20 mg/L with a COV of 0.10. The sediment feed rate for each run was checked three times during each run. The sediment weight checks, feed rates, final concentrations and compliance to QA/QC criteria are summarized in **Table 4**.

Filter Drain Down

The Kraken® Filter is designed with a drain down feature that allows the filter chambers to drain dry after each storm event. The drain down permits sediment which has accumulated on the surface of the membrane to be flushed off thereby extending the life of the filters. As per the NJDEP protocol, the amount of sediment that escapes the filter during the drain period must be accounted for.

The volume of water in the filter chambers was determined by multiplying the chamber area by the water level in the chamber at the end of the run. The water volume was corrected for the displacement volume of the filters. Effluent samples for total suspended solids (TSS), measured as suspended sediment concentration (SSC), determination were taken during the drain down period to permit estimation of the amount of sediment that was lost.

Table 3 Removal Efficiency Water Flow Rate

Run #	Flow (gpm)			COV	QA/QC Compliance (COV < 0.03)	Maximum Water Temperature (°C)
	Min	Max	Average			
1	135.5	140.8	136.2	0.007	Yes	22.1
2	136.0	136.7	136.4	0.001	Yes	20.9
3	131.1	136.1	135.4	0.005	Yes	20.8
4	135.4	138.0	136.6	0.005	Yes	16.1
5	135.5	137.2	136.4	0.003	Yes	15.9
6	125.9	135.4	134.8	0.010	Yes	18.9
7	134.5	135.7	135.2	0.002	Yes	17.2
8	134.7	136.2	135.3	0.003	Yes	16.5
9	135.3	136.6	135.9	0.002	Yes	16.2
10	135.6	137.2	136.3	0.003	Yes	18.8
11	135.6	137.1	136.3	0.003	Yes	17.7
12	136.0	137.5	136.6	0.003	Yes	17.0
13	134.6	137.0	136.0	0.003	Yes	19.3
14	135.4	137.0	136.1	0.003	Yes	17.6
15	135.6	136.9	136.2	0.002	Yes	17.1
16	135.8	137.0	136.2	0.002	Yes	16.6
Overall Average Flow			**136.0**	**gpm**		

A clean Kraken® Filter has a drain down period of approximately 15 minutes, so the initial drain down samples were taken at 5 and 10 minutes. As more sediment accumulated in the filter chambers, the drain down period was extended with the most substantial time increase occurring during the draining of the lower third volume fraction. The sampling times for the drain down samples were adjusted as the drain down period increased. For the purposes of conducting the NJDEP protocol, it was not practical to wait to start the next run. Therefore, runs were started even though the drain down process had not completed. Even though not all the water had drained from the filter chambers, the full filter chamber volume was used to estimate the amount of lost sediment.

The sampling data for the drain down periods are presented in **Table 5**. For the majority of the runs, the drain down samples were taken at 10 and 20 minutes. It is clear from the sediment concentration results that the longer the time for the drain down sample, the lower the sample concentration. Therefore, not extending the sampling time beyond 10 and 20 minutes was a worst case scenario.

Table 4 Removal Efficiency Sediment Feed Rate

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Sediment Concentration* (mg/L)	QA/QC Compliance (COV < 0.1)	Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Sediment Concentration* (mg/L)	QA/QC Compliance (COV < 0.1)
	1	105.7144	60.25	105.3	204.2			1	104.6282	60.03	104.6	203.2	
	19	105.4356	60.16	105.2	204.0			19	105.1987	60.31	104.7	203.4	
1	37	104.6116	60.15	104.4	202.4	Yes	9	37	103.0937	60.00	103.1	200.4	Yes
	Average			104.9	203.5			Average			104.1	202.3	
	COV			0.005				COV			0.008		
	1	105.2325	60.22	104.8	203.1			1	106.4722	60.06	106.4	206.1	
	19	103.1353	60.41	102.4	198.5			19	103.8356	60.03	103.8	201.1	
2	37	102.0098	60.37	101.4	196.4	Yes	10	37	106.3014	60.19	106.0	205.3	Yes
	Average			102.9	199.3			Average			105.4	204.2	
	COV			0.017				COV			0.013		
	1	106.1779	60.18	105.9	206.6			1	103.6329	60.25	103.2	200.0	
	19	103.9488	60.12	103.7	202.5			19	103.5600	60.09	103.4	200.4	
3	37	108.8630	60.15	108.6	211.9	Yes	11	37	103.6979	60.06	103.6	200.8	Yes
	Average			106.1	207.0			Average			103.4	200.4	
	COV			0.023				COV			0.002		
	1	107.1730	60.10	107.0	206.8			1	101.9027	60.03	101.9	196.9	
	19	105.7877	60.15	105.5	204.0			19	100.8734	60.29	100.4	194.1	
4	37	103.5596	60.12	103.4	199.8	Yes	12	37	104.0915	60.03	104.0	201.2	Yes
	Average			105.3	203.6			Average			102.1	197.4	
	COV			0.017				COV			0.018		
	1	107.0487	60.00	107.0	207.4			1	101.9121	59.97	102.0	198.0	
	19	105.1879	59.97	105.2	203.9			19	104.9849	59.94	105.1	204.1	
5	37	105.1524	60.06	105.0	203.5	Yes	13	37	104.2517	60.00	104.3	202.5	Yes
	Average			105.8	204.9			Average			103.8	201.5	
	COV			0.010				COV			0.016		
	1	100.3488	60.28	99.88	195.8			1	101.5009	59.93	101.6	197.2	
	19	101.3634	60.25	100.9	197.8			19	100.3165	60.09	100.2	194.4	
6	37	100.5773	60.10	100.4	196.8	Yes	14	37	100.5082	60.04	100.4	194.9	Yes
	Average			100.4	196.8			Average			100.7	195.5	
	COV			0.005				COV			0.008		
	1	99.5320	60.22	99.17	193.8			1	102.7679	60.06	102.7	199.1	
	19	104.2001	60.09	104.0	203.3			19	106.4613	60.15	106.2	206.0	
7	37	102.3150	60.00	102.3	200.0	Yes	15	37	106.0639	60.12	105.9	205.3	Yes
	Average			101.8	199.0			Average			104.9	203.5	
	COV			0.024				COV			0.019		
	1	97.1518	60.06	97.05	189.5			1	100.0968	60.03	100.0	194.0	
	19	102.8886	60.00	102.9	200.9			19	106.1592	60.25	105.7	205.0	
8	37	103.4748	60.31	102.9	201.0	Yes	16	37	104.9632	60.09	104.8	203.3	Yes
	Average			101.0	197.1			Average			103.5	200.8	
	COV			0.034				COV			0.029		

*Based on the run average water flow rate

Table 5 Removal Efficiency Drain Down Losses

Run #	Water Level at End of Run (inches)	Total Water Volume (L)	Time of Sample (min. from end of run)	Sediment Concentration (mg/L)	Average Concentration (mg/L)	Lost Sediment (g)
1	27	471.3	5	32	27	12
			10	21		
2	27	471.3	5	39	35	16
			10	30		
3	27	471.3	5	38	41	19
			10	43		
4	27	471.3	5	27	22	10
			10	17		
5	27 - 1/4	476.5	6	20	21	10
			12	22		
6	27 - 1/4	476.5	6	20	15	7
			12	10		
7	27 - 1/4	476.5	8	10	7	3
			16	3		
8	27 - 3/8	479.1	10	7	5	2
			20	2		
9	27 - 3/8	479.1	10	7	5	2
			20	2		
10	27-1/2	481.6	10	9	6	3
			20	2		
11	27-1/2	481.6	10	7	5	2
			20	2		
12	28	491.9	10	7	5	2
			20	2		
13	28-1/4	497.0	10	7	5	2
			20	2		
14	28-3/8	499.6	10	6	4	2
			20	2		
15	28-1/2	502.2	10	4	3	2
			20	2		
16	29	512.5	10	3	2	1
			20	1		

Removal Efficiency Calculations

All of the effluent and background samples for SSC were analysed by Maxxam Analytics of Mississauga ON, the results have been summarized in **Table 6**. The required background SSC concentration was < 20mg/L. The limit of detection for the analytical method was 1 mg/L. For the purposes of calculation, any result that was reported as being below the limit of detection (ND), was assigned a value of ½ the detection limit or 0.5 mg/L.

The adjusted average sediment concentration was determined by:

Average effluent concentration – Average background concentration

Table 6 Removal Efficiency SSC Data

Run #	Suspended Sediment Concentration, SSC							QA/QC Compliance (Background < 20 mg/L)
	Run Time (min.)	9	18	27	36	45	Average	
1*	Background	1	-	3	-	8	4	Yes
	Effluent	45	42	43	42	43	43	N/A
	Adjusted Average Sediment Concentration						**39**	
2*	Background	7	-	10	-	13	10	Yes
	Effluent	44	43	43	46	45	44	N/A
	Adjusted Average Sediment Concentration						**34**	
3	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	45	41	43	44	41	43	N/A
	Adjusted Average Sediment Concentration						**42**	
4	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	40	39	37	39	38	39	N/A
	Adjusted Average Sediment Concentration						**38**	
5	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	38	39	37	39	40	39	N/A
	Adjusted Average Sediment Concentration						**38**	
6	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	39	54	37	36	38	41	N/A
	Adjusted Average Sediment Concentration						**40**	
7	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	37	78	42	54	37	50	N/A
	Adjusted Average Sediment Concentration						**49**	

ND – non-detect

* Due to a communication error with the analytical lab, the sample container washout was not included as part of the sample analysis. This error only applies to Runs # 1-2.

Table 6 Removal Efficiency SSC Data (Cont'd)

Run #	Suspended Sediment Concentration, SSC							QA/QC Compliance (Background < 20 mg/L)
	Run Time (min.)	9	18	27	36	45	Average	
8	Background	ND	-	ND	-	2	1	Yes
	Effluent	36	37	34	33	32	34	N/A
	Adjusted Average Sediment Concentration						**33**	
9	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	36	35	33	33	32	34	N/A
	Adjusted Average Sediment Concentration						**33**	
10	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	40	38	34	49	30	38	N/A
	Adjusted Average Sediment Concentration						**38**	
11	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	34	33	31	29	27	31	N/A
	Adjusted Average Sediment Concentration						**30**	
12	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	29	49	26	26	29	32	N/A
	Adjusted Average Sediment Concentration						**31**	
13	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	34	29	27	26	25	28	N/A
	Adjusted Average Sediment Concentration						**28**	
14	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	24	22	19	20	45	26	N/A
	Adjusted Average Sediment Concentration						**26**	
15	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	23	19	30	19	19	22	N/A
	Adjusted Average Sediment Concentration						**22**	
16	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	19	19	16	17	21	18	N/A
	Adjusted Average Sediment Concentration						**18**	

ND – non-detect

The analytical results, along with the run data, were used to calculate the removal efficiency for each run, mass loading and overall removal efficiency average; the results are tabulated in **Table 7.** The removal efficiency was calculated as:

$$\text{Removal Efficiency (\%)} = \frac{\begin{pmatrix}\text{Average Influent}\\ \text{SS Concentration X}\\ \text{Total Volume}\\ \text{of Test Water}\end{pmatrix} - \begin{pmatrix}\text{Adjusted Effluent}\\ \text{SS Concentration X}\\ \text{Total Volume}\\ \text{of Test Water}\end{pmatrix} - \begin{pmatrix}\text{Average}\\ \text{Draindown Flow}\\ \text{SS Concentration X}\\ \text{Total Volume}\\ \text{of Draindown Water}\end{pmatrix}}{\begin{matrix}\text{Average Influent SS Concentration X}\\ \text{Total Volume of Test Water}\end{matrix}} \times 100$$

Table 7 Removal Efficiency Results

Run #	Average Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume gal	Average Drain Down SSC (mg/L)	Volume of Drain Down Water gal	Removal Efficiency (%)	Mass of Captured Sediment (lbs.)
1	203.5	39	5718.3	27	124.5	81	7.8
2	199.3	34	5724.4	35	124.5	82	7.9
3	207.0	42	5683.8	41	124.5	79	7.8
4	203.6	38	5738.3	22	124.5	81	7.9
5	204.9	38	5727.5	21	125.9	81	8.0
6	196.8	40	5659.6	15	125.9	79	7.4
7	199.0	49	5676.3	7	125.9	75	7.1
8	197.1	33	5682.2	5	126.6	83	7.8
9	202.3	33	5707.9	5	126.6	83	8.0
10	204.2	38	5726.0	6	127.2	81	7.9
11	200.4	30	5723.1	5	127.2	85	8.1
12	197.4	31	5737.3	5	129.9	84	7.9
13	201.5	28	5713.2	5	131.3	86	8.3
14	195.5	26	5717.4	4	132.0	87	8.1
15	203.5	22	5719.6	3	132.7	89	8.7
16	200.8	18	5719.7	2	135.4	91	8.7
Average Removal Efficiency						**83%**	
Captured Sediment Mass						**127 lbs.**	

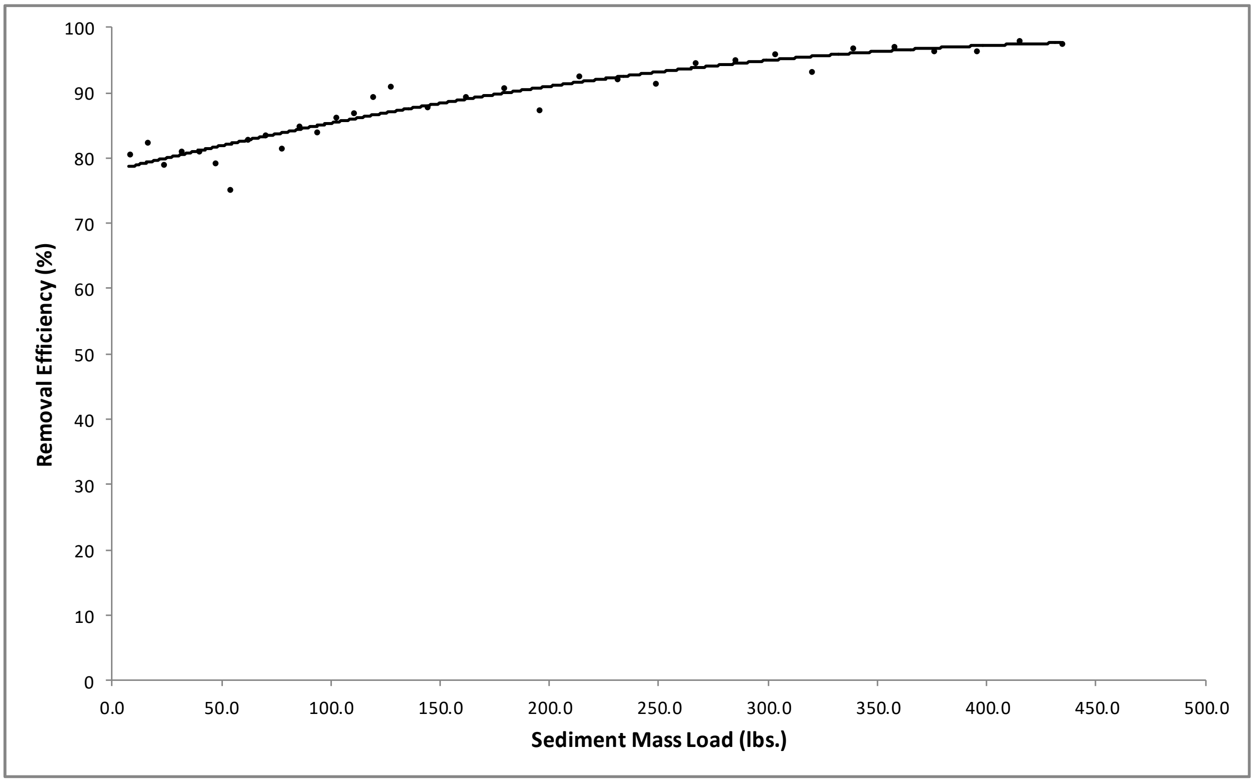
The results are typical for membrane filters in that the removal efficiency increases as the filters begin to ripen. The overall average removal efficiency was 83% for the first 16 runs. Runs #1 and 2 were included in the calculation of the average result, despite the error for the sample analysis indicated on the previous page. If these runs were excluded, there would be no change in the average result. During the Removal Efficiency testing, 127 pounds of sediment was captured in the Kraken® Filter.

4.2 Sediment Mass Loading Capacity

The Sediment Mass Loading Capacity study was a continuation of the removal efficiency study. All aspects of the testing remained the same, except that the feed concentration was increased to 400 mg/L, up from the 200 mg/L used for the removal efficiency test. To achieve the higher sediment feed rate, the 7/8″ auger screw was used. An additional 17 runs were completed for Sediment Mass Loading Capacity testing for a total of 33 runs overall. For Runs 17 – 33, the mass loading water flow rates, sediment feed rates, drain down loses, SSC data and removal efficiencies are presented in **Table 8** to **Table 12** respectively.

The Sediment Mass Loading Capacity test was terminated once the mass of the captured sediment exceeded 1.5X the recommended minimum amount for filter maintenance. By the end of run #33, filter by-pass had not yet occurred. The total mass of sediment captured was 434 lbs. and the overall removal efficiency was 89%. The relationship between removal efficiency and sediment mass loading is illustrated in **Figure 9**.

Figure 9 Removal Efficiency vs Sediment Mass Loading for the Kraken® KF 4-4



4.3 Filter Driving Head

The filter chambers, which drain down in between storm events, have been designed with riser tubes that maintain the hydraulic grade line at a minimum level during operation. The water level in the filter chambers at the end of each run, prior to drain down, has been tabulated in **Tables 5** and **10**. The reported level is the distance from the floor of the filter chamber. **Figure 10** illustrates the increase in driving head across the filters compared to the initial hydraulic grade line of 27 inches.

Figure 10 Increase in Driving Head vs Sediment Mass Load

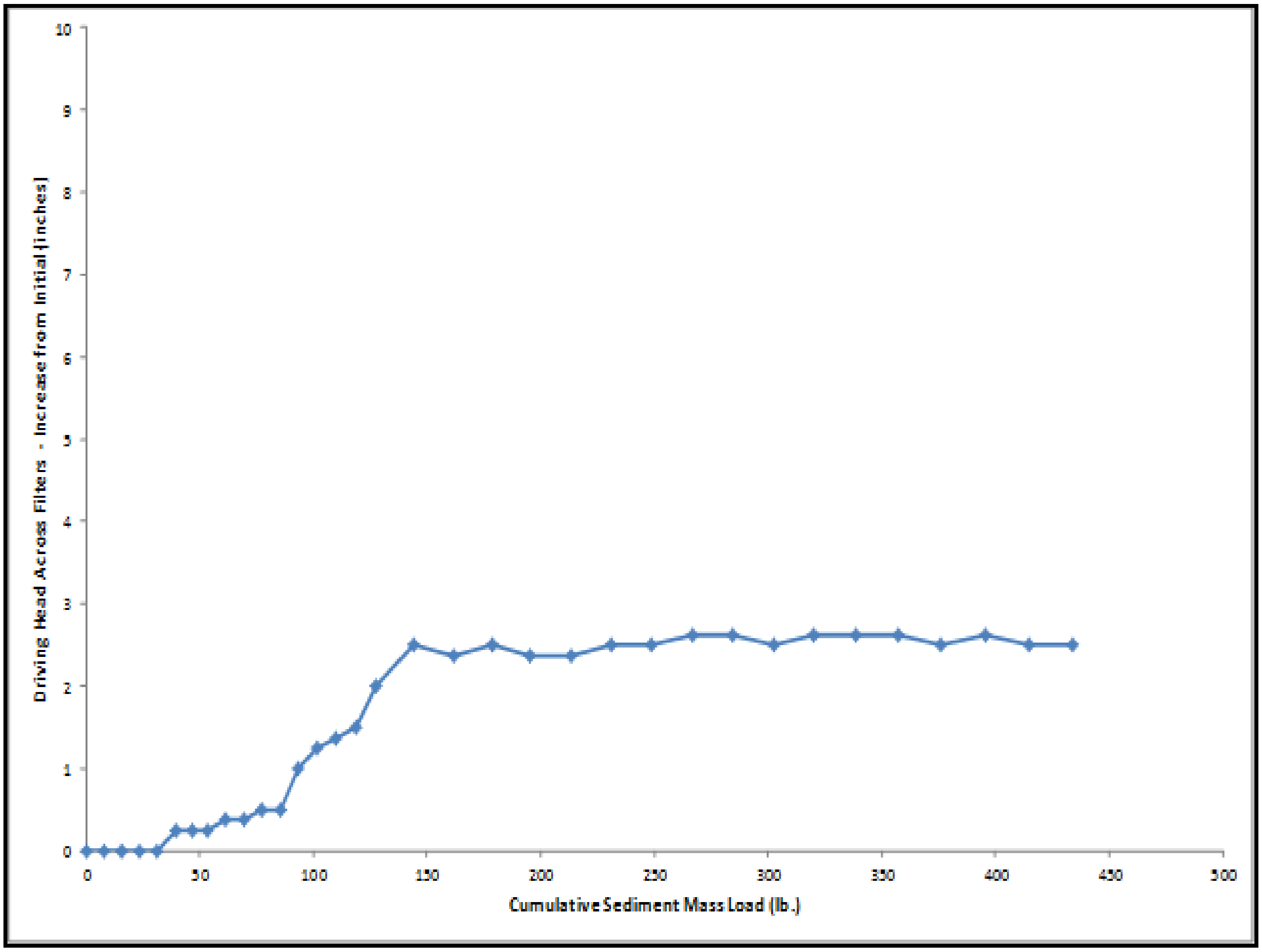


Table 8 Sediment Mass Loading Water Flow Rate

Run #	Flow (gpm)			COV	QA/QC Compliance (COV < 0.03)	Maximum Water Temperature (°C)
	Min	Max	Average			
17	135.4	136.9	136.1	0.003	Yes	22.4
18	135.8	137.0	136.4	0.002	Yes	17.2
19	135.3	136.9	136.0	0.003	Yes	15.1
20	135.5	136.9	136.2	0.003	Yes	18.2
21	134.5	136.4	135.8	0.003	Yes	15.4
22	135.7	137.2	136.2	0.003	Yes	14.9
23	135.6	136.4	136.0	0.001	Yes	18.2
24	134.9	135.9	135.4	0.002	Yes	16.7
25	134.8	135.9	135.3	0.002	Yes	16.3
26	134.7	136.0	135.3	0.002	Yes	16.1
27	134.5	136.0	135.3	0.003	Yes	18.4
28	135.0	136.3	135.7	0.002	Yes	18.3
29	135.3	136.7	135.8	0.002	Yes	18.7
30	135.0	136.1	135.7	0.002	Yes	18.6
31	135.3	137.1	136.1	0.003	Yes	19.8
32	135.4	136.8	135.9	0.002	Yes	18.6
33	135.2	136.3	135.8	0.002	Yes	18.0
Overall Average Flow (Runs 1 - 33)			**135.9**	**gpm**		

Table 9 Sediment Mass Loading Sediment Feed Rate

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Sediment Concentration* (mg/L)	QA/QC Compliance (COV < 0.1)
17	1	161.8189	48.09	201.9	391.8	Yes
	19	163.4834	48.03	204.2	396.3	
	37	164.8217	48.06	205.8	399.3	
	Average			204.0	395.8	
	COV			0.010		
18	1	163.4267	48.25	203.2	393.5	Yes
	19	169.1515	48.25	210.3	407.2	
	37	167.7238	48.50	207.5	401.7	
	Average			207.0	400.8	
	COV			0.017		
19	1	167.2969	48.18	208.3	404.6	Yes
	19	164.1222	48.32	203.8	395.8	
	37	160.5202	48.06	200.4	389.2	
	Average			204.2	396.5	
	COV			0.020		
20	1	160.4356	48.25	199.5	387.0	Yes
	19	161.7960	48.25	201.2	390.3	
	37	159.0258	48.12	198.3	384.7	
	Average			199.7	387.4	
	COV			0.007		
21	1	169.9442	48.18	211.6	411.6	Yes
	19	165.4688	48.44	205.0	398.6	
	37	170.8643	48.35	212.0	412.4	
	Average			209.5	407.5	
	COV			0.019		
22	1	167.7182	48.16	209.0	405.3	Yes
	19	161.1718	48.28	200.3	388.5	
	37	161.7489	48.25	201.1	390.1	
	Average			203.5	394.6	
	COV			0.023		
23	1	165.9782	48.16	206.8	401.7	Yes
	19	164.2494	48.22	204.4	397.0	
	37	159.2255	48.13	198.5	385.6	
	Average			203.2	394.7	
	COV			0.021		
24	1	160.5455	48.15	200.1	390.4	Yes
	19	160.7110	48.22	200.0	390.3	
	37	163.6502	48.19	203.8	397.6	
	Average			201.3	392.8	
	COV			0.011		
25	1	159.4441	48.13	198.8	388.1	Yes
	19	163.7207	48.13	204.1	398.5	
	37	162.9336	48.15	203.0	396.4	
	Average			202.0	394.3	
	COV			0.014		
26	1	160.6671	48.16	200.2	390.9	Yes
	19	159.5896	48.16	198.8	388.3	
	37	163.2527	48.09	203.7	397.8	
	Average			200.9	392.3	
	COV			0.012		
27	1	156.9578	48.06	196.0	382.6	Yes
	19	158.2386	48.32	196.5	383.6	
	37	162.6216	48.09	202.9	396.2	
	Average			198.4	387.5	
	COV			0.019		
28	1	162.5112	48.12	202.6	394.5	Yes
	19	172.4297	48.19	214.7	418.0	
	37	165.2404	48.25	205.5	400.0	
	Average			207.6	404.2	
	COV			0.030		
29	1	162.1700	48.28	201.5	392.0	Yes
	19	161.0325	48.12	200.8	390.5	
	37	164.0297	48.00	205.0	398.8	
	Average			202.5	393.8	
	COV			0.011		
30	1	165.5912	48.18	206.2	401.4	Yes
	19	159.2414	48.00	199.1	387.5	
	37	168.0281	48.13	209.5	407.7	
	Average			204.9	398.9	
	COV			0.026		
31	1	170.9893	48.00	213.7	414.8	Yes
	19	173.9133	48.16	216.7	420.5	
	37	170.3246	48.00	212.9	413.2	
	Average			214.4	416.2	
	COV			0.009		
32	1	168.8998	48.03	211.0	410.0	Yes
	19	166.3611	48.07	207.6	403.5	
	37	177.4280	51.16	208.1	404.4	
	Average			208.9	406.0	
	COV			0.009		
33	1	171.3137	48.09	213.7	415.9	Yes
	19	166.1098	48.07	207.3	403.5	
	37	171.7980	48.03	214.6	417.6	
	Average			211.9	412.3	
	COV			0.019		

*Based on the run average water flow rate

Table 10 Sediment Mass Loading Drain Down Loses

Run #	Water Level at End of Run (inches)	Total Water Volume (L)	Time of Sample (min. from end of run)	Sediment Concentration (mg/L)	Average Concentration (mg/L)	Lost Sediment (g)
17	29 - 1/2	522.8	10	16	12	6
			20	8		
18	29 - 3/8	520.2	10	18	14	7
			20	9		
19	29 - 1/2	522.8	10	19	15	8
			20	11		
20	29 - 3/8	520.2	10	24	18	9
			20	12		
21	29 - 3/8	520.2	10	18	14	7
			20	10		
22	29 - 1/2	522.8	10	20	16	8
			20	12		
23	29 - 1/2	522.8	10	20	16	8
			20	11		
24	29 - 5/8	525.3	10	15	12	6
			20	9		
25	29 - 5/8	525.3	10	13	10	5
			20	7		
26	29 - 1/2	522.8	10	10	8	4
			20	6		
27	29 - 5/8	525.3	10	10	8	4
			20	6		
28	29 - 5/8	525.3	10	7	6	3
			20	5		
29	29 - 5/8	525.3	10	6	5	3
			20	4		
30	29 - 1/2	522.8	10	7	6	3
			20	4		
31	29 - 5/8	525.3	10	6	5	3
			20	4		
32	29 - 1/2	522.8	10	3	3	2
			20	3		
33	29 - 1/2	522.8	10	4	4	2
			20	3		

Table 11 Sediment Mass Loading SSC Data

Run #	Suspended Sediment Concentration, SSC							QA/QC Compliance
	Run Time (min.)	9	18	27	36	45	Average	
17	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	52	42	39	68	39	48	N/A
	Adjusted Average Sediment Concentration						**48**	
18	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	47	42	50	37	38	43	N/A
	Adjusted Average Sediment Concentration						**42**	
19	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	41	39	36	33	33	36	N/A
	Adjusted Average Sediment Concentration						**36**	
20	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	73	46	44	43	40	49	N/A
	Adjusted Average Sediment Concentration						**49**	
21	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	35	34	31	27	26	31	N/A
	Adjusted Average Sediment Concentration						**30**	
22	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	35	32	34	30	31	32	N/A
	Adjusted Average Sediment Concentration						**32**	
23	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	35	36	33	35	28	33	N/A
	Adjusted Average Sediment Concentration						**33**	
24	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	21	23	22	20	19	21	N/A
	Adjusted Average Sediment Concentration						**21**	
25	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	21	21	19	18	21	20	N/A
	Adjusted Average Sediment Concentration						**20**	
26	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	15	15	17	18	14	16	N/A
	Adjusted Average Sediment Concentration						**15**	
27	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	34	28	27	23	21	27	N/A
	Adjusted Average Sediment Concentration						**26**	
28	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	10	10	13	14	17	13	N/A
	Adjusted Average Sediment Concentration						**12**	

ND – non-detect

Table 11 Sediment Mass Loading SSC Data (Cont'd)

Run #	Suspended Sediment Concentration, SSC							QA/QC Compliance
	Run Time (min.)	9	18	27	36	45	Average	
29	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	8	11	11	13	17	12	N/A
	Adjusted Average Sediment Concentration						12	
30	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	13	13	14	15	16	14	N/A
	Adjusted Average Sediment Concentration						14	
31	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	14	18	18	13	12	15	N/A
	Adjusted Average Sediment Concentration						15	
32	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	9	10	7	7	11	9	N/A
	Adjusted Average Sediment Concentration						8	
33	Background	ND	-	ND	-	ND	0.5	Yes
	Effluent	7	9	11	10	12	10	N/A
	Adjusted Average Sediment Concentration						9	

ND – non-detect

Table 12 Sediment Mass Loading Removal Efficiency Results

Run #	Average Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume Gal	Average Drain Down SSC (mg/L)	Volume of Drain Down Water gal	Removal Efficiency (%)	Mass of Captured Sediment (lbs.)
17	395.8	48	5799.4	12	138.1	88	16.8
18	400.8	42	5810.4	14	137.4	89	17.4
19	396.5	36	5793.8	15	138.1	91	17.4
20	387.4	49	5799.4	18	137.4	87	16.4
21	407.5	30	5784.2	14	137.4	93	18.2
22	394.6	32	5800.9	16	138.1	92	17.5
23	394.7	33	5792.4	16	138.1	92	17.5
24	392.8	21	5765.2	12	138.8	95	17.9
25	394.3	20	5762.7	10	138.8	95	18.0
26	392.3	15	5761.5	8	138.1	96	18.1
27	387.5	26	5762.7	8	138.8	93	17.4
28	404.2	12	5779.2	6	138.8	97	18.9
29	393.8	12	5785.3	5	138.8	97	18.5
30	398.9	14	5780.7	6	138.1	97	18.6
31	416.2	15	5798.0	5	138.8	96	19.4
32	406.0	8	5783.8	3	138.1	98	19.2
33	412.3	9	5782.6	4	138.1	98	19.4
Overall Average Removal Efficiency (Runs 1-33)						89%	
Overall Captured Sediment Mass (Runs 1-33)						434.0 lbs.	

5. Design Limitations

Bio Clean Environmental Services, Inc. provides engineering support to clients on all projects. Each system prior to submittal is evaluated and properly designed/sized to meet site specific conditions including treatment and bypass flow rates, load rating requirements, and pipe depth. All site and design constraints will be addressed during the design and manufacturing process.

Required Soil Characteristics

The Kraken® Filter is delivered to the job site as a complete pre-assembled unit housed in a concrete structure designed to meet site specific soil conditions, corrosiveness, top and lateral loading, and ground water. The system can be used in all soil types. A copy of the geotechnical report along with surface loading requirements are reviewed and verified for each project.

Slope

The Kraken® Filter is most commonly used in a piped-in configuration in which one or more pipes enter the side of the system subsurface. In general, it is not recommended that the pipe slope into the system exceed 10% nor be less than 0.5%. Slopes higher than 10% will cause increased velocities which could affect the performance of the pre-treatment chamber. Slopes less than 0.5% could cause sediment to accumulate in the bottom of the inflow pipe and affect its hydraulic capacity.

The Kraken® Filter is usually not affected by variations in slope of the finish surface as the unit is buried underground. Risers of various heights can be used to bring access to the system up to finish surface. In some configurations the Kraken® Filter can be installed with a built-in curb or drop inlet. In these configurations finish surface slope is more constrained and will require design review to ensure appropriate configuration.

Maximum Flow Rate

Maximum treatment flow rate is dependent on model size. The Kraken® Filter will be sized based upon the NJCAT tested hydraulic loading rate of 0.05 gallons per minute per square foot filter membrane surface area. Section 6 includes details pertaining to inspection and maintenance of the Kraken® Filter.

Maintenance Requirements

Requirements pertaining to maintenance of the Kraken® Filter will vary depending on pollutant loading and individual site conditions. It is recommended that the system be inspected at least twice during the first year as a way to determine loading conditions for each site. These first year inspections can be used as a way to establish inspection and maintenance frequency for subsequent years.

Driving Head

Driving head will vary for a given Kraken® Filter model based on the site specific configuration. Maximum treatment flow, maximum peak flow rate for online units, pipe slope and diameter will be assessed. At the conclusion of mass load testing the water level reached 29.5 inches. This should be used as the minimum driving head requirement for design. It is recommended that pipe fall between the inflow and outflow pipe be provided to minimize or eliminate the amount of surcharge required during lower flows. Bio Clean Environmental provides design support for each project. Site specific drawings (cut sheet) will be provided that show pipe inverts, finish surface elevation, flow rates, and hydraulic grade lines. The hydraulic grade line will be assessed for its effect on the overall drainage system to ensure no flooding at peak flow.

Installation Limitations

With each installation Bio Clean Environmental provides contractors with instructions prior to delivery. Contractors can request onsite assistance from an installation technician during delivery and installation. Pick weights and lifting details are also provided prior to delivery so the contractor can prepare appropriate equipment onsite to set the unit.

Configurations

The Kraken® Filter is available in various configurations. The units can be installed online or offline. However, this verification is for offline installation only. The Kraken® Filter has an internal bypass weir (optional) which allows for it to be installed online without the need for any external high flow diversion structure. For online installations peak bypass flow is routed directly from pre-treatment chamber to discharge chamber, thus fully bypassing the filter chambers and preventing any scouring of captured pollutants.

Structural Load Limitations

The Kraken® Filter is housed in a pre-cast concrete structure. Most standard structures are designed to handle indirect traffic loads with minimal cover. For deeper installation or installation requiring direct traffic rating or higher the structure will be designed and modified with potentially thicker tops, bottoms and/or walls to handle the additional loading. Various access hatch options are available for parkway, indirect traffic, direct traffic and other higher loading requirements such as airports or loading docks.

Pre-treatment Requirements

The Kraken® Filter is designed with built-in pre-treatment capable of capturing sediments, debris and floatables such as trash and other materials. No other pre-treatment is required.

Limitations in Tailwater

Site specific tailwater conditions must be assessed on each individual project. Tailwater conditions increase the amount of driving head required for optimal system operation. The manufacturer's internal protocols require that these conditions are discussed with the engineer of record and that a solution be implemented to adjust for any design variations caused by tailwater conditions at both treatment and bypass flow rates.

Depth to Seasonal High Water Table

High groundwater conditions will not affect the operation of the Kraken® Filter as it is a closed system. In conditions where high groundwater is present, various measures will be employed by Bio Clean Environmental's engineering department to ensure that there are no negative consequences caused by the high groundwater. Various measures can be employed such as waterproofing the inside and outside of the structure with an approved coating. A footing can also be added to the bottom of the structure to increase its footprint and offset any buoyancy concerns.

6. Maintenance Plans

The Kraken® Filter is designed at a loading rate of 0.05 gpm/ft^2 of media surface area to maximize longevity and minimize maintenance requirements. Passive backwash and pre-treatment also helps to minimize system maintenance requirements. The Kraken® Filter has proven to handle at least 18 months sediment loading with no maintenance or loss of treatment capacity.

As with all stormwater BMPs inspection and maintenance on the Kraken® Filter is necessary. Stormwater regulations require that all BMPs be inspected and maintained to ensure they are operating as designed to allow for effective pollutant removal and provide protection to receiving water bodies. It is recommended that inspections be performed multiple times during the first year to assess site specific loading conditions. This is recommended because pollutant loading can vary greatly from site to site. Variables such as nearby soil erosion or construction sites, winter sanding of roads, amount of daily traffic and land use can increase pollutant loading on the system. The first year of inspections can be used to set inspection and maintenance intervals for subsequent years. Without appropriate maintenance a BMP can exceed its storage capacity which can negatively affect its continued performance in removing and retaining captured pollutants. The Kraken® Filter Operation & Maintenance Manual is available at: http://www.biocleanenvironmental.com/kraken-operation-and-maintenance/

Inspection Equipment

Following is a list of equipment to allow for simple and effective inspection of the Kraken® Filter:

- Bio Clean Environmental Inspection Form (contained in O&M Manual).
- Flashlight.
- Manhole hook or appropriate tools to access hatches and covers.
- Appropriate traffic control signage and procedures.
- Measuring pole and/or tape measure.
- Protective clothing and eye protection.
- Note: entering a confined space requires appropriate safety and certification. It is generally not required for routine inspections of the system.

Inspection Steps

The core to any successful stormwater BMP maintenance program is routine inspections. The inspection steps required on the Kraken® Filter are quick and easy. As mentioned above the first year or two should be seen as the maintenance interval establishment phase. During the first two years more frequent inspections should occur in order to gather loading data and maintenance requirements for that specific site. This information can be used to establish a base for long term inspection and maintenance interval requirements.

The Kraken® Filter can be inspected though visual observation without entry into the system. All necessary pre-inspection steps must be carried out before inspection occurs, especially traffic control and other safety measures to protect the inspector and near-by pedestrians from any dangers associated with an open access hatch or manhole. Once these access covers have been safely opened the inspection process can proceed:

- Prepare the inspection form by writing in the necessary information including project name, location, date & time, unit number and other info (see inspection form).
- Observe the inside of the system through the access hatches. If minimal light is available and vision into the unit is impaired utilize a flashlight to see inside the system and all of its chambers.
- Look for any out of the ordinary obstructions in the inflow pipe, pre-treatment chamber, filter chambers, discharge chamber or outflow pipe. Write down any observations on the inspection form.
- Through observation and/or digital photographs estimate the amount of floatable debris accumulated in the pre-treatment chamber. Record this information on the inspection form. Next utilizing a tape measure or measuring stick estimate the amount of sediment accumulated in the primary and secondary sedimentation chambers. Record this depth on the inspection form. Through visual observation inspect the condition of the filter cartridges. Look for excessive build-up of sediments on the surface and any build-up on the top of the cartridges. Record this information on the inspection form.
- Finalize inspection report for analysis by the maintenance manager to determine if maintenance is required.

Maintenance Indicators

Based upon observations made during inspection, maintenance of the system may be required based on the following indicators:

- Missing or damaged internal components or cartridges.
- Obstructions in the system or its inlet or outlet.
- Excessive accumulation of floatable in the pre-treatment chambers in which the length and width of the chambers behind oil/floatables skimmer is fully impacted.
- Excessive accumulation of sediment in the primary sedimentation chamber of more than 18” in depth.
- Excessive accumulation of sediment in the secondary sedimentation chamber of more than 6”.
- Excessive accumulation of sediment in the filter chambers of more than 3” on average.
- Substantial build-up of sediments on the membrane of the filter cartridges which will have a very dark appearance indicating the membrane may be fully saturated with sediment.

Maintenance Equipment

While maintenance can be done fully by hand it is recommended that a vacuum truck be utilized to minimize the time required to maintain the Kraken® Filter:

- Bio Clean Environmental Maintenance Form (contained in O&M Manual).
- Flashlight.
- Manhole hook or appropriate tools to access hatches and covers.
- Appropriate traffic control signage and procedures.
- Measuring pole and/or tape measure.
- Protective clothing and eye protection.
- Note: entering a confined space requires appropriate safety and certification. It is generally not required for routine inspections of the system. Entry into the system will be required if it is determine the cartridge filters need washing/cleaning.

- Vacuum truck
- Trash can
- Pressure washer

Maintenance Procedures

It is recommended that maintenance occurs at least three days after the most recent rain event to allow for drain down of the system and any associated upstream detention systems. Maintaining the system while flows are still entering it will increase the time and complexity required for maintenance. Cleaning of the pre-treatment chamber can be performed from finish surface without entry into the vault utilizing a vacuum truck. Once all safety measures have been set up cleaning of the pre-treatment chamber can proceed as followed:

- Using an extension on a vacuum truck position the hose over the opened access hatch and lower into the center of the primary sedimentation chamber. Remove all floating debris, standing water and sediment from the chamber. A power washer can be used to assist if sediments have become hardened and stuck to the walls or the floor of the chamber. Repeat the same procedure for the secondary sedimentation chamber. This completes the maintenance procedure required on the pre-treatment chamber.

If maintenance is required on the filter cartridges the following procedure can be followed after maintenance on the pre-treatment chamber is performed:

- Following rules for confined space entry use a gas meter to detect the presence of any hazardous gases. If hazardous gases are present do not enter the vault. Follow appropriate confined space procedures, such as utilizing venting system, to address the hazard. Once it is determined to be safe to enter utilize appropriate entry equipment such as a ladder and tripod with harness to enter the system.
- Once entry into the system has been established the maintenance technician should position themselves to stand in the pre-treatment chamber. From here the removal of the cartridges can commence.
- Each cartridge is pressure fitted in place and includes a handle for easy removal. To remove a cartridge, simply grab the handle and pull straight up. It may be required to gently shift pressure from side to side while pulling up to break the pressure seal. Removal of the cartridge should be done by hand with minimal effort and requires no tools.
- Once the cartridges are removed they should be taken out of the vault and brought up to finish surface for cleaning. Using a large garbage can and a standard garden hose (low pressure nozzle), each cartridge should be rinsed off from the outside to remove accumulated sediments and debris. Once each cartridge is rinsed it should be placed to the side for re-installation.
- Each filter chamber should be power washed and vacuumed clean before re-inserting the cleaned cartridges.
- After all cartridges have been washed they can be replaced back into the vault. To replace each cartridge simply slide the cartridge over each pressure fitted coupler. Push down on the handle to ensure the cartridge has been fully seated and the bottom of the cartridge is making contact with the floor.
- The last step is to close up and replace all access hatches and remove all traffic control.

- All removed debris and pollutants shall be disposed of following local and state requirements.
- Disposal requirements for recovered pollutants and spent cartridges may vary depending on local guidelines. In most areas the sediment and spent cartridges, once dewatered, can be disposed of in a sanitary landfill. It is not anticipated that the sediment would be classified as hazardous waste.
- In the case of damaged components or spend cartridges, replacement parts can be ordered by the manufacture.

7. Statements

The following attached pages are signed statements from the manufacturer (Bio Clean Environmental Services, Inc.), the independent test laboratory (Good Harbour Labs), and NJCAT. These statements are a requirement of the verification process.

In addition, it should be noted that this report has been subjected to public review (e.g. stormwater industry) and all comments and concerns have been satisfactorily addressed.

BIO CLEAN
ENVIRONMENTAL SERVICES, INC.

Date: 11-11-2015

To Whom It May Concern,

We are providing this letter as our statement certifying that the protocol titled "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) has been strictly followed. In addition, we certify that all requirements and criteria were met and/or exceeded during testing of the Kraken™ Filter Membrane Filtration System.

If you have any questions please contact us at your convenience.

Sincerely,

Zachariha J. Kent
Director of Research & Development
Bio Clean Environmental Services, Inc.

Signature: ____________ Date: 11/11/2015

P O Box 869 Oceanside CA 92049
(760) 433-7640 • Fax (760) 433-3176
www.BioCleanEnvironmental.net

November 11, 2015

Dr. Richard Magee, ScD., P.E., BCEE
Technical Director
New Jersey Corporation for Advanced Technology

Re: Performance Verification of the Kraken® Membrane Filtration System

Dear Dr. Magee,

Good Harbour Laboratories was contracted by BioClean Environmental Services Inc. to conduct a performance verification of their Kraken® Membrane Filtration System in accordance with New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January, 2013).

Good Harbour Laboratories is an independent hydraulic test facility located in Mississauga, Ontario Canada. I certify that we have evaluated the Kraken® Filter model KF-4-4 from August 10 - 21, 2015 according to the aforementioned test protocol. The results presented in the NJCAT Verification Report dated November 11, 2015 are accurate and all procedures and requirements stated in the test protocol were met or exceeded. Good Harbour Laboratories has no vested interest in the test results or financial conflict of interest in providing independent testing services to BioClean Environmental Services Inc.

Sincerely,

Greg Williams

Dr. Greg Williams, PhD, P.Eng.
Managing Director
Good Harbour Laboratories

Good Harbour Laboratories
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A: 2596 Dunwin Drive, Mississauga, ON L5L 1J5
www.goodharbourlabs.com

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030-0000

December 10, 2015

Titus Magnanao
NJDEP
Division of Water Quality
Bureau of Non-Point Pollution Control
401-02B
PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Magnanao,

Based on my review, evaluation and assessment of the testing conducted on the Kraken® Membrane Filtration System by Good Harbour Laboratories, an independent technology testing laboratory, at their site in Mississauga, Ontario, Canada, the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) were met or exceeded. Specifically:

Test Sediment Feed

Good Harbour used test sediment that was a blend of two commercially available silica sediments. The blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. With a d_{50} of 52 µm, the test sediment was slightly finer than the sediment required by the NJDEP test protocol.

Removal Efficiency Testing

A total of 16 test runs were conducted during removal efficiency testing. All of these test runs met the requirements of the Filter Protocol. The 16 test runs had an overall average removal efficiency of 83%.

Sediment Mass Loading Capacity

A total of 33 test runs were conducted at the MTFR during the Sediment Mass Loading Capacity (SMLC) testing. The SMLC study was a continuation of the removal efficiency study (an additional 17 test runs). The SMLC test was terminated once the mass of the captured sediment exceeded 1.5X the recommended minimum amount for filter maintenance (one year). By the end of run #33, filter bypass had not yet occurred. The total mass of sediment captured was 434 lbs. and the overall removal efficiency was 89%.

Scour Testing

At this time the Kraken® filter System is being submitted for approval for off-line testing; therefore no scour test data was provided.

Sincerely,

Richard S. Magee, Sc.D., P.E., BCEE

8. References

1. Good Harbour Laboratories 2015. *Laboratory Performance Testing Quality Assurance Project Plan (QAPP) for Bio Clean's Kraken™ Membrane Filtration System*. Prepared by Good Harbour Laboratories, June 2015.

2. Good Harbour Laboratories, Notebook A010, pp. 17-29, 53-66, 69, 84-99.

3. NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. January 25, 2013.

4. NJDEP 2013b. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device*. January 25, 2013.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Bio Clean Environmental Services, Inc., 2972 San Luis Rey Road, Oceanside, CA 92054. Website: http://www.BioCleanEnvironmental.com Phone: 760-433-7640.

- MTD - Kraken® Filter verified models are shown in **Table A-1**.

- TSS Removal Rate – 80%

- Off-line installation

Detailed Specification

- NJDEP sizing tables and physical dimensions for Kraken® Filter verified models are attached (**Table A-1** and **Table A-2**). These Sizing Tables are valid for NJ following NJDEP Water Quality Design Storm Event of 1.25" in 2 hours (NJAC 7:8-5.5(a)).
- Maximum inflow drainage area
    - The maximum inflow drainage area is governed by the maximum treatment flow rate of each model size as presented in **Table A-1** and **Table A-4**.

- Driving head will vary for a given Kraken® Filter model based on the site specific configuration. For standard design, as tested under the NJDEP Protocol, 29.5 inches should be used as the driving head requirement. Bio Clean Environmental provides design support for each project.

- The drain down flow is regulated by a drain down orifice, sized so that a clean filter drains down in approximately 15 minutes. The drain down flow rate is expected to decrease as the filters ripen.
- See Kraken® Filter O&M Manual for maintenance needs and procedures. http://www.biocleanenvironmental.com/kraken-operation-and-maintenance/

- This certification does not extend to the enhanced removal rates under NJAC 7:8-5.5 through the addition of settling chambers (such as hydrodynamic separators) or media filtration practices (such as a sand filter).

Table A-1 Kraken® Filter Model MTFRs and Sediment Storage Capacity

.

Model	# of Cartridges	MTFR (cfs)[1]	50% Maximum Sediment Storage Volume (ft^3)
KF-2.5-4	8	0.152	1.37
KF-4-4	16	0.303	1.70
KF-4-6	24	0.455	2.59
KF-4-8	32	0.606	3.44
KF-8-8	48	0.909	8.38
KF-8-10	66	1.250	11.5
KF-8-12	78	1.477	13.4
KF-8-14	96	1.818	16.9
KF-8-16	114	2.159	19.9
KF-10-16	152	2.879	24.0

NOTES:

1. Calculated based on 1.11×10^{-4} cfs/ft^2 of effective filtration treatment area.

Table A-2 Kraken® Filter Model Standard Dimensions

Model	Sediment Chamber 1 Dimensions & Storage Capacity					Sediment Chamber 2 Dimensions & Storage Capacity					Filter Chambers Dimensions & Storage Capacity										TOTAL	Total Effective Sedimenation Area (sq ft)	Wet Volumes				Total Wet Volume (cf)
	Length (ft)	Width (ft)	Area (Sq Ft)	Storage Depth (ft)	Storage Capacity (cu ft)	Length (in)	Width (in)	Area (Sq Ft)	Storage Depth (ft)	Storage Capacity (cu ft)	Width (ft)	Length (ft)	Area (Sq Ft)	# of Chambers	Total Area (Sq Ft)	Storage Depth (ft)	Storage Capacity (cu ft)	# of Cartridges	[2]Minus Cartridges Volume (cu ft)	Storage Capacity (cu ft)	Total Sediment Storage Capacity (cu ft)		[1]Pre-Treatment Chamber Depth (ft)	[1]Filter Chambers Depth (ft)	Wet Volume Pre-Treatment Chamber (cf)	Wet Volume Filtration Chamber (cf)	
KF-2.5-4	1.00	0.93	0.93	1.50	1.40	1.94	0.93	1.80	0.50	0.90	0.77	2.84	2.19	2.00	4.37	0.25	1.09	8.00	0.65	0.44	2.74	**7.11**	2.92	2.67	7.98	11.68	**19.66**
KF-4-4	1.00	1.02	1.02	1.50	1.53	1.96	1.02	2.00	0.50	1.00	1.47	2.96	4.35	2.00	8.70	0.25	2.18	16.00	1.31	0.87	3.40	**11.72**	2.92	2.67	8.82	23.24	**32.05**
KF-4-6	1.50	1.02	1.53	1.50	2.30	3.02	1.02	3.08	0.50	1.54	1.50	4.40	6.60	2.00	13.20	0.25	3.30	24.00	1.96	1.34	5.17	**17.81**	2.92	2.67	13.46	35.24	**48.71**
KF-4-8	2.00	1.02	2.04	1.50	3.06	3.98	1.02	4.06	0.50	2.03	1.47	6.00	8.82	2.00	17.64	0.25	4.41	32.00	2.62	1.79	6.88	**23.74**	2.92	2.67	17.81	47.10	**64.91**
KF-8-8	1.92	2.99	5.74	1.50	8.61	3.85	2.99	11.51	0.50	5.76	2.18	5.79	12.62	2.00	25.24	0.25	6.31	48.00	3.93	2.38	16.75	**42.50**	2.92	2.67	50.38	67.40	**117.78**
KF-8-10	2.67	2.99	7.98	1.50	11.97	5.21	2.99	15.58	0.50	7.79	2.18	7.90	17.22	2.00	34.44	0.25	8.61	66.00	5.40	3.21	22.97	**58.01**	2.92	2.67	68.80	91.97	**160.76**
KF-8-12	3.08	2.99	9.21	1.50	13.81	6.21	2.99	18.57	0.50	9.28	2.18	9.31	20.30	2.00	40.59	0.25	10.15	78.00	6.38	3.76	26.86	**68.37**	2.92	2.67	81.11	108.38	**189.49**
KF-8-14	3.87	2.99	11.57	1.50	17.36	7.77	2.99	23.23	0.50	11.62	2.18	11.67	25.44	2.00	50.88	0.25	12.72	96.00	7.86	4.86	33.84	**85.68**	2.92	2.67	101.63	135.85	**237.48**
KF-8-16	4.58	2.99	13.69	1.50	20.54	9.10	2.99	27.21	0.50	13.60	2.18	13.67	29.80	2.00	59.60	0.25	14.90	114.00	9.33	5.57	39.72	**100.50**	2.92	2.67	119.44	159.14	**278.57**
KF-10-16	4.58	3.57	16.35	1.50	24.53	9.10	3.57	32.49	0.50	16.24	2.88	13.67	39.37	2.00	78.74	0.25	19.68	152.00	12.44	7.24	48.01	**127.58**	2.92	2.67	142.61	210.23	**352.84**

NOTES:

1. Depth of water in chambers during operation at MTFR. Depths above are based upon original estimates used in the QAPP of 2.92 ft for pre-treatment chamber & 2.67 ft for filter chambers. Maximum observed depths during NJ CAT testing were 2.60 ft for pre-treatment chamber & 2.46 ft for filter chambers at end the of run 33 indicating additional capacity was still available. The unit never got close to reaching the internal bypass weir.

2. The cartridges are 0.6458 feet in diameter. This is used to calculate the total volume of the cartridges and subtract it from the sediment storage volume in the filter chambers. This is a conservative calculation as the pleats in the cartridge allow for up to 50% of it's volume to store sediment on their influent side. For wet volume calculations the volume of the cartridges is not subtracted because water fills both the influent and effluent sides of the cartridges and actual volume of pleated material is negligible . Cartridge height is 2.5625 feet.

Table A-3 Kraken® Filter Model Scaling Ratios

Model	# of Cartridges*	Effective Filtration Treatment Area (sq. ft.)	Total Effective Sedimentation Area (sq. ft.)	Total Wet Volume (cu ft.)	MTFR (cfs)	Ratio of the MTFR to Effective Filtration Treatment Area	Ratio of Effective Sedimentation Area to Effective Filtration Treatment Area	Ratio of Wet Volume to Effective Filtration Treatment Area
KF-2.5-4	8	1360	7.107	19.645	0.152	1.114E-04	5.226E-03	1.444E-02
KF-4-4	**16**	**2720**	**11.720**	**32.019**	**0.303**	**1.114E-04**	**4.309E-03**	**1.177E-02**
KF-4-6	24	4080	17.814	48.673	0.455	1.114E-04	4.366E-03	1.193E-02
KF-4-8	32	5440	23.739	64.849	0.606	1.114E-04	4.364E-03	1.192E-02
KF-8-8	48	8160	42.500	117.703	0.909	1.114E-04	5.208E-03	1.442E-02
KF-8-10	66	11220	58.000	160.634	1.250	1.114E-04	5.169E-03	1.432E-02
KF-8-12	78	13260	68.377	189.376	1.477	1.114E-04	5.157E-03	1.428E-02
KF-8-14	96	16320	85.676	237.287	1.818	1.114E-04	5.250E-03	1.454E-02
KF-8-16	114	19380	100.497	278.355	2.159	1.114E-04	5.186E-03	1.436E-02
KF-10-16	152	25840	127.570	352.559	2.879	1.114E-04	4.937E-03	1.364E-02

Notes:

*Each 30.75” tall cartridge has 170 sq. ft. of surface area and operates at an orifice controlled loading rate of 0.05 gpm/sq. ft.

Other sizes and configurations available. All models sized based upon the maximum NJ CAT approved pre-treatment and filtration chamber area loading rate.

Table A-4 Kraken® Filter Model Sizing and Loading

Model	Treatment Flow Rate			NJCAT Observed Storage Capacity			Applied Capacity to Other Models			Allowable Drainage Area
	# of Cartridges	Total Cartridge Surface Area (sq ft)	MTFR (cfs)	Total Sediment Storage Capacity (cu ft)	Total Sediment Storage Capacity (lbs)	Weight of Sediment (lbs/cu ft)	[1]Storage Capacity Per Sq Ft of Sedimentation Area (lbs)	Total Effective Sedimentation Area (sq ft)	Applied Storage Capacity (lbs)	[2]Maximum Allowable Drainage Area Based on Loading (acres)
KF-2.5-4	8	1360	0.152	n/a	n/a	96.44	37.03	7.11	263.20	0.439
KF-4-4	**16**	**2720**	**0.303**	**4.50**	**434.00**	**96.44**	**37.03**	**11.72**	**434.00**	**0.723**
KF-4-6	24	4080	0.455	n/a	n/a	96.44	37.03	17.81	659.52	1.099
KF-4-8	32	5440	0.606	n/a	n/a	96.44	37.03	23.74	879.08	1.465
KF-8-8	48	8160	0.909	n/a	n/a	96.44	37.03	42.50	1573.65	2.623
KF-8-10	66	11220	1.250	n/a	n/a	96.44	37.03	58.01	2147.93	3.58
KF-8-12	78	13260	1.477	n/a	n/a	96.44	37.03	68.37	2531.69	4.219
KF-8-14	96	16320	1.818	n/a	n/a	96.44	37.03	85.68	3172.91	5.288
KF-8-16	114	19380	2.159	n/a	n/a	96.44	37.03	100.50	3721.68	6.203
KF-10-16	152	25840	2.879	n/a	n/a	96.44	37.03	127.58	4724.17	7.874

NOTES:

1. Calculated based upon actual sediment accumilated inside the system during NJDEP protocol testing. Applied to other models based upon total effective sedimentation area.

2. Based upon the equation found in the NJDEP Filter Protocol: Maximum Inflow Drainage Area (acres) = Weight of TSS Before 10% Loss in MTFR (lbs) / 600 lbs per Acre of Drainage Area Annually.

NJCAT TECHNOLOGY VERIFICATION ADDENDUM REPORT

Kraken® Membrane Filtration System
Bio Clean Environmental Services, Inc.

April 2016

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1. Introduction

In February 2016, NJCAT published a Technology Verification Report on the Kraken® Membrane Filtration System (Kraken® Filter System) manufactured by Bio Clean Environmental Services Inc. The Kraken® Filter System is an engineered storm water quality treatment device utilizing a reusable membrane filter designed to remove high levels of TSS, hydrocarbons, and particulate bound metals and nutrients found in contaminated storm water. Each filter contains a large surface area which is designed to deal with high TSS concentrations. (See page 1 - **Description of Technology** for a more complete description of the technology.)

The test program was conducted by Good Harbour Laboratories, an independent water technology testing lab, at their site in Mississauga, Ontario. Testing occurred during the month of August, 2015. Laboratory testing was done in accordance with the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January, 2013)*. Limitations with the Good Harbour Laboratories testing capabilities at that time precluded conducting sediment scour testing. This addendum report provides the necessary sediment scour test results to support the use of the Kraken® Filter System for on-line installations.

2. Laboratory Testing

Scour testing occurred during the month of January, 2016. The same Kraken® Filter System that was used for the Removal Efficiency Testing described in the February 2016 Verification Report was also used for the sediment scour test.

2.1 Test Setup

The test flow loop (**Figure 3** – page 3) that was used for the removal efficiency testing had to be modified for the sediment scour test (**Figure 1).** These modifications were made due to flow capacity limitations of the laboratory. During performance and load testing the lab has sufficient water supply flow rates to run testing at 0.30 cfs without the need to recirculate the water. This allowed testing to be done with no filter for the effluent water. Since scour testing was done at a flow rate greater than the water supply's flow capacity a recirculating system needed to be used. Therefore the addition of a filter was used to remove background particulates. The test flow loop was modified as follows:

- Water was pumped from the inlet reservoir to the standpipe through a 6″ PVC line using an Armstrong Model 4380 centrifugal pump;
- Flow measurement was done using a MJK Magflux 7200 mag-type flow meter;
- Effluent samples were taken using an isokinetic sampler (**Figure 2**). The isokinetic sampler consisted of three, ½″ sampling tubes that were evenly spaced and vertically and centrally aligned;
- The system was configured as a closed loop, rather than a single pass; and
- A Fil-Trek model S4LPD24-712-6F filter housing (**Figure 3**) with pleated bag filters (0.5 µm absolute) was used to remove background particulate.

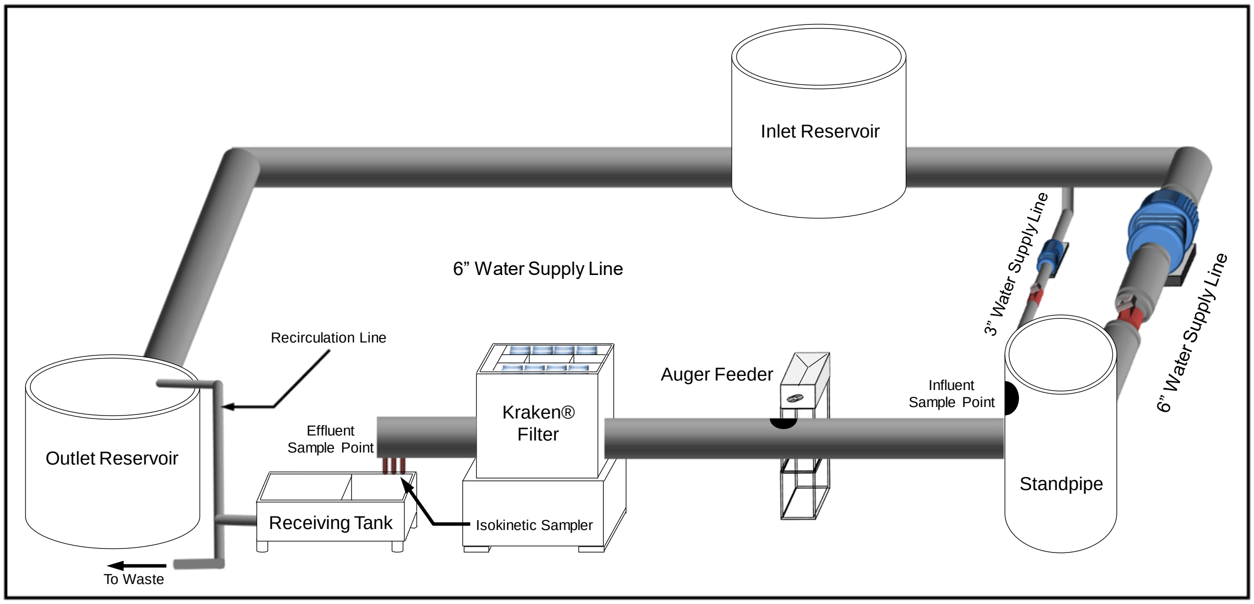

Figure 1 Test Flow Loop

Figure 2 Isokinetic Sampler

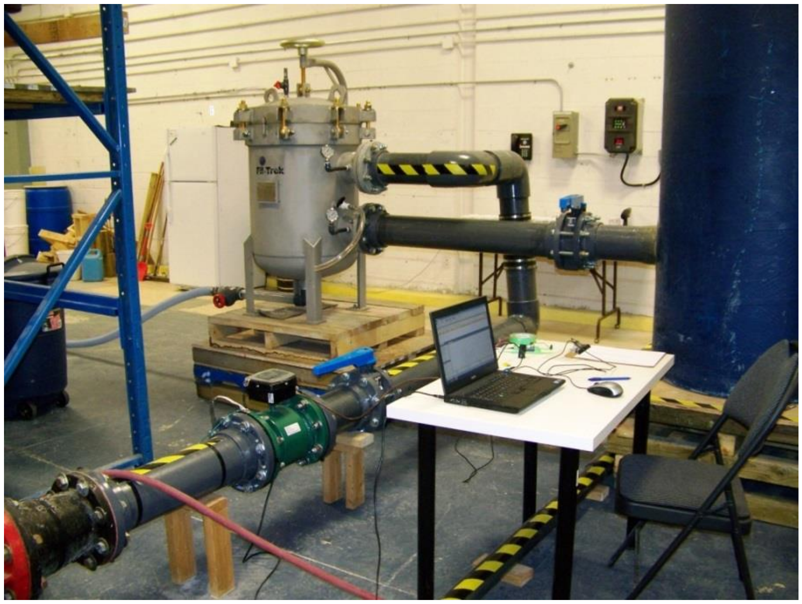

Figure 3 Fil-Trek Filter Housing

Following removal efficiency testing, the Kraken® Filter System sat undisturbed and allowed to dry out until the sediment scour testing was ready to begin. In preparation for the test, all of the filter elements were removed, being careful not to dislodge any of the captured sediment on the filters. The weight of the dry filter elements was recorded. All of the captured sediment inside the Kraken® Filter System chambers was then removed and the system was hosed out.

2.2 Test Sediment

The same batch of test sediment (**Table 1** and **Figure 8** – page 7) used for the removal efficiency testing was also used for the sediment scour test.

2.3 Scour Testing

Scour testing was conducted in accordance with Section 4 of the NJDEP Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (NJDEP, 2013). Testing was conducted at a target flow rate of 200% of the maximum treatment flow rate (MTFR).

The used filters that were removed following removal efficiency testing were placed back into the Kraken® Filter System in their original position. The mass of each used filter was compared to the average mass of a clean filter to determine the amount of sediment it held, the data is summarized in **Table 1**.

Table 1 Filter Element Retained Sediment

Filter ID	Net Weight of Sediment (kg)	Filter ID	Net Weight of Sediment (kg)
1-1	7.655	2-1	8.065
1-2	9.435	2-2	10.170
1-3	9.735	2-3	8.815
1-4	10.250	2-4	10.040
1-5	9.835	2-5	10.085
1-6	10.325	2-6	9.150
1-7	10.310	2-7	10.405
1-8	10.870	2-8	11.040
Total sediment mass on filters: 156.2 kg (344.4 lb.)			

In addition to the sediment retained on the filters, additional sediment was preloaded into the chambers of the Kraken® Filter System to represent 50% of the manufacture's recommended maximum storage volume for all chambers. The distribution of the sediment in the various chambers reflected the distribution that was measured when sediment was captured during removal efficiency testing. The amount of sediment added and its distribution is summarized in **Table 2**.

Table 2 Chamber Sediment Pre-Load Amounts

Chamber	Sediment Volume (cf)	Sediment Depth (inches)	Sediment Mass (lbs)	Sediment % of Total
Primary Sedimentation	0.46	5.43	45	15
Secondary Sedimentation	0.15	0.93	15	5
Filter Chamber 1	1.23	4.14	120	40
Filter Chamber 2	1.23	4.14	120	40
Total sediment pre-load in chambers: 300 lb. (50% of manufacture's maximum recommended storage capacity of all chambers which is 600 lbs) (does not include additional sediment storage within the individual cartridges).				

In total, the Kraken® Filter System was preloaded with 644.4 pounds of sediment for the scour test. After preloading, the unit sat for approximately 90 hours before starting the test.

Scour testing began by gradually increasing the flow rate to the target flow within a 5 minute period. Effluent samples were taken from an isokinetic sampler while background samples were once again taken as grab samples from the Stand Pipe. The sampling frequency is summarized in **Table 3**. All samples were collected in clean 1L wide-mouth jars.

Table 3 Scour Test Sampling Frequency

Sample/ Measurement Taken	Run Time (min.)															
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Effluent		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Background	X		X		X		X		X		X		X		X	

Note: The Run time of 0 minutes is the time the 1st background sample was taken, following the 5 minute flow equilibration period.

3. Additional Performance Claims

The Kraken® Filter System qualifies for use in on-line systems up to a maximum flow of 200% of the MTFR.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report.

4.1 Scour Testing

The scour testing was performed with a total sediment load of 644.4 lb. of sediment comprised of sediment preload and sediment that had been captured by the filter elements during the removal efficiency testing. The scour test flow rate was 0.60 cfs (269 gpm), 200% of the MTFR. At the test flow rate, the Kraken® Filter System did not achieve internal bypass.

To start the test, the flow rate was gradually increased to the target flow within a five minute period, as required by the NJDEP protocol. The test flow summary is provided in **Table 4**.

Table 4 Scour Test Flow Summary

Scour Test Flow Rate (gpm)		QA/QC Compliance (COV < 0.03 and avg. ± 10% of target)
Min.	263.9	YES
Max.	273.2	
Average	268.9	
COV	0.008	

The suspended sediment concentration (SSC) results for the background (influent) samples taken during the scour test are presented in **Table 5** and illustrated in **Figure 4**. The method detection limit (MDL) is 1 mg/L. To allow for the adjustment of effluent concentrations, a value of 0.5 mg /L or ½ of the method detection limit, was used for any result of < MDL.

Table 5 Scour Test Background SSC Results

Runtime (minutes)	Sample ID	Sediment Concentration (mg/L)	QA/QC Compliance (Background ≤ 20 mg/L)
5	Background-1	< MDL	YES
9	Background-2	< MDL	YES
13	Background-3	< MDL	YES
17	Background-4	< MDL	YES
21	Background-5	< MDL	YES
25	Background-6	1	YES
29	Background-7	< MDL	YES
33	Background-8	1	YES

MDL = 1 mg/L

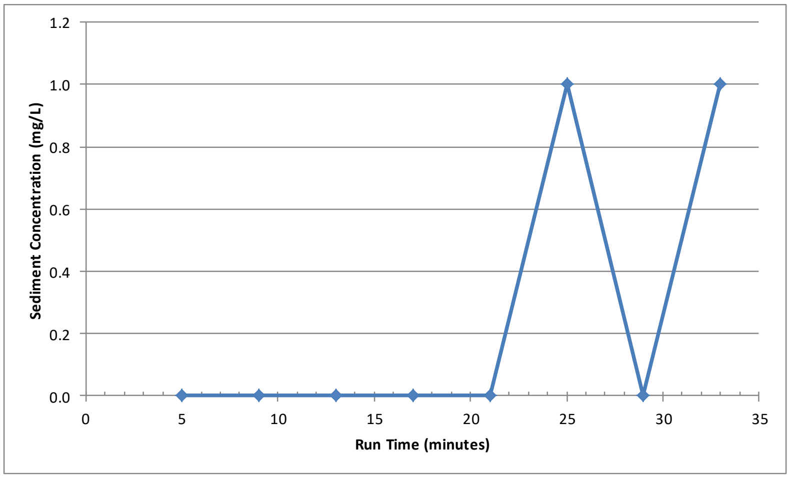

Figure 4 Scour Test Background SSC

The effluent SSC results are reported in **Table 6**. The adjusted effluent concentration was calculated as:

$$Adjusted\ Effluent\ Concentration\ \left(\frac{mg}{L}\right) = Initial\ Concentration - Background\ Concentration$$

The background concentration from **Figure 4** was used for the calculation. The average adjusted effluent concentration was 17 mg/L; therefore when operated at 200% of the MTFR, the Kraken® Filter KF 4-4 meets the criteria (average adjusted effluent SSC concentration <20 mg/L) for on-line use.

Table 6 Scour Test Effluent SSC Results

Runtime (minutes)	Sample ID	Sediment Concentration (mg/L)	
		Initial	Adjusted
7	Effluent-1	34	33.5
9	Effluent-2	29	28.5
11	Effluent-3	26	25.5
13	Effluent-4	24	23.5
15	Effluent-5	21	20.5
17	Effluent-6	19	18.5
19	Effluent-7	18	17.5
21	Effluent-8	16	15.5
23	Effluent-9	15	14.5
25	Effluent-10	13	12.0
27	Effluent-11	12	11.5
29	Effluent-12	11	10.5
31	Effluent-13	10	9.5
33	Effluent-14	10	9.0
35	Effluent-15	9	8.0
Average Adjusted Effluent Concentration			**17**

5. Statements

The following attached pages are signed statements from the manufacturer (Bio Clean Environmental Services, Inc.), the independent test laboratory (Good Harbour Labs), and NJCAT. These statements are a requirement of the verification process.

In addition, it should be noted that this report has been subjected to public review (e.g. stormwater industry) and all comments and concerns have been satisfactorily addressed.

February 23, 2016

Dr. Richard Magee, ScD., P.E., BCEE
Technical Director
New Jersey Corporation for Advanced Technology

Re: Performance Verification of the Kraken® Membrane Filtration System

Dear Dr. Magee,

Good Harbour Laboratories was contracted by BioClean Environmental Services Inc. to conduct a scour performance test of their Kraken® Membrane Filtration System in accordance with New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January, 2013).

Good Harbour Laboratories is an independent hydraulic test facility located in Mississauga, Ontario Canada. I certify that we completed the test on the Kraken® Filter model KF-4-4 from January 15 - 19, 2016 according to the aforementioned test protocol. The results presented in the NJCAT Verification Report Addendum dated February, 2016 are accurate and all procedures and requirements stated in the test protocol were met or exceeded. Good Harbour Laboratories has no vested interest in the test results or financial conflict of interest in providing independent testing services to BioClean Environmental Services Inc.

Sincerely,

Greg Williams

Dr. Greg Williams, PhD, P.Eng.
Managing Director
Good Harbour Laboratories

Good Harbour Laboratories
T: 905.696.7276 | F: 905.696.7279
A: 2596 Dunwin Drive, Mississauga, ON L5L 1J5
www.goodharbourlabs.com

Date: 3-11-2016

To Whom It May Concern,

We are providing this letter as our statement certifying that the protocol titled "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013), Scour testing portion has been strictly followed. In addition, we certify that all scour testing requirements and criteria were met and/or exceeded during testing of the Kraken™ Filter Membrane Filtration System.

If you have any questions please contact us at your convenience.

Sincerely,

Zachariha J. Kent
Director of Research & Development
Bio Clean Environmental Services, Inc.

Signature: Zach Kent Date: 3-11-2016

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www.BioCleanEnvironmental.net

Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030-0000

April 4, 2016

Titus Magnanao
NJDEP
Division of Water Quality
Bureau of Non-Point Pollution Control
401-02B
PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Magnanao,

Based on my review, evaluation and assessment of the testing conducted on the Kraken® Membrane Filtration System by Good Harbour Laboratories, an independent technology testing laboratory, at their site in Mississauga, Ontario, Canada, the scour test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) for on-line installation were met or exceeded. Specifically:

Scour Testing

Scour testing was conducted at 0.60 cfs (200% of the MTFR), the maximum flow rate that Bio Clean Environmental Services intends to convey through the Kraken® Filter System, in order to demonstrate the ability of the Kraken® Filter to be used as an on-line treatment device. Background concentrations were ≤ 1 mg/L (the MDL) throughout the scour testing, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Unadjusted effluent concentrations ranged from 9 mg/L to 34 mg/L. When adjusted for background concentrations, the effluent concentrations range from 8 to 33.5 mg/L with a mean of 17 mg/L, qualifying the Kraken® Filter System for on-line installation up to 200% of the MTFR.

Sincerely,

Richard S. Magee

Richard S. Magee, Sc.D., P.E., BCEE

6. References

[1] Good Harbour Laboratories, Notebook A012, pp. 3-4, 18-XX.

Round Kraken Filter Models

February 2022

Introduction

Bio Clean has developed a round (manhole) version of the Kraken Filter (KF) vault system in response to increases in costs and lead times for square and rectangular concrete vaults resulting from labor/supply chain issues. The Round Kraken Filter (KFR) systems are more readily available and Bio Clean has added this new model configuration to the existing vault system offerings. **Figure R-1** shows a view looking down into a 10 cartridge KFR system (KFR-4). Key KFR model parameters are shown in **Table R-1.**

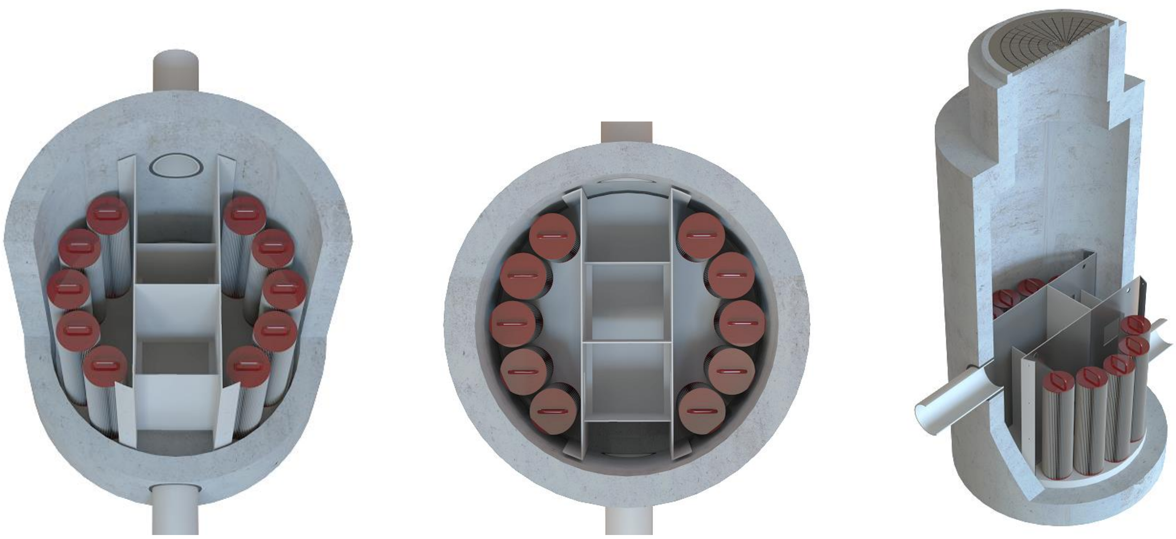

Figure R-1 10 Cartridge KFR-4 System (Front Iso, Top, Side Iso) Views

The KFR systems function identically to the KF vault systems. They are offered in three model diameters: 4-ft, 6-ft, and 8-ft. The ratio of the MTFR to Effective Filtration Treatment Area (EFTA) is identical to the tested KF-4-4 vault model and the ratios of effective sedimentation treatment area to EFTA and wet volume to EFTA exceed the ratios of the KF-4-4 vault model, qualifying the KFR models for verification. (**Table R-2)**

Table R-1 Round Kraken Filter Model MTFRs, Sediment Storage Capacity and Maximum Allowable Drainage Area

Model	Diameter (ft)	# of Cartridges[1]	Maximum Treatment Flow Rate, MTFR[2] (cfs)	50% Maximum Sediment Storage Volume (ft^3)	Maximum Allowable Drainage Area Based on Loading (acres)[3]
KFR-4	4	10	0.189	2.16	0.452
KFR-6	6	30	0.568	4.17	1.356
KFR-8	8	52	0.985	7.12	2.351

Notes:

1. Each cartridge has 170 sq. ft. of effective filtration treatment area (EFTA).
2. Calculated based on 1.114×10^{-4} cfs/sf (0.05 gpm/sf) of EFTA.
3. Based on a loading of 27.125 lbs/cartridge and the equation in the NJDEP Filter Protocol: Maximum Inflow Drainage Area (acres) = weight of TSS before 10% loss in MTFR (lbs/600 lbs per acre of drainage area annually.

Table R-2 Round Kraken® Filter Model Scaling Ratios

Model	# of Cartridges[1]	Effective Filtration Treatment Area (sq. ft.)	Total Effective Sedimentation Area (sq. ft.)	Total Wet Volume (cu ft.)	MTFR (cfs)	Ratio of the MTFR to Effective Filtration Treatment Area	Ratio of Effective Sedimentation Area to Effective Filtration Treatment Area	Ratio of Wet Volume to Effective Filtration Treatment Area
KF-4-4	**16**	**2720**	**11.720**	**32.019**	**0.303**	**1.114E-04**	**4.309E-03**	**1.177E-02**
KFR-4	10	1700	11.91	32.75	0.189	1.114E-04	7.001E-03	1.926E-02
KFR-6	30	5100	26.01	71.34	0.568	1.114E-04	5.100E-03	1.399E-02
KFR-8	52	8840	46.73	127.77	0.985	1.114E-04	5.286E-03	1.445E-02

Notes:

1. Each 30.75" tall cartridge has 170 sq. ft. of surface area and operates at an orifice-controlled loading rate of 0.05 gpm/sq. ft.