Independent Review of CDS 2015 Product Evaluation

Report by
FB Environmental Associates, Inc.
97A Exchange St.
Portland ME 04101

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Introduction

FB Environmental Associates, Inc. (FB Environmental), was hired by Contech Construction Products, Inc. (Contech), in 2009 to serve as an independent reviewer of the CDS 2015 test unit. The CDS 2015 is a stormwater treatment device with a design flow of 0.7 cubic feet per second. It is intended to remove pollutants, including suspended solids, from stormwater. Flow up to the treatment design capacity is guided by a diversion weir into a separation chamber for treatment. The primary methods used to remove pollutants are swirl concentration, a continuous deflective separation screen, and an oil baffle. Flows which exceed the treatment design capacity flow over an internal diversion weir and by-pass the separation chamber. A diagram of a CDS unit is shown in Figure 1.

Tests were conducted under controlled conditions, and repeated three times at each flow level, with FB Environmental serving as a third-party, independent reviewer. Our role was to observe all test runs and sample collection, review data records and calculations, and state whether tests conformed to the written protocol provided by Contech.

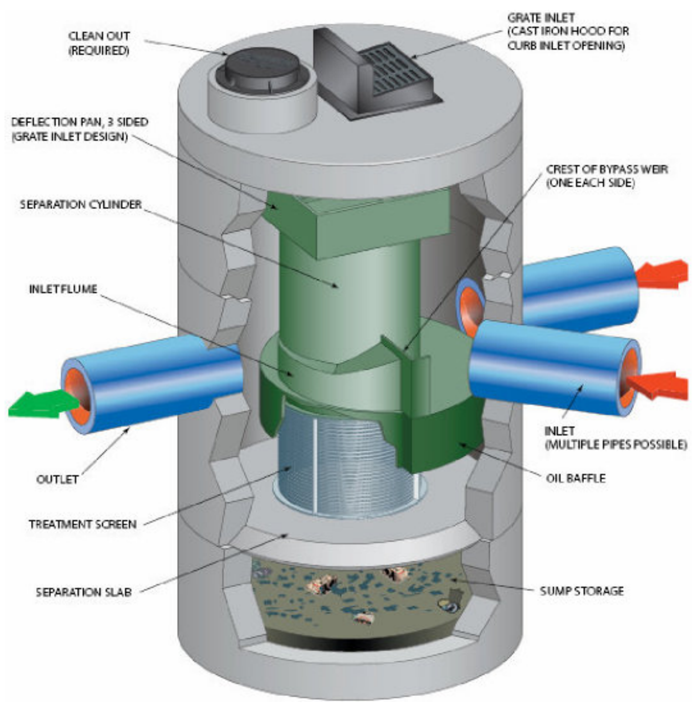

Figure 1: Design and construction of the CDS unit.

Procedure

Contaminant

A commercial sand product, OK-110, was used to provide a standardized contaminant for solids removal testing. This product was manufactured by the US Silica Company[1] and the materials used for testing originated from the Mill Creek, OK plant. OK-110 is a natural silica sand product (SG=2.65) consisting of unground sand that has been processed to produce a distribution of particles between 50-µm and 200-µm with a d50 of approximately 105-µm. The particle size distribution for OK-110 is shown in Figure 2.

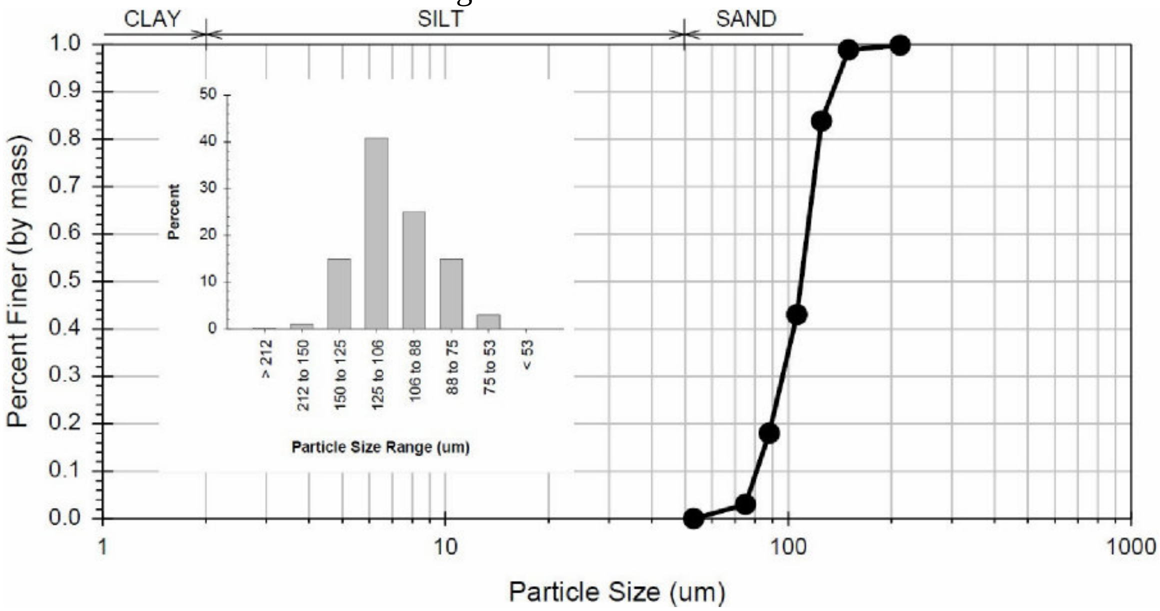

Figure 2: Particle size distribution of OK-110 based upon manufacturer's specifications (US Silica, ND).

Test Apparatus

Removal Efficiency Testing

The CDS consists of a swirl concentrator and deflective screen and is shown in Figure 1. During operation, water enters the CDS unit's diversion chamber where the diversion weir guides the flow into the unit's separation chamber and pollutants are removed. The grit storage sump is located beneath the separation chamber. All flows up to the system's design capacity enter the separation chamber, while higher flows are bypassed. Treated water moves through 2400-micron screen aperture openings, under the oil baffle and exits the system. The separation screen remains clog free due to continuous deflection.

A CDS 2015 was used for testing. This unit consisted of a 5-ft diameter welded aluminum structure with a maximum depth of 4.17-ft between the floor of the sump and the invert of the inlet pipe. The diameter of the inlet and outlet pipes of the test system were 12-in and entered and exited the system as shown in Figure 3.

[1] U.S. Silica Company, P.O. Box 187, Berkeley Springs, WV 25411; (800) 243-7500; www.u-s-silica.com

As shown in Figure 3, the CDS test unit was tested using a recirculation system. Water is pumped through the test unit and into the catch tank. Water is recirculated directly from the 6.0-ft x 12.0-ft x 3.0-ft (LxWxD) aluminum catch tank by a 10-hp submersible pump, directly back into the influent line, Figure 3. Flow was controlled by a calibrated butterfly valve placed on the influent line that was operated to produce a steady state flow condition. Flow was measured with an electromagnetic flow meter, Sea Metrics WMX-Series Industrial Magmeter. All piping consisted of schedule 40 PVC.

OK-110 was injected as concentrated slurry downward into the influent pipe via a slurry injection port located 5-ft upstream of the test unit, and kept from recirculating within the test apparatus by filtering the effluent as it passed through the catch tank. The slurry injection system is detailed in Figure 4. Slurry was produced in a 1200-L conical bottom, polyethylene (PE) tank (Chem-Tainer). The conical bottom design ensured the continuous circulation of materials within the slurry tank. Suspension of solids within the slurry tank was maintained by a 1-hp, electric mixer with dual 5-in propellers (INDCO Model CL1-T). The propeller design maximized the vertical circulation of solids within the tank and ensured the homogeneity of the mixture. Four evenly spaced, vertically oriented baffles, measuring 42-in x 3.0-in x 0.5-in (LxWxThickness), affixed to the sidewalls of the slurry tank prevented mixer-induced vortexing.

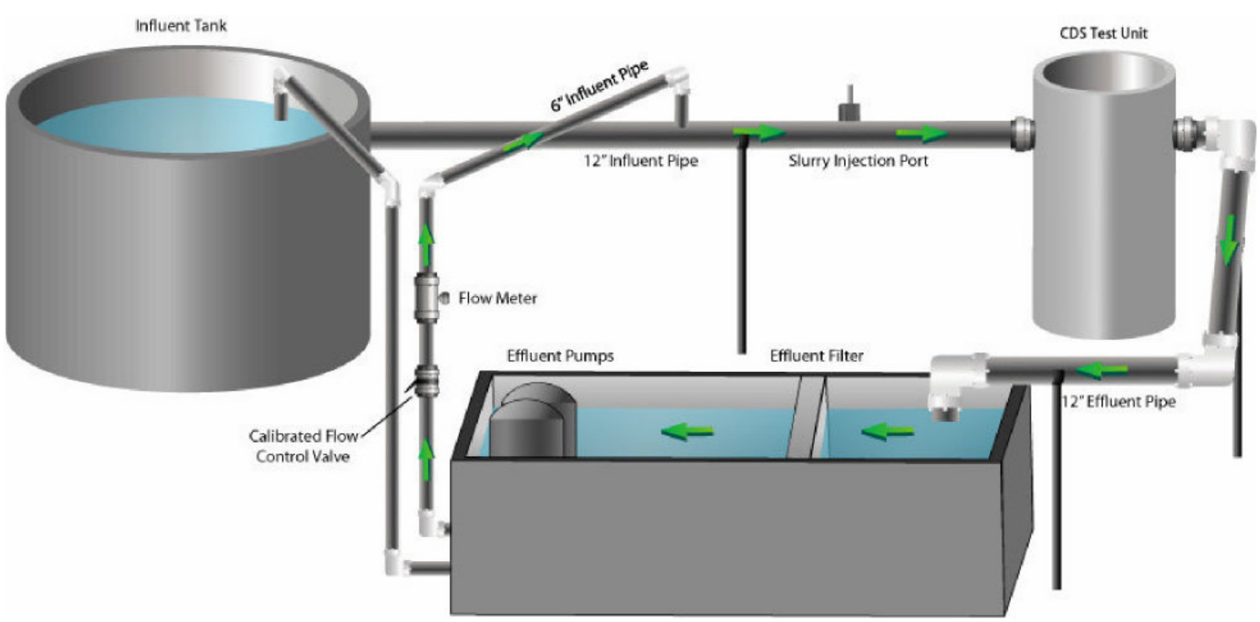

Figure 3: Diagram of the test facility, with flow pathways indicated by arrows. The CDS 2015 unit. (Figure courtesy of Contech Construction Products, Inc.)

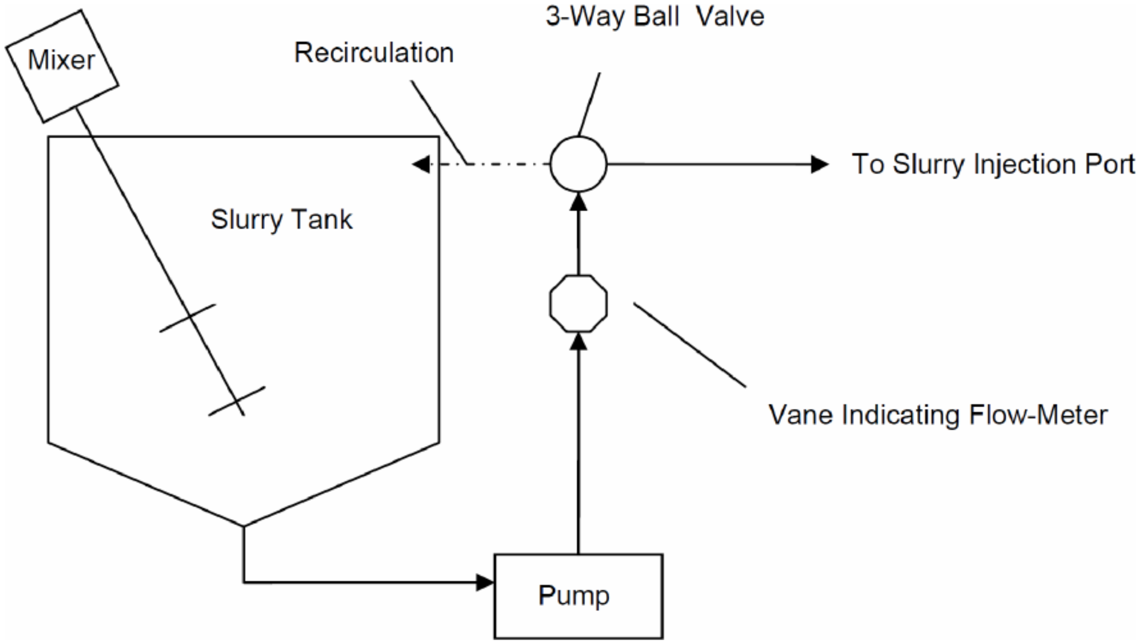

Figure 4: Schematic diagram of the slurry injection system. Arrows indicate flow pathway. (Figure courtesy of Contech Construction Products, Inc.)

A peristaltic pump (Randolph Austin) was used to inject slurry into the slurry injection port at a flow rate of 7 gpm to 15 gpm depending upon desired sediment loading rate. The pump also served to circulate water through the underlying manifold of the slurry tank before injection so as to eliminate any possibility of sediment accumulation in the manifold. A one-inch, three-way ball valve was used to divert a portion of the recirculating slurry to the injection port via an injection manifold consisting of one-inch wire-reinforced PVC tubing and a vane-indicator flow meter (ERDCO See-Flow 3222-03T0). Influent samples were collected by reversing the ball valve to recirculate the slurry into a 500 ml sample bottle prior to injection, as seen in Figure 4.

Effluent was sampled directly by sweeping a 500-mL sample bottle through the free discharge from the effluent pipe. Effluent from the CDS outlet pipe freely discharged into the catch tank and was pumped back to the influent line after passing through the filter bags. The effluent filter consisted of a plate containing eighteen 7-in dia. x 34-in long, 50-µm nominal-rated, polypropylene felt filter bags. Background samples were collected by dipping a 500 ml bottle into the furthest bay of the catch tank downstream from the filters.

The operational procedure for removal efficiency testing consisted of performing multiple runoff simulations (sims). Prior to each sim, a new slurry solution was prepared by filling the drained and cleaned slurry tank with 1200-L of tap water, activating the pump and mixer, and adding the predetermined quantity of OK-110 material. Slurry was allowed to mix and recirculate in the slurry tank for several minutes before use. Each sim was begun by commencing influent and effluent return flows at a predetermined flow rate. After attaining a steady-state flow condition, slurry injection was started at a predetermined flow rate and the temperature of water in the test apparatus was measured. The system was then given 3 residence times to equilibrate before the first set of corresponding background, slurry, and effluent samples were taken at 1-min intervals until a total of six sets had been collected. Following the collection of the last set of performance assessment samples, slurry injection and flow to the test unit were stopped. The test unit was drained and emptied of captured sediment between simulations.

Discrete influent, effluent, and background sample sets were collected for solids analysis. For this document, a set is defined as a collection of background, influent, and effluent sample pairs corresponding to a specific sim. Sample handling was performed in accordance with standard handling techniques. All samples to be tested for solids were promptly refrigerated and analyzed following collection. Maine Environmental Laboratory[2] performed analysis according to ASTM method D3977—essentially a "whole sample" variation of EPA method 160.2.

Re-suspension Testing
A CDS 2015 was used for testing. This unit consisted of a 5-ft diameter welded aluminum structure with a maximum depth of 4.83-ft between the floor of the sump and the invert of the inlet pipe. The difference in depth between the removal efficiency testing and the re-suspension testing is due to the inclusion of an 8-in aluminum insert in the latter tests, to better simulate the concrete insert found in most field deployments. The diameter of the inlet and outlet pipes of the test system were 12-in, and entered and exited the system as shown in Figure 3.

Re-suspension testing was conducted with a false floor installed into the sump to efficiently represent 75% and 100% sediment storage capacity conditions. The false floor was constructed of plywood and supported by cement blocks. It was then sealed with plastic sheeting and waterproof tape. The floor was installed 3-in below the target sediment depth and 3-in of OK-110 material was loaded onto the floor to bring the top of the sediment pile to the appropriate elevation for each trial.

For the CDS 2015, the 75% sediment storage capacity is defined as 12.6-in, with a distance of 45.44-in between the top of the sediment pile and the invert of the influent pipe. The 100% sediment storage capacity is defined as 16.1-in, with a distance of 41.9-in between the top of the sediment pile and the invert of the influent pipe.

During re-suspension testing no sediment was injected into the unit and only background and effluent samples were collected. During each trial, flow was introduced and allowed to stabilize before sampling in one minute increments. A total of 6 effluent samples and 1 background sample were collected at each flow rate. Re-suspension tests began at the lowest target flow rate. Once sampling was complete, the flow rate was increased and the sampling process was repeated. This continued until the maximum flow rate was achieved.

[2] Maine Environmental Laboratory, 1 Main St, Yarmouth, ME 04096

The operational procedure for re-suspension testing consisted of performing two runoff simulations (sims), one at sediment storage at 75% of capacity, the other at 100%. Each sim was begun by commencing effluent return flows at a predetermined flow rate. After attaining a steady-state flow condition using clean influent, flow rate and temperature of water in the test apparatus was measured. The system was then given 3 residence times to equilibrate before the first set of effluent and background samples were taken at 1-min intervals. After each set of six samples, the flow rate was increased and sampling was conducted again. The initial target flow rate was set at 0.1 cfs, and increasing through the following series: 0.28, 0.63, 0.88, 1.22, 1.47, 1.76, and 1.92 cfs. These flows correspond to the target flows of the removal efficiency testing. Actual measured flow rates are presented in Table 2. Following the collection of the last set of re-suspension samples, flow to the test unit was stopped. The test unit was drained, emptied, inspected, and refilled with OK-110 to the appropriate sediment storage capacity between simulations.

Since the invert of the effluent pipe was several feet above the water surface elevation of the catch tank, effluent was sampled directly from the discharge of the effluent pipe. All sampling was conducted in the presence of an observer from FB Environmental.

Results and Discussion

Removal Efficiency Testing

The testing plan was successfully carried out. All 21 test runs were completed, three at each of the seven stated treatment capacities, with results presented in Table 1. Measured flow rates were between 0.12 and 1.8 cfs, corresponding to between 17% and 257% of the CDS 2015 treatment capacity. Influent concentration averaged 313 mg/L, compared to a target concentration of 300 mg/L. Reported influent and effluent values are averages of grab samples taken once per minute for six minutes immediately after the calculated detention time at the appropriate flow rate.

Data integrity was very good. Six grab samples were taken of influent, effluent, and background TSS concentrations during each test run, for a total of 126 samples each, and a combined total of 378 grab samples. During the course of sampling, a total of five influent samples were considered outliers. No more than one grab sample per sample run was excluded, and a maximum of 2 out of 18 possible influent samples (over three test runs) were rejected for any given target treatment capacity. Dixon's Q-test was used to confirm outlier status. Removal of these outliers resulted in a more conservative statement of removal efficiency, since their TSS figures were higher than the corrected average influent concentration in every case. Three effluent samples and three background samples were lost during processing (e.g., accidental spill). There were a total of 11 missing and excluded samples out of a possible 387, for an overall data completeness of 97%.

Removal efficiencies were calculated by using the following equation:

RE = ((influent solids concentration) – (effluent solids concentration)) / (influent solids concentration).

Of the 123 background samples collected, 112 (91%) were below the limit of detection of 4 mg/L. Only 5 of the 21 test runs had any background samples with detectable TSS. The maximum concentration was 8 mg/L, and the highest average value for a test run was 6.5 mg/L. High background levels would indicate that the filter plate between the effluent and the intake for recycled clean water was leaking, and would lead to an underestimation of TSS removal efficiency. The data indicate this was not a significant problem during this product evaluation.

Figure 5 shows a strong a linear relationship between flow rate and removal efficiency. The relationship is both strong (R^2=0.975) and significant ($p<0.001$).

Table 1: Observed performance of removal of OK- 110 material by the CDS Model 2015 under "maintained" conditions (sediment storage at 0% capacity).

Actual Treatment Capacity	Measured Flow Rate (cfs)	Influent Concentration TSS (mg/L)	Effluent Concentration TSS (mg/L)	Removal Efficiency
20%	0.14	292	0	100%
17%	0.12	303	0	100%
19%	0.13	262	0	100%
43%	0.30	305	11	97%
44%	0.31	309	10	97%
44%	0.31	309	12	96%
87%	0.61	299	53	82%
80%	0.56	333	51	85%
83%	0.58	327	59	82%
133%	0.93	303	128	58%
136%	0.95	295	115	61%
131%	0.92	294	120	59%
163%	1.14	341	162	52%
169%	1.18	298	153	49%
167%	1.17	320	152	53%
210%	1.47	323	194	40%
210%	1.47	323	194	40%
210%	1.47	324	202	38%
257%	1.80	325	227	30%
250%	1.75	326	231	29%
257%	1.80	355	226	36%

Table 2: Observed re-suspension performance of the CDS Model 2015 using influent with zero TSS, and sediment storage at 75% and 100% of capacity. ND means below detection limit.

Sediment Storage at 75% Capacity Average			Sediment Storage at 100% Capacity Average		
Treatment Capacity	Influent Flow Q (cfs)	Effluent Concentration TSS (mg/L)	Treatment Capacity	Influent Flow Q (cfs)	Effluent Concentration TSS (mg/L)
14%	0.10	ND	17%	0.12	ND
40%	0.28	ND	40%	0.28	ND
90%	0.63	ND	84%	0.59	ND
126%	0.88	ND	126%	0.88	ND
174%	1.22	ND	170%	1.19	ND
210%	1.47	ND	209%	1.46	ND
251%	1.76	ND	250%	1.75	ND
274%	1.92	ND	273%	1.91	7

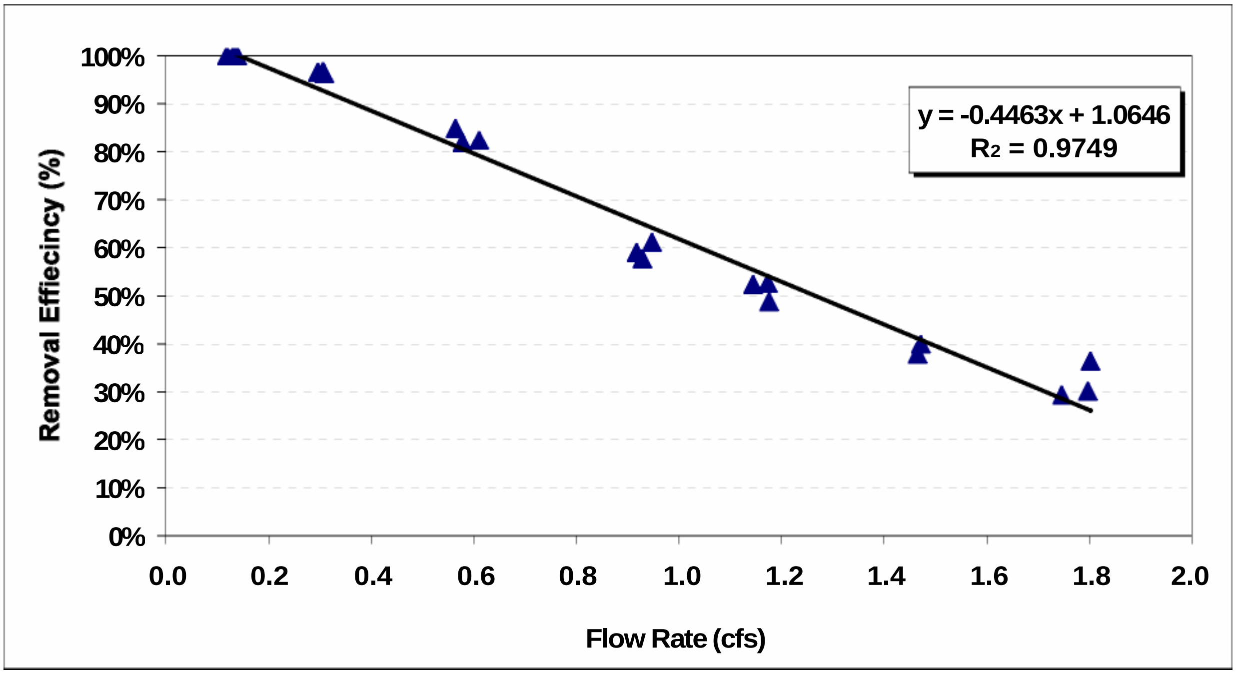

Figure 5: Observed TSS removal efficiency of the CDS 2015 under "maintained" conditions (sediment storage at 0% of capacity) using OK- 110 silica.

Re-suspension Testing

The results of re-suspension testing at 75% and 100% of the sediment storage capacity are shown in Table 2. As seen in Table 2, at 75% sediment storage capacity, the effluent concentration remained at or below the limit of analytical detection (4 mg/L) across the range of flows from 0.09 cfs to 1.92 cfs. At 100% sediment storage capacity, the effluent concentration was below the limit of detection for flow of 0.12 cfs to 1.75 cfs. Only at 1.91 cfs (corresponding to 273% of the design capacity) was there detectable TSS, averaging 7 mg/L.

Background sediment concentrations were below the limit of detection throughout both re-suspension trials and were not used to adjust effluent concentrations.

Conclusion

Removal Efficiency Testing

This test successfully measured CDS Model 2015 performance at influent flows from 17% to 257% of design flow, with influent TSS concentrations in the range of 300 mg/L. A strong and highly significant linear relationship between flow and removal efficiency was demonstrated. Removal efficiency ranged from 100% to approximately 30% across tested conditions, as shown in Figure 5.

Re-suspension Testing

The re-suspension test indicated that there is no observable re-suspension of TSS with the sediment storage capacity at 75% and 100% of capacity, except for a small amount (7 mg/L TSS) at very high flows (273% of design capacity of the CDS 2015) when the sediment storage sump was 100% full.

A representative from FB Environmental, an independent, third-party reviewer, observed every sample run, as indicated in Table 3. Original data files from Maine Environmental Laboratory and subsequent spreadsheets and calculations were examined as well. FB Environmental reviewed sample plans, verified measurements, witnessed all sample collections, checked data against signed laboratory analysis reports, and performed the statistical analysis presented in this report. The data collected meet a high standard for completeness, and the results are deemed to accurately represent the total suspended solids removal efficiency and storage of the model CDS 2015 under the stated conditions.

Table 3: Testing schedule, lab analysis date, and reviewer.

Date Sampled	Date Lab Tests	Test[4]	Test Run	FB Environmental Reviewer
7/27/2009	7/31/2009	CDS 125	2	Fred Dillon
7/28/2009	8/3/2009	CDS 125	3	Fred Dillon
7/30/2009	8/6/2009	CDS 100	1	Fred Dillon
7/31/2009	8/6/2009	CDS 100	2	Fred Dillon
8/3/2009	8/12/2009	CDS 100	3	Fred Dillon
8/4/2009	8/12/2009	CDS 75	1	Fred Dillon
8/6/2009	8/13/2009	CDS 75	2	Fred Dillon
8/7/2009	8/13/2009	CDS 75	3	Fred Dillon
8/10/2009	8/26/2009	CDS 50	1	Cayce Dalton
8/11/2009	8/26/2009	CDS 50	2	Forrest Bell
8/13/2009	8/26/2009	CDS 50	3	Cayce Dalton
8/13/2009	8/31/2009	CDS 25	1	Cayce Dalton
8/14/2009	8/31/2009	CDS 25	2	Forrest Bell
8/17/2009	9/1/2009	CDS 25	3	Cayce Dalton
8/18/2009	9/1/2009	CDS 10	1	Forrest Bell
8/19/2009	9/3/2009	CDS 10	2	Cayce Dalton
8/20/2009	9/3/2009	CDS 10	3	Cayce Dalton
9/2/2009	9/15/2009	CDS 150	1	Cayce Dalton
9/3/2009	9/15/2009	CDS 150	2	Cayce Dalton
9/28/2009	10/9/2009	CDS 50 washout	1	Cayce Dalton
10/20/2009	10/26/2009	CDS 100 washout	1	Cayce Dalton

[4] Test refers to unit (CDS 2015) together with the identifier used during laboratory analyses. These identifiers are incremental, so that CDS 10 refers to test runs at 20% capacity, and CDS 125 refers to test runs at 250% capacity. Washout refers to re-suspension testing.

I have reviewed and approve this report, entitled "Independent Review of CDS 2015 Product Evaluation."

Forrest Bell

January 22, 2010

Forrest Bell
Principal of FB Environmental
97A Exchange St., Portland ME 04101

Date