Vancouver Energy
NPDES Engineering Report

EFSEC Application for Site Certification No. 2013-01
Docket No. EF131590

Appendix H
Water Quality Vault Sizing Calculations

Catchment ID	**Area 200 - West**	
WQ Volume	6,242.15	cf
	46,691.28	
WQ volume	176,757.71	liter
WQ Flow Rate	0.21	cfs
WQ Flow Rate	94.25	gpm
WQ Flow Rate	5.95	liter/sec
100-Year Flow Rate	1.27	cfs
100-Year Flow Rate	569.98	gpm
100-Year Flow Rate	35.96	liter/sec

Surface Coverage:	Roof Industrial	Parking Industrial	Industrial Yard	Landscaping	Driveway
Curve Number	98	98	98	20	98
Contributing Area (ac)	0.17	0.91	0.17	0.10	0.02
Product	16.66	89.18	16.66	2	1.96
Area Percentage	12%	66%	12%	7%	1%
Weighted Runoff	13%	71%	13%	2%	2%
Weighted CN	92.30656934				
Total Area (ac)	1.4				

Pollutant Loading							Total
TSS	mg/L	17.0	228.0	96.0	37.0	173.0	178.9
Copper, Total	µg/L	7.0	34.0	34.0	94.0	17.0	31.1
Zinc, Total	µg/L	256.0	224.0	150.0	263.0	107.0	217.3

Catchment ID	**Area 200 - East**	
WQ Volume	16,003.94	cf
WQ Volume	119,709.47	gallons
WQ volume	453,180.37	liter
WQ Flow Rate	0.52	cfs
WQ Flow Rate	233.38	gpm
WQ Flow Rate	14.72	liter/sec
100-Year Flow Rate	3.25	cfs
100-Year Flow Rate	1,458.60	gpm
100-Year Flow Rate	92.03	liter/sec

Surface Coverage:	Roof Industrial	Parking Industrial	Industrial Yard	Landscaping	Driveway
Curve Number	98	98	98	20	98
Contributing Area (ac)	0.05	0.03	1.29	0.00	0.04
Product	4.9	2.94	125.93	0	3.92
Area Percentage	4%	2%	91%	0%	3%
Weighted Runoff	4%	2%	91%	0%	3%
Weighted CN	98				
Total Area (ac)	1.4				

Pollutant Loading							Total
TSS	mg/L	17.0	228.0	96.0	37.0	173.0	98.2
Copper, Total	µg/L	7.0	34.0	34.0	94.0	17.0	32.6
Zinc, Total	µg/L	256.0	224.0	150.0	263.0	107.0	154.1

Catchment ID	**Area 300 - Containment Area**	
WQ Volume	58,670.96	cf
WQ Volume	438,858.78	gallons
WQ volume	1,661,373.84	liter
WQ Flow Rate	1.96	cfs
WQ Flow Rate	879.65	gpm
WQ Flow Rate	55.50	liter/sec
100-Year Flow Rate	1.96	cfs
100-Year Flow Rate	879.65	gpm
100-Year Flow Rate	55.50	liter/sec

Surface Coverage:	Tesoro Anacortes Stormwater
Curve Number	98
Contributing Area (ac)	11.96
Product	1172.08
Area Percentage	100%
Weighted Runoff	100%
Weighted CN	98
Total Area (ac)	12.0

Pollutant Loading			Total
Oil & Grease	mg/l	8.0	8.0
TSS	mg/L	23.7	23.7
Benzene	µg/L	1.2	1.2
Toluene	µg/L	1.2	1.2
Etheylbenzene	µg/L	1.0	1.0
Copper, Total	µg/L	6.4	6.4
Zinc, Total	µg/L	43.0	43.0

Catchment ID	**Area 300 - Parking Area**	
WQ Volume	64,978.45	cf
WQ Volume	486,038.82	gallons
WQ volume	1,839,981.83	liter
WQ Flow Rate	2.13	cfs
WQ Flow Rate	955.94	gpm
WQ Flow Rate	60.31	liter/sec
100-Year Flow Rate	13.23	cfs
100-Year Flow Rate	5,937.62	gpm
100-Year Flow Rate	374.63	liter/sec

Surface Coverage:	Tesoro Anacortes Stormv	Roof Industrial	Parking Industrial	Industrial Yard	Landscaping	Driveway
Curve Number	98	98	98	98	20	98
Contributing Area (ac)	11.96	0.09	0.50	0.57	0.36	0.05
Product	1172.08	8.82	49	55.86	7.2	4.9
Area Percentage	88%	1%	4%	4%	3%	0%
Weighted Runoff	90%	1%	4%	4%	1%	0%
Weighted CN	95.92461197					
Total Area (ac)	13.5					

Pollutant Loading								Total
TSS	mg/L	23.7	17.0	228.0	96.0	37.0	173.0	35.1
Benzene	µg/L	1.2	0.0	0.0	0.0	0.0	0.0	1.1
Toluene	µg/L	1.2	0.0	0.0	0.0	0.0	0.0	1.1
Etheylbenzene	µg/L	1.0	0.0	0.0	0.0	0.0	0.0	0.9
Copper, Total	µg/L	6.4	7.0	34.0	34.0	94.0	17.0	9.2
Zinc, Total	µg/L	43.0	256.0	224.0	150.0	263.0	107.0	57.3

Catchment ID	**Area 400 - Containment Area**	
WQ Volume	749.23	cf
WQ Volume	5,604.24	gallons
WQ volume	21,215.80	liter
WQ Flow Rate	0.02	cfs
WQ Flow Rate	8.98	gpm
WQ Flow Rate	0.57	liter/sec
100-Year Flow Rate	0.15	cfs
100-Year Flow Rate	67.32	gpm
100-Year Flow Rate	4.25	liter/sec

Surface Coverage:	Tesoro Anacortes Stormwater
Curve Number	98
Contributing Area (ac)	0.11
Product	10.78
Area Percentage	7%
Weighted Runoff	100%
Weighted CN	6.416666667
Total Area (ac)	1.7

Pollutant Loading			Total
Oil & Grease	mg/l	8.0	8.0
TSS	mg/L	23.7	23.7
Benzene	µg/L	1.2	1.2
Toluene	µg/L	1.2	1.2
Etheylbenzene	µg/L	1.0	1.0
Copper, Total	µg/L	6.4	6.4
Zinc, Total	µg/L	43.0	43.0

Class	Parameter	Units	Analytical I	Ind General SW Benchmark	Driveway	Industrial Yard	Landscaping	Parking Industrial	Roof Industrial	Tesoro Anacortes Stormwater
	Oil & Grease	mg/l								8
	TSS	mg/L	SM 2540-D	100	173	96	37	228	17	23.7
Volatiles										
	Benzene	µg/L								1.2
	Toluene	µg/L								1.2
	Etheylbenzene	µg/L								1
Metals										
	Copper, Total	µg/L	EPA 200.8	14	17	34	94	34	7	6.4
	Zinc, Total	µg/L	EPA 200.8	117	107	150	263	224	256	43

Water Quality Vault: Area 200-West

Water Qualty Flow Rate (online): 0.2 cfs

89.76 gpm

100-Year Flow Rate: 1.27 cfs

Required Cartridge Calculations

Unit	Low Drop (12")	Standard (18")	Tall (27")
Capacity at 1gpm/SF (gpm)	5.0	7.5	11.3
Hydrualic Drop (feet)	1.80	2.30	3.05
# of Cartridges	18	12	8

Pollutant Calculations	Parameter	Influent Concentrations	Removal Efficiency ZPG	Metal Rx	GAC	Anticipated Effluent Concentration ZPG	Metal Rx	GAC	WQ Benchmark
	Oil & Grease (mg/L)	0	0.0%	0.0%	0.0%	0	0	0	10
	Total Suspended Solids (TSS) (mg/L)	178.9	75.0%	85.0%	85.0%	44.725	26.835	26.835	30
	Benzene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Toluene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Ethylbenzene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Copper, Total (µg/L)	31.1	40.0%	60.0%	50.0%	18.66	12.44	15.55	14
	Zinc, Total (µg/L)	217.3	40.0%	60.0%	50.0%	130.38	86.92	108.65	117

Water Quality Vault: Area 200-East

Water Qualty Flow Rate (online): 0.22 cfs

98.736 gpm

100-Year Flow Rate: 3.25 cfs

Required Cartridge Calculations

Unit	Low Drop (12")	Standard (18")	Tall (27")
Capacity at 1gpm/SF (gpm)	5.0	7.5	11.3
Hydrualic Drop (feet)	1.80	2.30	3.05
# of Cartridges	20	14	9

Pollutant Calculations	Parameter	Influent Concentrations	Removal Efficiency ZPG	Metal Rx	GAC	Anticipated Effluent Concentration ZPG	Metal Rx	GAC	WQ Benchmark
	Oil & Grease (mg/L)	0	0.0%	0.0%	0.0%	0	0	0	10
	Total Suspended Solids (TSS) (mg/L)	98.2	75.0%	85.0%	85.0%	24.55	14.73	14.73	30
	Benzene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Toluene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Ethylbenzene (µg/L)	0	25.0%	40.0%	40.0%	0	0	0	1.2
	Copper, Total (µg/L)	32.6	40.0%	60.0%	50.0%	19.56	13.04	16.3	14
	Zinc, Total (µg/L)	154.1	40.0%	60.0%	50.0%	92.46	61.64	77.05	117

Water Quality Vault: Area 300-Containment

Water Qualty Flow Rate (online): 1.96 cfs

879.648 gpm

100-Year Flow Rate: 1.96 cfs

Required Cartridge Calculations

Unit	Low Drop (12")	Standard (18")	Tall (27")
Capacity at 1gpm/SF (gpm)	5.0	7.5	11.3
Hydrualic Drop (feet)	1.80	2.30	3.05
# of Cartridges	176	118	79

Pollutant Calculations

Parameter	Influent Concentrations	Removal Efficiency ZPG	Removal Efficiency Metal Rx	Removal Efficiency GAC	Anticipated Effluent Concentration ZPG	Anticipated Effluent Concentration Metal Rx	Anticipated Effluent Concentration GAC	WQ Benchmark
Oil & Grease (mg/L)	8	0.0%	0.0%	0.0%	8	8	8	10
Total Suspended Solids (TSS) (mg/L)	23.7	75.0%	85.0%	85.0%	5.925	3.555	3.555	30
Benzene (µg/L)	1.2	25.0%	40.0%	40.0%	0.9	0.72	0.72	1.2
Toluene (µg/L)	1.2	25.0%	40.0%	40.0%	0.9	0.72	0.72	1.2
Ethylbenzene (µg/L)	1	25.0%	40.0%	40.0%	0.75	0.6	0.6	1.2
Copper, Total (µg/L)	6.4	40.0%	60.0%	50.0%	3.84	2.56	3.2	14
Zinc, Total (µg/L)	43	40.0%	60.0%	50.0%	25.8	17.2	21.5	117

Water Quality Vault: Area 300-Parking & Support

Water Qualty Flow Rate (online): 2.13 cfs

955.944 gpm

100-Year Flow Rate: 13.23 cfs

Required Cartridge Calculations

Unit	Low Drop (12")	Standard (18")	Tall (27")
Capacity at 1gpm/SF (gpm)	5.0	7.5	11.3
Hydrualic Drop (feet)	1.80	2.30	3.05
# of Cartridges	192	128	85

Pollutant Calculations

Parameter	Influent Concentrations	Removal Efficiency ZPG	Removal Efficiency Metal Rx	Removal Efficiency GAC	Anticipated Effluent Concentration ZPG	Anticipated Effluent Concentration Metal Rx	Anticipated Effluent Concentration GAC	WQ Benchmark
Oil & Grease (mg/L)	0	0.0%	0.0%	0.0%	0	0	0	10
Total Suspended Solids (TSS) (mg/L)	35.1	75.0%	85.0%	85.0%	8.775	5.265	5.265	30
Benzene (µg/L)	1.1	25.0%	40.0%	40.0%	0.825	0.66	0.66	1.2
Toluene (µg/L)	1.1	25.0%	40.0%	40.0%	0.825	0.66	0.66	1.2
Ethylbenzene (µg/L)	0.9	25.0%	40.0%	40.0%	0.675	0.54	0.54	1.2
Copper, Total (µg/L)	9.2	40.0%	60.0%	50.0%	5.52	3.68	4.6	14
Zinc, Total (µg/L)	57.3	40.0%	60.0%	50.0%	34.38	22.92	28.65	117

Water Quality Vault:	Area 400-Containment		
Water Qualty Flow Rate (online):		0.02	cfs
		8.976	gpm
100-Year Flow Rate:		0.15	cfs

Required Cartridge Calculations

Unit	Low Drop (12")	Standard (18")	Tall (27")
Capacity at 1gpm/SF (gpm)	5.0	7.5	11.3
Hydrualic Drop (feet)	1.80	2.30	3.05
# of Cartridges	2	2	1

Pollutant Calculations	Parameter	Influent Concentrations	Removal Efficiency ZPG	Removal Efficiency Metal Rx	Removal Efficiency GAC	Anticipated Effluent Concentration ZPG	Anticipated Effluent Concentration Metal Rx	Anticipated Effluent Concentration GAC	WQ Benchmark
	Oil & Grease (mg/L)	8	0.0%	0.0%	0.0%	8	8	8	10
	Total Suspended Solids (TSS) (mg/L)	23.7	75.0%	85.0%	85.0%	5.925	3.555	3.555	30
	Benzene (µg/L)	1.2	25.0%	40.0%	40.0%	0.9	0.72	0.72	1.2
	Toluene (µg/L)	1.2	25.0%	40.0%	40.0%	0.9	0.72	0.72	1.2
	Ethylbenzene (µg/L)	1	25.0%	40.0%	40.0%	0.75	0.6	0.6	1.2
	Copper, Total (µg/L)	6.4	40.0%	60.0%	50.0%	3.84	2.56	3.2	14
	Zinc, Total (µg/L)	43	40.0%	60.0%	50.0%	25.8	17.2	21.5	117

Table B.5: Summary of Pollutant EMCs Associated with Stormwater Hotspots						
	TSS	**Total P**	**Total N**	**Fecal Coliform[1]**	**Total Cu[2]**	**Total Zn[2]**
Land Use	**Median Event Mean Concentrations (mg/L or ppm, except where noted)**					
Lawns	602	2.1	9.1	2,400	17	50
Landscaping	37	--	--	9,400	94	263
Residential Roof	19	0.11	1.5	26	200	312
Commercial Roof	9	0.14	2.1	110	7	256
Industrial Roof	17	--	--	580	62	1390
Res/Comm Parking Lot	27	0.15	1.9	180	51	139
Industrial Parking Lot	228	--	--	270	34	224
Driveway	173	0.56	2.1	1,700	17	107
Local Residential Street	172	0.55	1.4	3,700	25	173
Commercial Street	468	--	--	1,200	73	450
Gas Station	31	--	--	--	88	290
Auto Recycler	335	--	--	--	103	520
Heavy Industry	124	--	--	--	148	1600

Sources: Claytor *et al.*, 1996; Steuer *et al.*, 1997; Bannerman, 1993; and Waschbuch, 2000.
[1] MPN/100 mL, which represents the most probable number (MPN) of bacteria that would be found in 100 mL of water
[2] Cu and Zn values are shown in μg/l

18 March 2013

Technical Memorandum

To: Matt Graves, Port of Vancouver

From: Alan Flemming

Subject: Terminal 4 Pond Particle Size Distribution and Sample Analysis
Port of Vancouver Decant Facility
K/J 1092004*00

This technical memorandum summarizes the sampling and particle size distribution (PSD) analyses completed for the Terminal 4 stormwater pond, and presents a discussion of initial indications of the data. Four locations near the pond were sampled on 28 January 2013 and on 28 February 2013; one at the outlet (T4M) and three at the inlets (M1, 1D, 1A). In October 2012, three locations were sampled and optical/microscopic particle size distribution analyses were completed for locations T4M, M001, and 1D001. These data and the particle size distribution histograms are presented in the following pages and discussed below. The approximate sample locations and areas draining to each location are shown on Figure 1.

Table 1: Sample Points

Sample Location - Description	Approx. Drainage Area
T4M – Pond Outlet	250 acres
M1 (1M, M001) – East Side of Pond; maintenance shop, Terminal 3	120 acres
1D (1D001) – Parcel 1D; West side of pond, parking lot/laydown area	75 acres
1A – Parcel 1A; North side of Pond, Farwest Steel, new construction	55 acres

Table 2: Sample Data

Sample Point	T4M		M1		1D		1A	
Sample Date (2013)	Jan	Feb	Jan	Feb	Jan	Feb	Jan	Feb
Turbidity (NTU)	25.5	24.5	68.6	61.8	81.3	422.0	196.1	500.0
TSS (mg/L)	< 5.0	< 5.0	31.0	45	24.0	55	34.0	270
pH	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Conductivity (umhos/cm)	74.1	52	18.1	63	16.8	60	67.0	63
total Cu (µg/L)	44.7	33	123.0	120	13.3	78	27.3	57
dissolved Cu (µg/L)	18.3	14	20.7	33	3.43	6.2	3.48	4.5
% dissolved Cu	41%	42%	17%	28%	26%	8%	13%	8%
total Zn (µg/L)	87.9	54	109.0	170	47.2	320	64.6	170
dissolved Zn (µg/L)	71.1	30	62.0	110	24.8	13	< 4.0	< 4.0
% dissolved Zn	81%	56%	57%	65%	53%	4%	0%	0%
mean particle size (µm)	0.969	0.975	2.008	1.033	2.137	2.059	11.04	2.357
median part. size (µm)	0.677	0.693	1.664	0.656	1.646	0.744	2.240	1.146

Notes:

1 - Red values would exceed ISGP benchmarks.

© Kennedy/Jenks Consultants, Inc.

Abbreviations:

µg/L = micrograms per liter
µm = micron/micrometer
umhos/cm = micromho per centimeter
Mg/L = milligrams per liter
NTU = nephelometric turbidity unit
TSS = total suspended solids
Cu = copper
Zn = zinc

Turbidity and copper are the only parameters that exceeded the Industrial Stormwater General Permit (ISGP) benchmarks at the Pond outlet for these sampling events. Turbidity exceeded the benchmark by a very small amount, and that parameter may improve as the pond continues to age and construction completion reduces influent solids concentrations. Sample point M1 appears to be a significant source of copper, particularly in the dissolved fraction, which is assumed to originate from copper concentrate handling in that drainage basin.

Parcel 1A appears to be a significant source of turbidity, which is presumed to originate from construction activity. Turbidity at sample location 1A is more than twice the level at the other locations for the January sample, but Total Suspended Solids (TSS) is not significantly higher. This sample also has a higher percentage of larger particles with high surface area and high conductivity. A similar high turbidity and low TSS occurs at sample location 1D for the February sample. In any case, the pond appears to be effective at reducing both turbidity and TSS to near benchmark levels. As construction activity is reduced, turbidity in the pond effluent is anticipated to continue to improve.

The laser PSDs presented in the figures on the following pages show that the inlet and outlet samples have a high percentage of particles near the 0.5 micron (µm) size (except for sample point 1A, which has a high percentage at 0.2 µm) and near the 2.0 µm size. These particular particle size distributions may be due to coagulation and preferential settling of other size ranges, but this cannot be confirmed with the current data. Additional analysis would be required to characterize the settling behavior. It should also be noted that these particle sizes are at the bottom of the size range of settleable airborne dust which may never settle in a turbulent atmosphere unless washed out by rain. Additional characterization of airborne particulate matter at the port may be helpful in understanding contamination in the stormwater if it confirms high copper concentrations in airborne dust.

Sample point M1 has both a high total copper level and a high dissolved copper level. The other inlet samples have low dissolved copper levels and relatively low total copper levels. This sample data appears to confirm the source of copper in the pond is through sample point M1 and its watershed east of the pond. The high dissolved copper level measured at sample point M1 appears to pass through the pond with little removal, and the observed reduction in dissolved copper level at the pond outlet may be due only to dilution.

© Kennedy/Jenks Consultants, Inc.

Based on the analytical methods used in sample preparation before analysis, metals associated with particles smaller than 0.45 µm may be reported as dissolved metals because they may pass through the filter used to separate particulate from the dissolved fraction. Based on review of particle size on a volume percent (%) basis (data not presented here) for the January T4M sample, 13% of the particles by volume were less than 0.452 µm, and for the February T4M sample, 1.8% of the particles by volume were less than 0.452 µm. Approximately 40% of the copper and 70% of the zinc are reported as dissolved in these same samples. This difference between the percent of particles that are less than 0.45 µm and the percentages of dissolved metals suggests that metals reported as dissolved may be truly dissolved, and not associated with particles less than 0.45 µm.

Comparisons of the particle size distributions obtained through optical methods data generally show similar PSDs in October and January. This suggests that the particle size distributions were similar for these two sampling events. However, the optical analyses generally show much larger particle sizes than the laser analyses. For the optical analysis, the sample is shaken by hand, and then observed under a microscope. For the laser particle size distribution, the sample is circulated during the analysis by a pump operating at 1865 revolutions per minute (rpm). The larger particles observed in the optical analysis are likely to be coagulated particles that are broken apart by the pump during the laser PSD analysis. This supposition is supported by the descriptions in the Chemoptix reports. For example, the T4M sample from October includes the following description: “This particle assemblage contained large fractions of soft amalgamates with ~ 1 µm particle inclusions. Despite their poor consolidation, the amalgamates remained intact despite brisk hand-agitation. The data presented here represent the amalgamates…” Similar descriptions were included for all the October samples and most of the January samples.

Review of the laser PSD data suggests that the pond effectively removes particles larger than approximately 5 µm. This may be occurring through settling of naturally coagulated particles. However, as discussed above, the optical analyses show much larger particle amalgamates in both the pond inlets and outlet. It may be that amalgamates containing larger particles have sufficient density to settle in the pond, while those containing only finer particles do not. It also appears that no particles larger than ~ 8 µm are reaching the inlets at sample points M1 and 1D in January. This may be due to removal of larger particles by sweeping or removal in catch basin sumps or inserts. A size distribution analysis of sweeper truck waste might help confirm this last supposition. The high turbidity and high total zinc measured at sample point 1D in February may be related to the larger particles (10-20 µm) seen in this sample and may be the result of the area not having been swept recently.

On a length basis, the optical analyses of samples from locations 1D and 1A appear to be very similar in January; however, on an area basis (data not presented here), the sample from location 1A appears to have larger particles. On a length basis, the optical analysis at 1D also shows smaller particles in October. As noted above in the discussion on turbidity and TSS, and

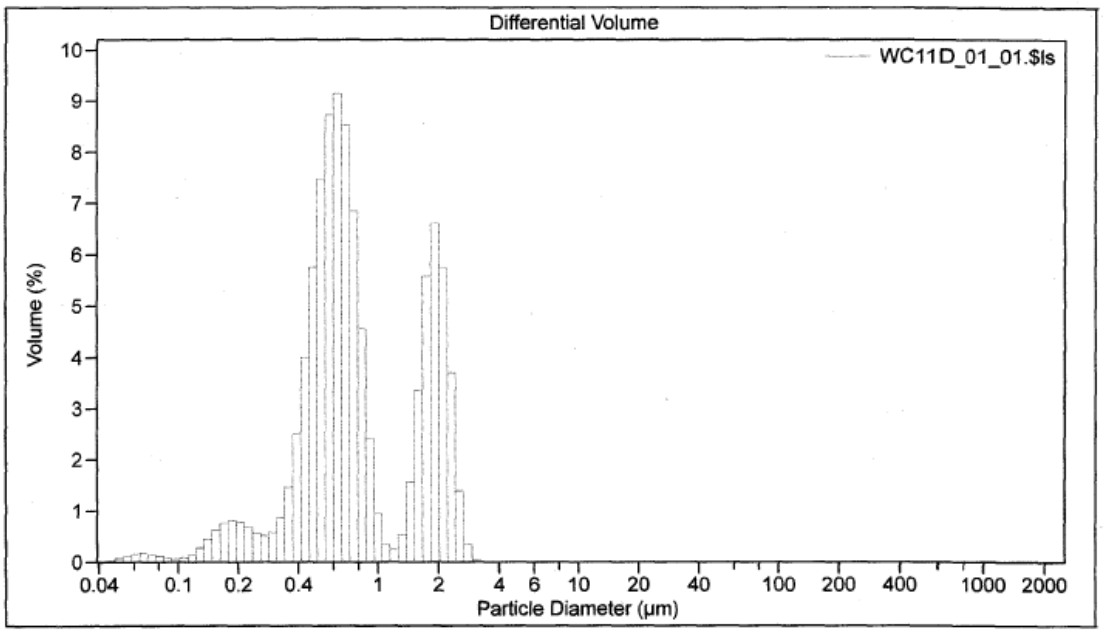
© Kennedy/Jenks Consultants, Inc.

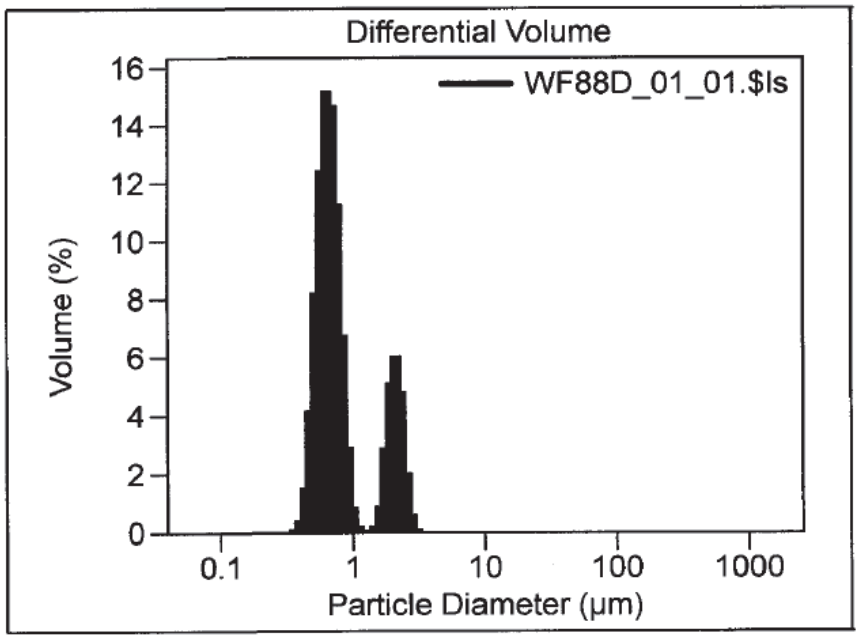
as indicated by its higher conductivity, the January sample from location 1A is likely to have different types of particles from the other two locations and samples.

We recommend that the port consider collecting at least one additional sample at these same locations and request the same analyses, to characterize the potential variability in stormwater influent and effluent at the Terminal 4 Pond. We also recommend the port consider characterization of the airborne dust at the port, and its copper concentration. Kennedy/Jenks Consultants (Kennedy/Jenks) can assist with developing a specific sampling plan to determine the contribution of airborne pollutants to the port's stormwater runoff if the port chooses to pursue this option.

© Kennedy/Jenks Consultants, Inc.

T4M – Pond Outlet
28 January 2013 top figure, 28 February 13 bottom figure, (same analysis, presentation differs)
- very similar results for two samples, bimodal at ~0.5 and ~ 2.0 µm, all < ~5.0 µm

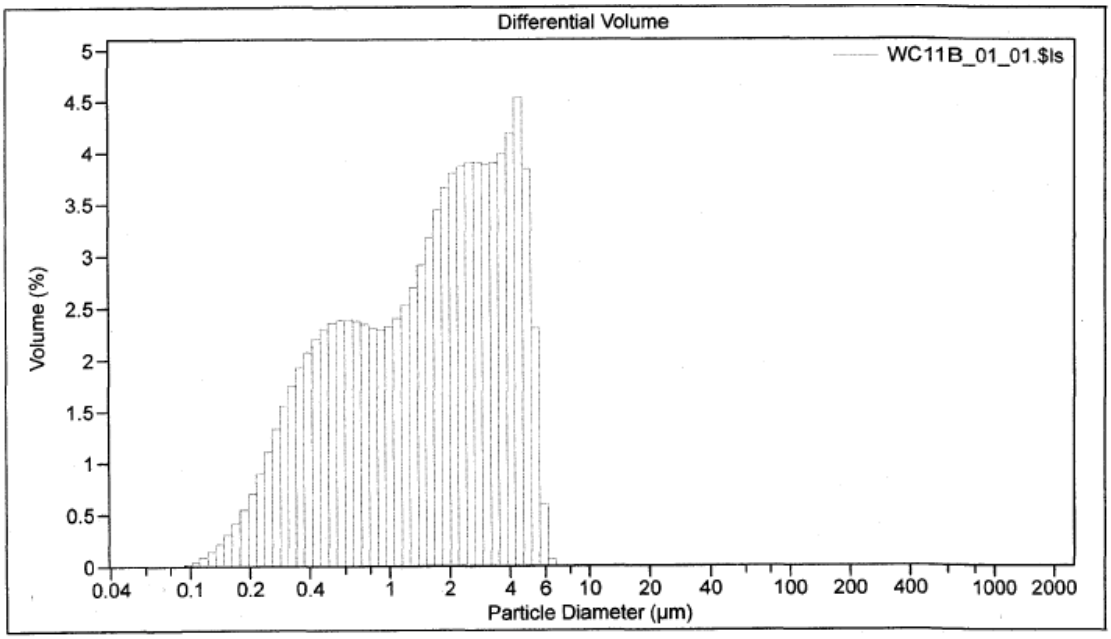


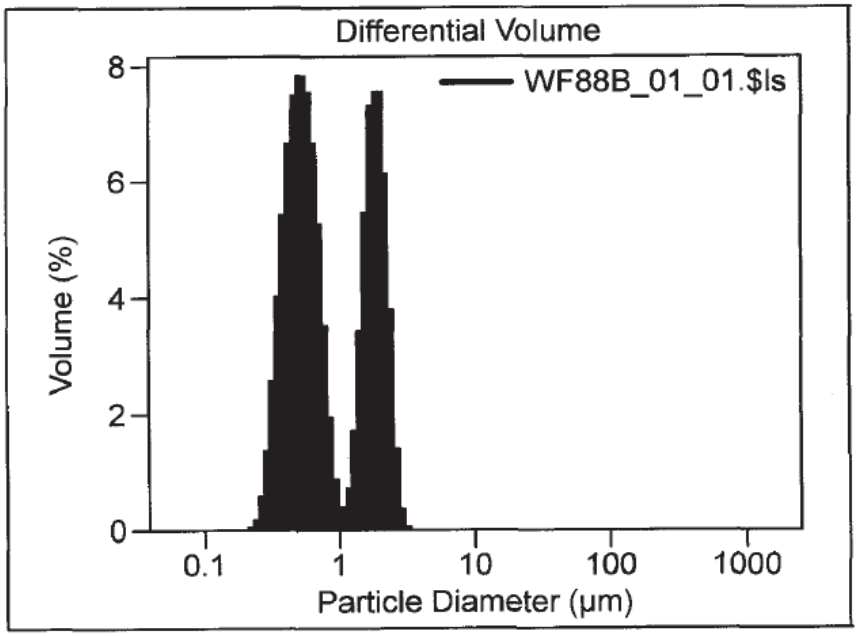


© Kennedy/Jenks Consultants, Inc.

M1 – East Side of Pond; maintenance shop, Terminal 2

28 January 2013 top figure, 28 February 13 bottom figure, (same analysis, presentation differs)
- similar bimodal samples at ~0.4 and ~ 3.0 µm, all < ~6.0 µm, variability unexplained

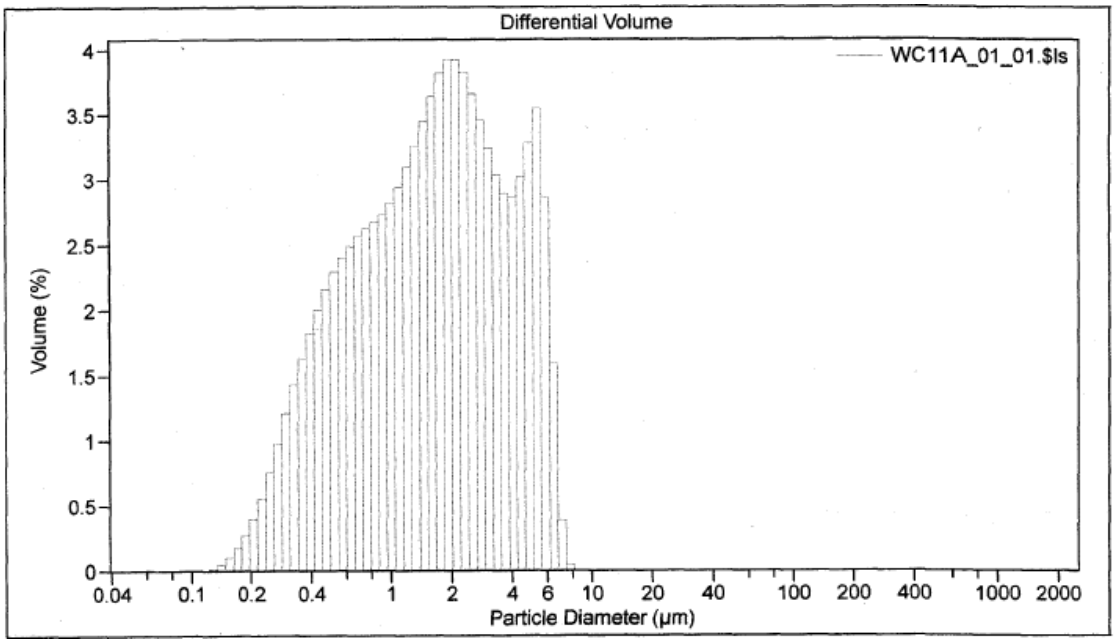


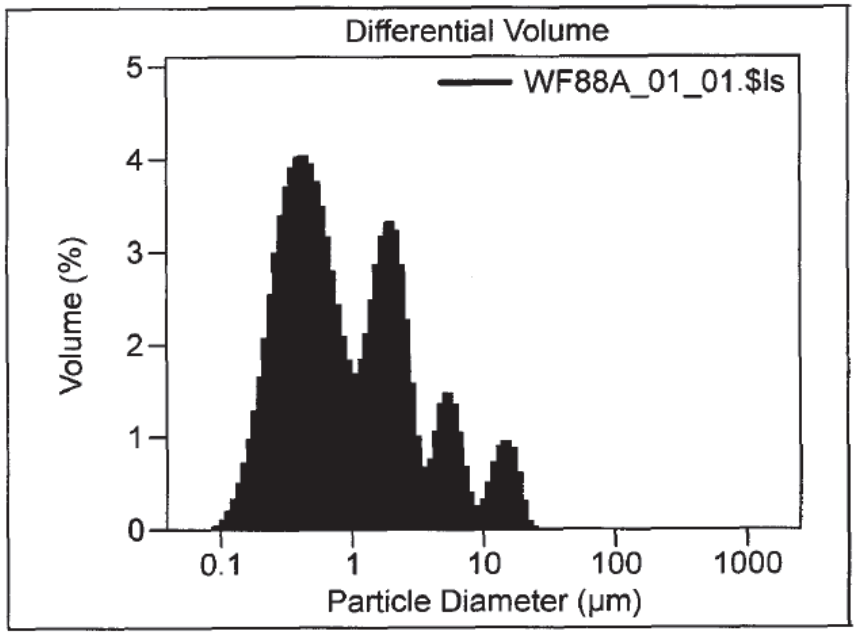


© Kennedy/Jenks Consultants, Inc.

1D – Parcel 1D; West side of pond, parking lot/laydown area

28 January 2013 top figure, 28 February 13 bottom figure, (same analysis, presentation differs) - samples variable, may be due to timing of sweeping?,

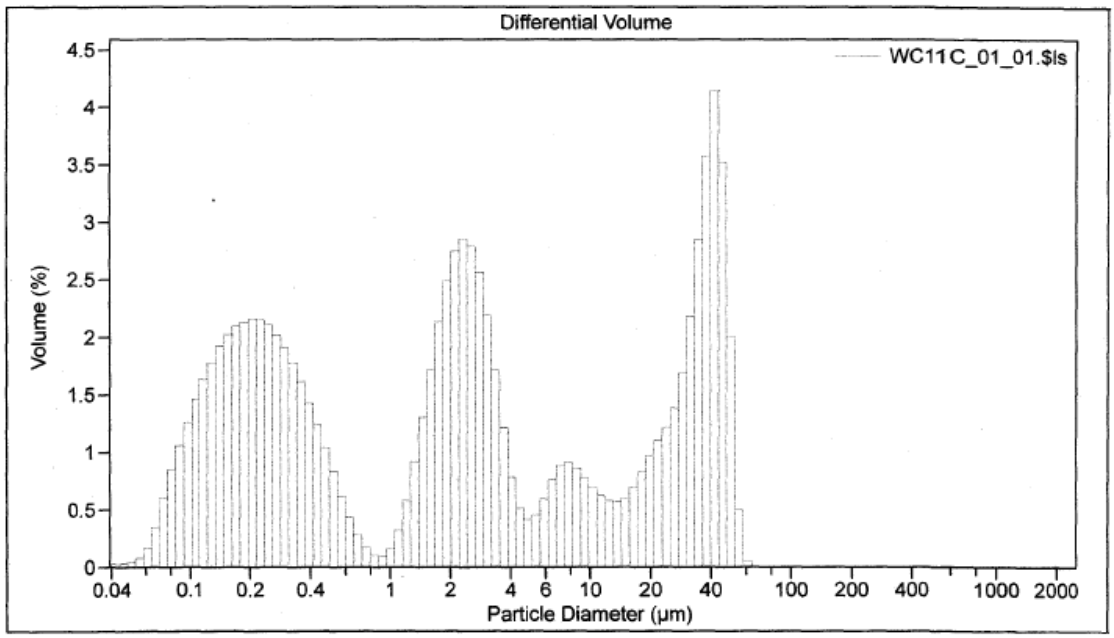


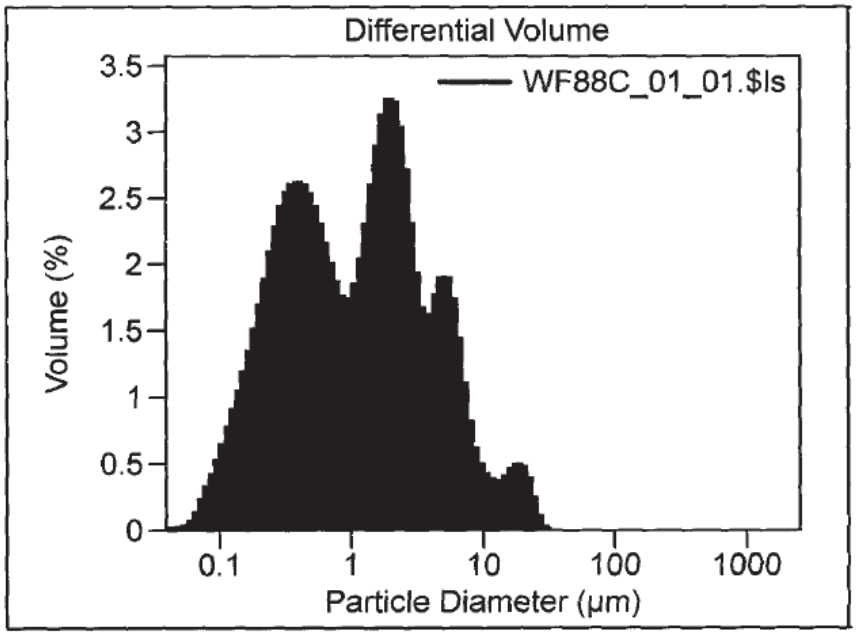


© Kennedy/Jenks Consultants, Inc.

1A – Parcel 1A; North side of Pond, Farwest Steel, new construction

28 January 2013 top figure, 28 February 13 bottom figure, (same analysis, presentation differs)
- similar distributions below ~ 20 µm , ~ 40 µm particles in January may be due to construction

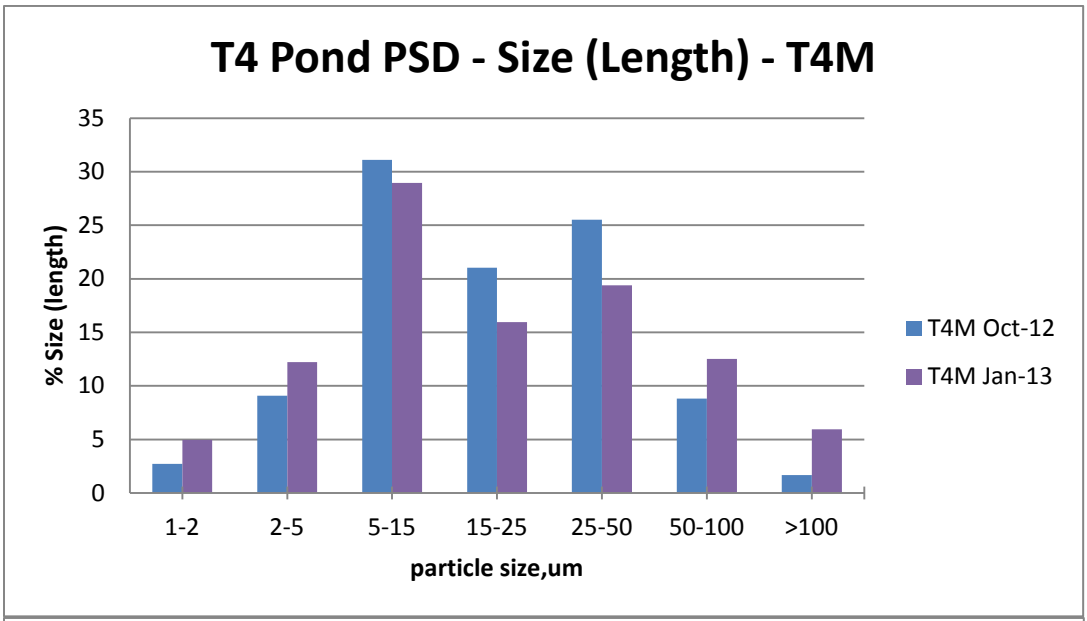


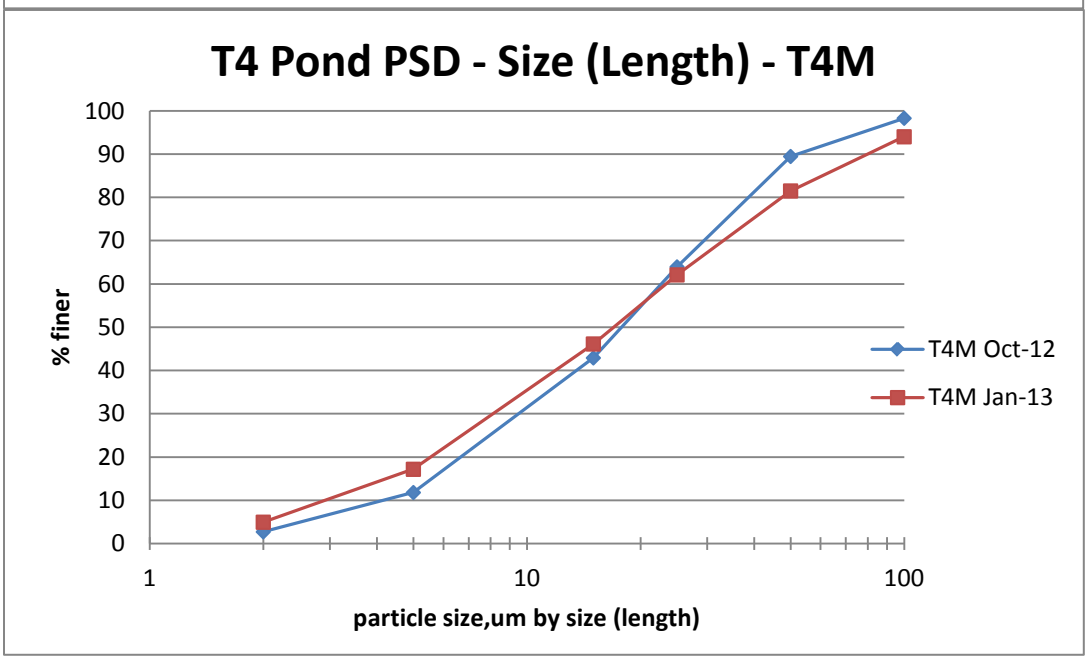


© Kennedy/Jenks Consultants, Inc.

OPTICAL DATA

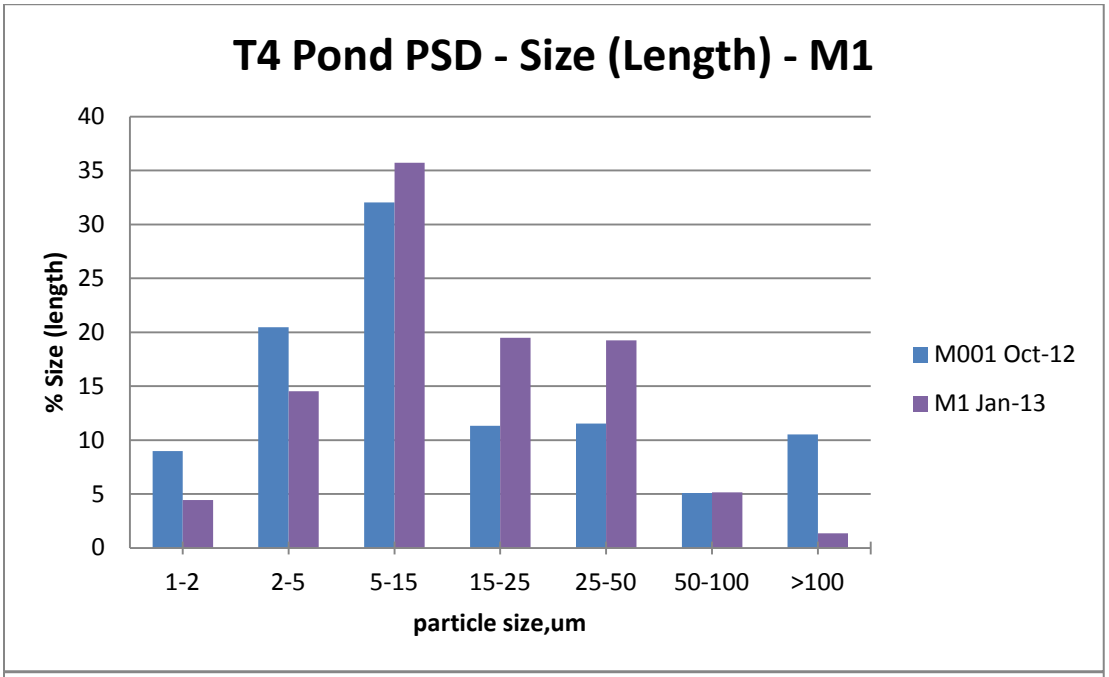
T4M

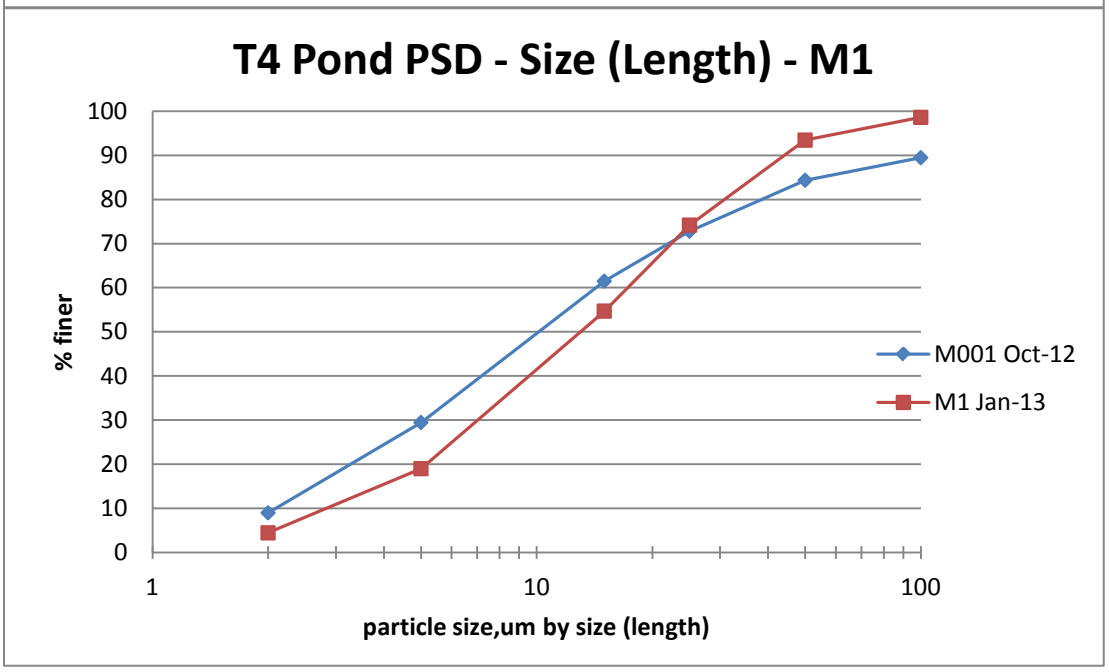




© Kennedy/Jenks Consultants, Inc.

M1



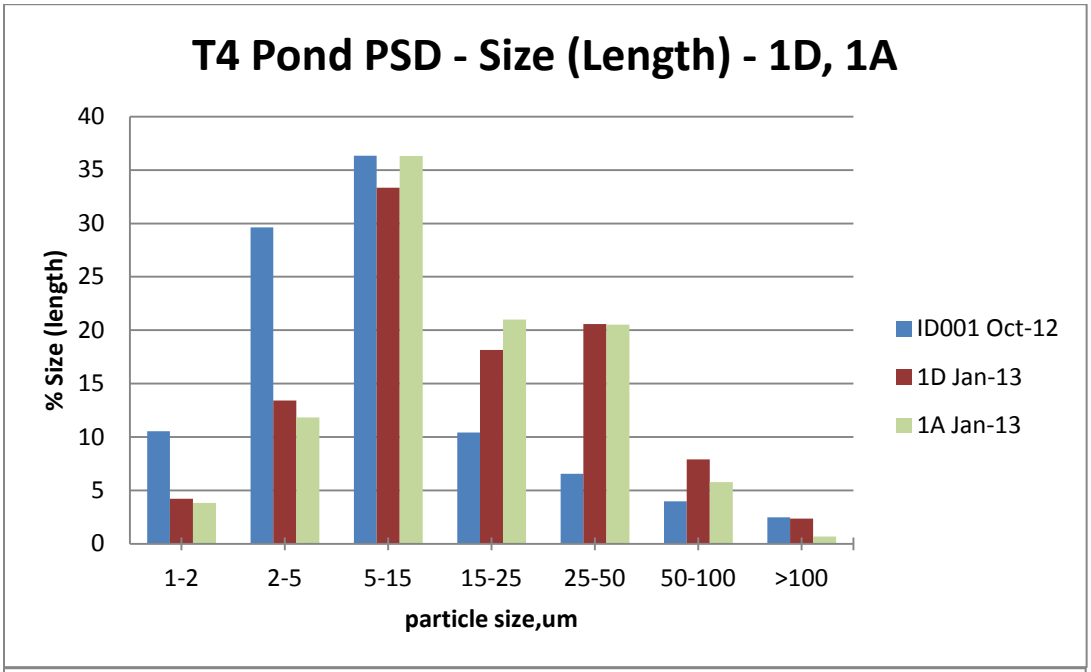


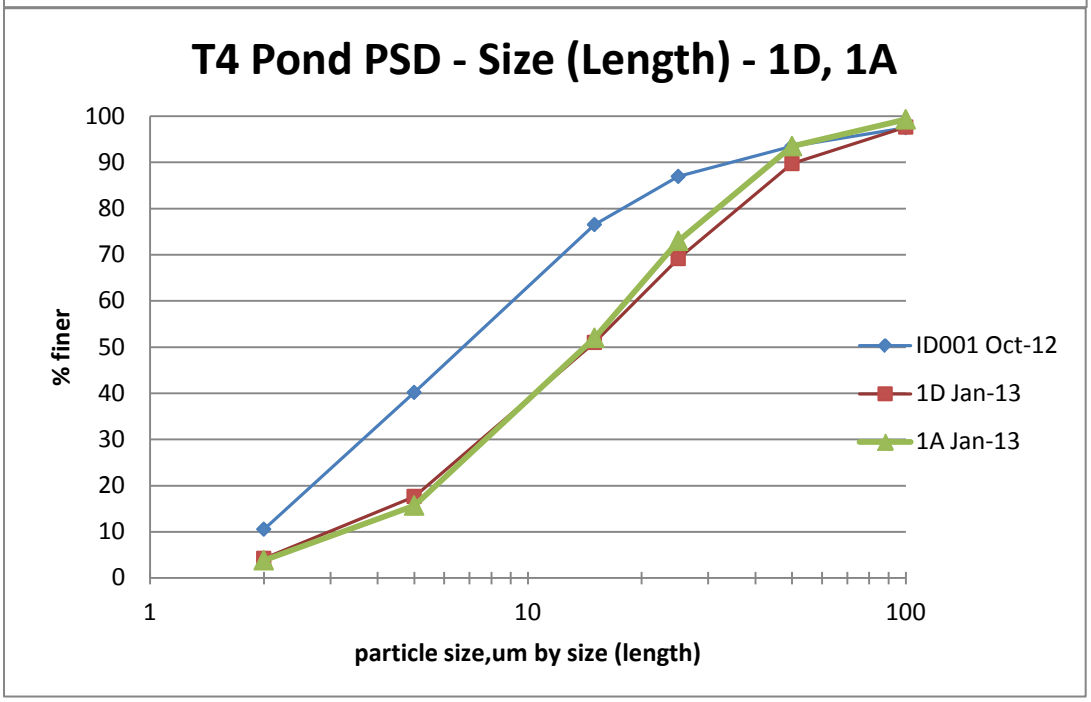
© Kennedy/Jenks Consultants, Inc.

Technical Memorandum

Matt Graves, Port of Vancouver
18 March 2013
1092004*00
Page 11

1D & 1A



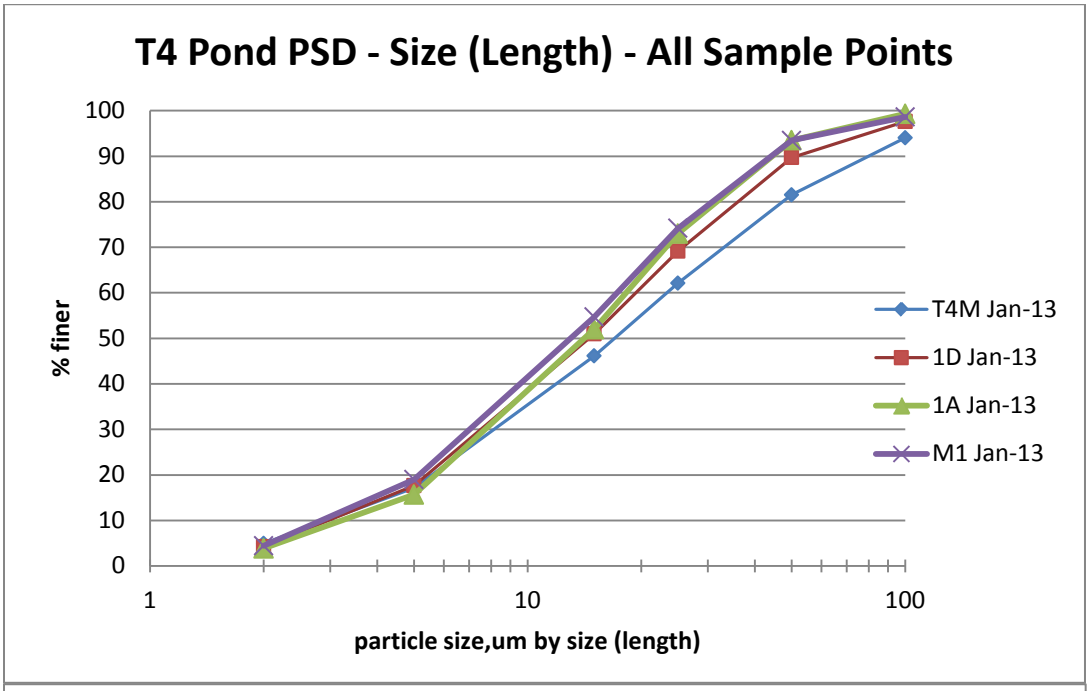


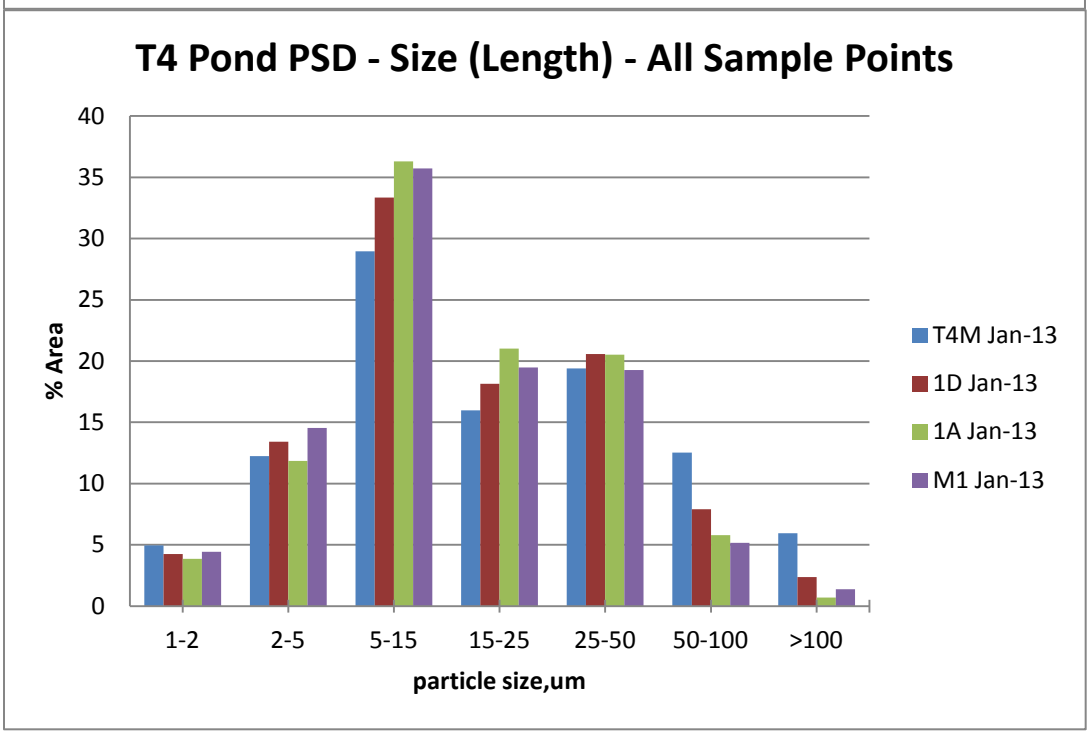
© Kennedy/Jenks Consultants, Inc.

Technical Memorandum

Matt Graves, Port of Vancouver
18 March 2013
1092004*00

Jan 13 – All Samples





© Kennedy/Jenks Consultants, Inc.

Kennedy/Jenks Consultants

Approximate location of sample point

Approximate subbasin boundary

TERMINAL 4 POND SAMPLING LOCATIOINS AND DRAINAGE BASINS

FIGURE 1

Parameter Brief

Total Suspended Solids (TSS) Removal Using Different Particle Size Distributions with the Stormwater Management StormFilter®

Introduction

Total Suspended Solids (TSS) is commonly used in the stormwater industry as a surrogate pollutant and a measure of Best Management Practice (BMP) performance. Although a practical standard, it is becoming evident that the measurement of TSS can be complex. Historically, parameters such as particle size distribution and specific gravity have not been included as part of BMP performance due to the difficulty of measuring these parameters in the field. For example, in a situation where road-sanding material is being washed into a BMP, the removal of 80% of TSS is easily achieved as the majority of the mass of the particles is composed of large sand and grit particles with a high specific gravity. In other situations, the TSS particles are much finer and have lower specific gravity, such as runoff from parking lots and high travel roads that frequently have "gray" water resulting from suspensions of silts, tire and brake dust, and associated fractions of oil and grease at low concentrations.

TSS Definitions

CONTECH Stormwater Solutions Inc. (CONTECH) has been investigating various particle size distributions (PSDs) for BMP acceptance or verification for various agencies: Washington State Department of Ecology (Ecology), New Jersey Corporation for Advanced Technology (NJ CAT), New Jersey State Department of Environmental Protection (NJ DEP), City of Portland, OR Bureau of Environmental Services (BES).

Five different PSDs are presented in Table 1. These particle sizes consist of natural soils (sandy loam and silt loam), manufactured sediment (SIL-CO-SIL 106), and two protocols for evaluating stormwater (APWA and City of Portland BES). The StormFilter was tested with the natural soils and SIL-CO-SIL sediments (finer distribution than the APWA or BES protocols). PSD testing was predominantly conducted in the CONTECH laboratory using simulated stormwater in a TSS concentration range between approximately 0 – 350 mg/L.

CONTECH would recommend that a jurisdiction define TSS with a range of PSDs such as the sandy loam, silt loam, or SIL-CO-SIL 106 used in these laboratory investigations, as opposed to a uniform PSD (i.e. 80% removal of 125 microns). Manufactured sediments are commercially available and can easily be used in comparing different BMPs. The PSDs are idealized at a specific gravity of 2.65, while field studies by CONTECH clearly show a high fraction of the TSS as organic in texture (seasonally) with a specific gravity at approximately 1.0. Investigations by CONTECH show that PSDs in the Pacific Northwest tend to be characteristic of silt loams and PSDs in the NE tend to be sandy loams or loamy sands, especially where road sanding is practiced.

Table 1 has a summary of various PSDs that have been investigated by CONTECH. For further information, Appendix A contains the graphical representation of each sediment type. Table 2 contains the TSS removal performance with these different sediments.

Table 1. Sediment Particle Size Distributions

Particle Size (microns)	Percent by mass (approximate)				
	Sandy loam [a]	Silt loam [a]	SIL-CO-SIL 106 [b]	APWA 1999 Protocol [c]	Portland BES [c]
500 – 1000	5.0	5.0	0	20.0	10.0
250 – 500	5.0	2.5	0	10.0	10.0
100 – 250	30.0	2.5	0	35.0	25.0
50 –100	15.0	5.0	20.0	10.0	25.0
2 – 50	40.0	65.0	80.0	25.0	30.0
1 – 2	5.0	20.0	0.0	0	0

[a] CONTECH tested Oregon silt and sandy loams for New Jersey Corporation for Advanced Technology verification of TSS performance claims.

[b] CONTECH tested SIL-CO-SIL 106 for Washington State Department of Ecology per the Technology Assessment Protocol – Ecology (2001).

[c] Hypothetical particle size distributions from these testing protocols. Particle sizes were presented in a range available in Appendix A; the table represents the least conservative (coarser) approximate particle size range.

Table 2. TSS removal using differing particle size distributions

Media Type	Cartridge Flow Rate (gpm)	Percent Removal (%)			PSD Effectiveness
		Sandy loam [a]	Silt loam [a]	SIL-CO-SIL 106 [a]	SIL-CO-SIL 106 (lowest micron)
Standard Perlite	15	77 - 80		72 – 78	10
Standard Perlite	7.5			78 – 83	7
Coarse Fine Perlite	15				
Coarse Fine Perlite	7.5		68 – 75	79 – 82	7
Fine Perlite	15			73 – 78	10
Fine Perlite	7.5			85 – 88	6
CSF® leaf [b]	15		68 – 79		
Coarse Perlite/Zeolite [c]	15		63 – 84		
ZPG™	15			80 – 82	7
ZPG™	7.5			86 – 89	5
PhosphoSorb™	15			80 – 84	7
PhosphoSorb™	7.5			87 – 89	6
Perlite/CSF® leaf	7.5			82 – 86	6
Perlite/Metal Rx™	7.5			89 – 92	5
Granular Activated Carbon	7.5			89 – 92	5

[a] Linear regression was used in the data analysis, the table presents the upper and lower 95% confidence limits. Data was collected in the CONTECH laboratory using simulated stormwater for TSS concentrations between 0 – 350 mg/L. Silt and sandy loam performance data was NJCAT-verified.

[b] Performance of the CSF leaf media was tested using both field and laboratory investigations. Laboratory studies used a Palatine loam sediment. Field data is from the Pacific Northwest.

[c] Performance of the coarse perlite / coarse zeolite media was tested using a Palatine loam sediment. Reported in Total Suspended Solids Removal using StormFilter Technology.

References

American Public Works Association (APWA). (1999). Protocol for the acceptance of unapproved stormwater treatment technologies for use in the Puget Sound watershed. Washington: APWA Washington Chapter, Stormwater Managers Committee. Retrieved January 3, 2002 from the Municipal Research and Services Center of Washington website:
www.mrsc.org/environment/water/water-s/apwa/protocol.htm

CONTECH Construction Products, Inc. (2005). Evaluation of the Removal of Sil-Co-Sil® 106 by PhosphoSorb in the Stormwater Management StormFilter® at 7.5 gpm (28 L/min) and 15 gpm (56 L/min). Portland, Oregon: Author.

CONTECH Stormwater Solutions, Inc. (2005). Evaluation of the Stormwater Management StormFilter® cartridge for the removal of SIL-CO-SIL® 106, a standardized silica product: Standard Perlite StormFilter cartridge at 28 L/min (7.5 gpm) (Report No. PE-05-013.0). Portland, Oregon: Author.

CONTECH Stormwater Solutions, Inc. (2005). Evaluation of the Stormwater Management StormFilter® cartridge for the removal of SIL-CO-SIL® 106, a standardized silica product: Standard Perlite StormFilter cartridge at 56 L/min (15 gpm) (Report No. PE-05-014.0). Portland, Oregon: Author.

CONTECH Stormwater Solutions Inc. (2006). Evaluation of the Stormwater Management StormFilter® for the removal of SIL-CO-SIL® 106, a standardized silica product: GAC StormFilter cartridge at 28 L/min (7.5 gpm) (Document PE-G170). Portland, Oregon: Author.

de Ridder, S. A., Darcy, S. I., and Lenhart, J. H. (2002). Silt loam TSS removal efficiency of a stormwater BMP: Coarse/fine perlite StormFilter cartridge at 28 L/min (7.5 gpm). (Report No. PD-01-001.1). Portland, Oregon: Stormwater Management Inc.

de Ridder, S. A., Darcy, S. I., and Lenhart, J. H. (2002). Sandy loam TSS removal efficiency of a stormwater BMP: Coarse perlite StormFilter cartridge at 57 L/min (15 gpm). (Report No. PD-01-002.1). Portland, Oregon: Stormwater Management Inc.

New Jersey Corporation for Advanced Technology. (2002). NJCAT Technology Verification Stormwater Management, Inc. Bordentown, NJ: Author. Retrieved July 31, 2003 from:
www.resourcesaver.com/file/toolmanager/O56F24106.doc

Portland Bureau of Environmental Services (Portland BES). (2001). Vendor submission guidance for evaluating stormwater treatment technologies. Portland, Oregon: City of Portland, Bureau of Environmental Services.

State of Washington Department of Ecology (WADOE). (2002, October). Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol—Ecology (WADOE Publication No. 02-10-037). Retrieved November 11, 2002 from: www.ecy.wa.gov/programs/wq/stormwater/newtech/02-10-037%20TAPE.pdf

Stormwater Management, Inc. (2004). Evaluation of the Stormwater Management StormFilter® cartridge for the removal of SIL-CO-SIL 106, a synthetically graded sand material: ZPG StormFilter cartridge at 28 L/min (7.5 gpm). (Report No. PD-04-006.0). Portland, Oregon: Author.

Stormwater Management, Inc. (2003). Influence of flow rate and media gradation on the cost-effective design of stormwater filtration best management practices for the removal of total suspended solids. (Report No. PD-03-006.0). Portland, Oregon: Author.

Stormwater Management, Inc. (2000). Total Suspended Solids Removal using StormFilter Technology. Portland, Oregon: Author.

Stormwater Management, Inc. (2005). Evaluation of the Stormwater Management StormFilter® cartridge for the removal of SIL-CO-SIL 106, a synthetically graded sand material: Perlite/CSF StormFilter cartridge at 28 L/min (7.5 gpm). (Report No. PE-05-002.0). Portland, Oregon: Author.

Stormwater Management, Inc. (2005). Evaluation of the Stormwater Management StormFilter® cartridge for the removal of SIL-CO-SIL 106, a synthetically graded sand material: Perlite/MetalRx StormFilter cartridge at 28 L/min (7.5 gpm). (Report No. PE-05-004.0). Portland, Oregon: Author.

U.S. Silica. (2000, March). Product Data, OK-110 Unground Silica, Plant: Mill Creek, Oklahoma. Retrieved June 12, 2003, from: www.u-s-silica.com/prod_info/PDS/Mill_Creek/ MiCOK-1102000.PDF

Revision

RS-0091 1/20/10 Added PhosphoSorb™ to Table 1.

RS-0091 12/27/07 Added lowest micron threshold to Table 2.

RS-0091 07/27/07 Added GAC to Table 1.

RS-0091 04/14/06 Rebranded to Contech Stormwater Solutions, Inc.

PD-03-13.4 09/08/05 Added Standard Perlite at 15 and 7.5 gpm, and ZPG at 15 gpm to Table 1. Updated Reference Section.

PD-03-13.3 04/28/05 Added Perlite/CSF leaf & Perlite/MetalRX to Table 1. Updated Reference Section.

PD-03-013.2 12/02/04 Added ZPG™ to Table 1.

PD-03-013.1 12/15/03 Altered Table 1 - SIL-CO-SIL to reflect 20:80:0 (sand:silt:clay)
Added content to section 2, paragraph 3, last sentence.

PD-03-013.0 10/28/03

APPENDIX A

SIL-CO-SIL 106 Particle Size Distribution

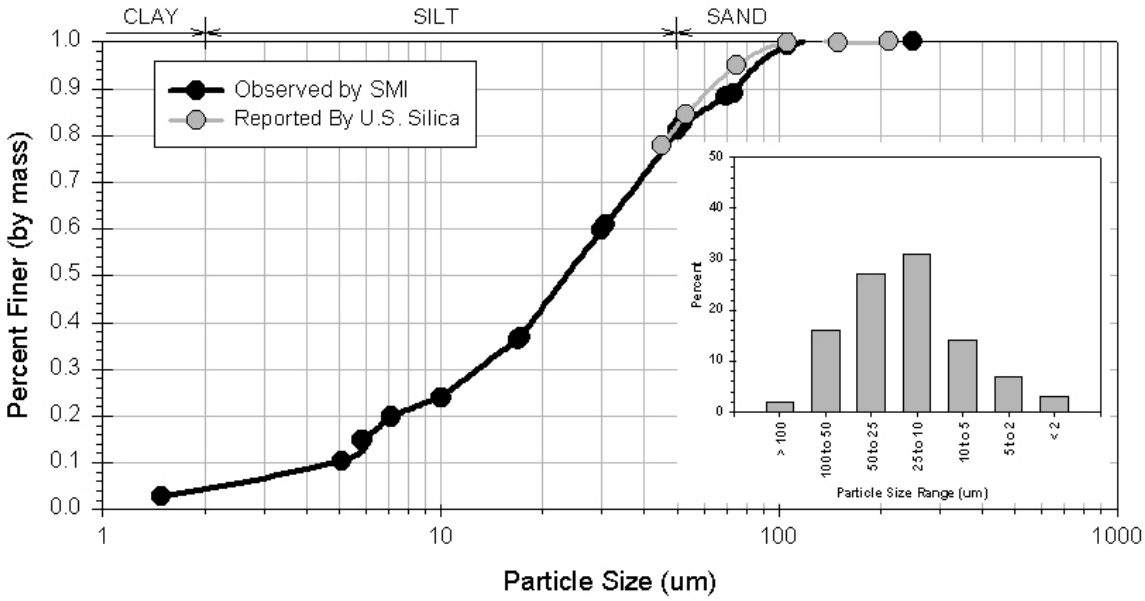


Figure 1. Particle size distribution for SIL-CO-SIL 106. Sand/silt/clay fractions according to USDA definitions are approximately 20%, 80%, and 0% for SIL-CO-SIL 106, indicating that the texture corresponds to a silt material. Specific gravity is 2.65.

Silt Loam Particle Size Distribution

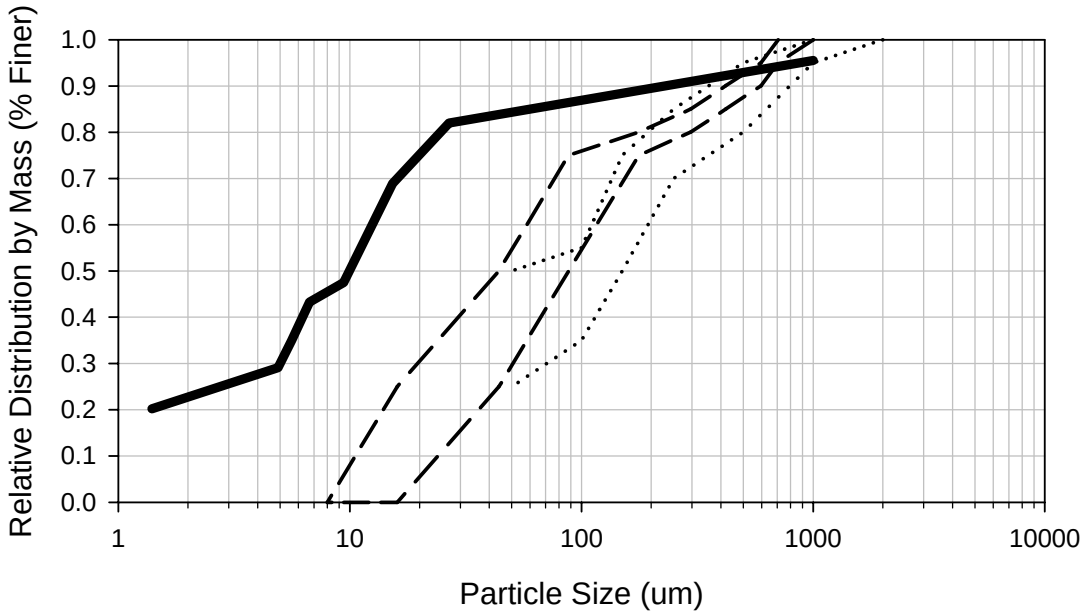


Figure 2. Particle size distribution (shown as solid line) for bulk soil sample "OSU Silt Loam GPS W.P. #10" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 15%, 65%, and 20%, indicating that the texture corresponds to a silt loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

Sandy Loam Particle Size Distribution

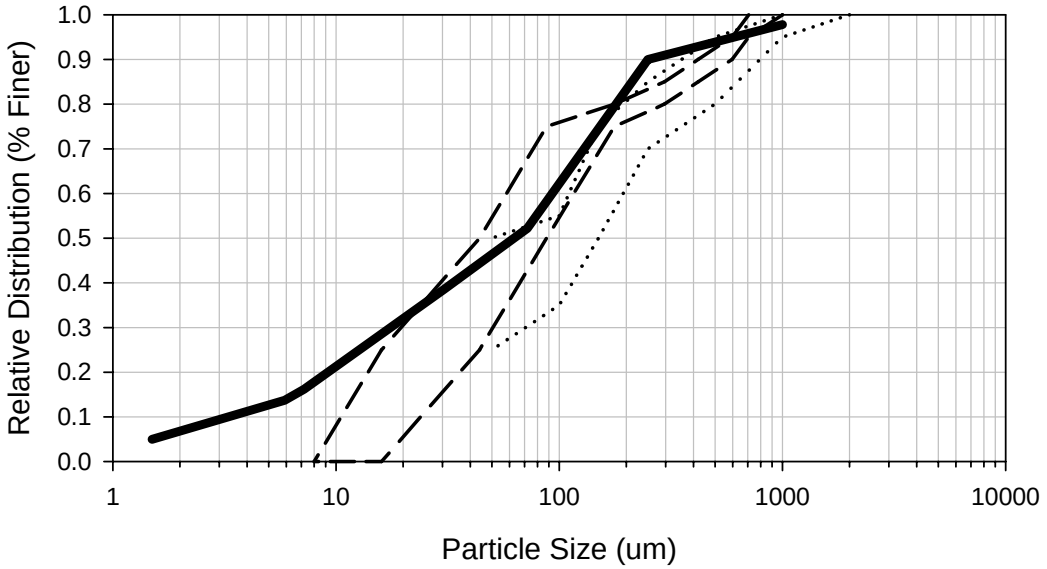


Figure 3. Particle size distribution (shown as solid line) for bulk soil sample "OSU Loam GPS W.P. #13" used for testing. Sand/silt/clay fractions according to USDA definitions are approximately 55%, 40%, and 5%, indicating that the texture corresponds to a sandy loam material. Dashed and dotted lines indicate particle size distribution range recommended by Portland BES (2001) and APWA (1999), respectively, for materials used for laboratory evaluation of TSS removal efficiency.

A COMPARISON OF TWO MEDIA FILTRATION BMP TREATMENTS FOR THE REMOVAL OF PAHS AND PHTHALATES FROM ROADWAY RUNOFF

Carla Milesi, Taylor Associates, Inc., Seattle, WA
Scott A. de Ridder, Stormwater360, Portland, OR
Dana DeLeon, City of Tacoma, Tacoma, WA
Heidi Wachter, Taylor Associates, Inc., Seattle, WA

INTRODUCTION

Urban runoff is a major contributor to the degradation of our urban streams, rivers, and lakes (Pitt, 1995). Organic pollutants, such as PAHs and phthalates, in urban stormwater can contribute to receiving water degradation (EPA, 1983). A study in Rhode Island's Narragansett Bay watershed found that urban runoff accounted for 71 percent of the total inputs to the bay for higher molecular weight PAHs, and for 36 percent of the total PAHs (Hoffman et al, 1984). Testing done in 2003 by King County, the City of Seattle, and the City of Tacoma found high levels of phthalates in products such as brake pads and tires used in vehicles (King County et al, 2004 and City of Tacoma, 2005). In the Lower Duwamish Waterway in King County, Washington and in the Thea Foss Waterway in Tacoma, Washington these products are thought to contribute phthalates to surface waters by atmospheric deposition or direct deposition and stormwater runoff (King County et al, 2004). This contribution of PAHs and phthalates to our waters is a regional concern in Western Washington State if not a national and international concern.

Reducing the pollutant loading of phthalates and PAHs from automobile use can be extremely difficult. Therefore, the effectiveness of most stormwater control practices is dependent on their ability to remove pollutants from the water, and not through source reduction (Pitt, 2000). One stormwater pollutant removal technology, which can be incorporated into stormwater control practices, is the Stormwater Management StormFilter™ (StormFilter). This technology is a stand-alone stormwater treatment system that utilizes media filtration to remove contaminants, such as phthalates and PAHs, from stormwater.

The StormFilter is a flow-through stormwater filtration system consisting of a concrete vault, which houses filter cartridges filled with treatment media selected by the end user. The vault is composed of three bays: an inlet bay, filtration bay, and outlet bay. Stormwater enters the inlet bay, which is designed to settle out heavy solids, and is directed through a flow spreader, which traps some floatables, oils, and surface scum. As it leaves the inlet bay, stormwater flows over an energy dissipater and enters the filtration bay, where the media-filled StormFilter filtration cartridges are located. Once in the filtration bay, the stormwater begins to pond and percolate horizontally through the cartridges. The StormFilter utilizes a "siphon" system to pass flow through these cartridges. In the center of the cartridge, a float system is designed to prime a siphon that draws stormwater through the filtration media and into an under-drain. The treated stormwater in the under-drain discharges into the outlet bay before exiting the StormFilter vault through a single outlet pipe.

As part of the Tacoma Thea Foss Waterway Study, a StormFilter was used to assess the ability of different media mixes to remove phthalates and PAHs from stormwater in true, side-by-side fashion. The two media mixes contained different levels of bituminous granular activated carbon (GAC) to test the hypothesis that GAC enhances the removal of these anthropogenic organic contaminants. Testing was done using the discrete flow composite (DFC) method as outlined by the Technology Assessment Protocol - Ecology (TAPE) (Ecology, 2004), which specifies that sampling occur during periods when inflow to the treatment device is relatively constant (less than 20 percent variation of the median inflow). Testing of these two media mixes was conducted during 12 storm events between October 2004 and November 2005 at the Washington State Department of Transportation Lake Union Ship Canal Test Facility (Test Facility).

The Test Facility is located in Seattle, Washington in the Interstate Route 5 right of way beneath the north side of the Lake Union Ship Canal Bridge. The site contains four test bays to allow for the simultaneous testing of four ultra-urban stormwater treatment technologies. The drainage area to the site is approximately 33 acres and the land cover in the basin is predominantly pavement. Runoff from the drainage area is collected in catch basins and conveyed to Lake Union by a 30-inch pipe. Flow is diverted from the 30-inch pipe to the site using a "draw-bridge" half-pipe structure and is partitioned to the separate test bays using flow splitters and gate valves. A more detailed description of the Test Facility can be found in the EvTec Ultra-urban Stormwater Technology Evaluation, Stormwater360 StormFilter® Quality Assurance Project Plan (2005).

Individual StormFilter units are sized based on the anticipated inflow rates for a site. The StormFilter selected for evaluation at the Test Facility is a 6 foot by 12 foot vault containing 11 filtration cartridges. The cartridges are aligned in three rows, with four cartridges in each of the outer rows and three cartridges in the middle row. Each row of cartridges drains to a separate under-drain, which allows for each row of cartridges to be tested independently. At the start of the study two media mixes were selected for testing, a perlite/zeolite (PZ) mix and a zeolite/perlite/GAC (ZPG) mix. The PZ cartridges contained a 50/50 mix of perlite and zeolite in the inner core with an outer ring of perlite. The ZPG cartridges contained a 50/50 mix of zeolite and GAC in the inner core, with an outer ring of perlite. Early examination of water quality data collected during five initial storm events did not show a significant difference in the removal efficiencies for organics between the PZ and the ZPG media. Thus, in October 2004 the cartridges containing the PZ mixture were replaced with cartridges containing 100 percent GAC. This change was made to determine if an increased percentage of GAC in the media mix would lead to improved removal rates for organics. This paper focuses on the comparative ability of the ZPG and GAC media mixes to remove PAHs and phthalates.

METHODS

The side by side testing of the ZPG and GAC media mixes was conducted during 12 storm events between October 2004 and November 2005. To assess the average influent and effluent water quality, or mean concentrations (MCs), at specific inflow conditions, samples were collected using a DFC sampling approach over a relatively constant inflow period (less than 20 percent variation of the median flow) (EvTec 2001, Ecology 2004). The inflow rates that were sampled were 50 percent, 100 percent, and 125 percent of the filtration capacity of the StormFilter installed at the Test Facility. These target inflow rates encompassed the range suggested by the TAPE guidelines (Ecology 2004). When storm conditions allowed, two inflow rates were sampled during each storm event. This resulted in the collection of 23 paired influent and effluent stormwater samples for the two media mixes.

To perform the DFC sampling, flow into and out of the StormFilter unit was monitored using Palmer-Bowlus (P-B) flumes installed in the inlet and outlet conveyance pipes. Isco 6700 samplers with 730 bubbler modules were used to measure and record water level in the flumes, which was converted to flow using the rating curve supplied by the flume manufacturer. To monitor when and if flow was bypassed into the outlet bay without treatment by the filtration cartridges, an Isco 6700 sampler with 730 bubbler module was used to measure water level in the filtration bay.

Side-by-side testing of the media required the collection of one influent sample and two independent effluent samples (one from each media type). Influent samples were collected just upstream of the StormFilter's inlet pipe. Effluent samples were collected from the two separate under-drains, one draining from the ZPG cartridges and one from the GAC cartridges. Collecting effluent samples from the inside of the under-drain was necessary to isolate the effluent from each media type before they mixed in the outlet bay. This approach allowed for the comparison of the influent concentrations with effluent concentrations for each media type (zeolite/perlite/GAC and GAC).

Flow-weighted composite samples were collected using one Isco 6700 automated sampler for the influent and two Isco 6700 automated samplers for the two effluent samples. The influent sampler and a

primary effluent sampler were automatically triggered to collect samples based on flow volumes measured in the respective P-B flumes. The second effluent sampler was linked to the primary sampler using an Isco SPA 1026 cable which would trigger the second sampler to collect a sample simultaneously with the primary sampler. As recommended by TAPE (Ecology 2004), each composite sample was collected throughout a time period during which the volume of water passing through the unit was equal to or greater than eight times the StormFilter's detention volume. For the StormFilter, the detention volume is defined as the maximum storage volume between the inlet to the vault and the effluent sample location.

In accordance with TAPE protocols (Ecology 2004), all samples were collected through Teflon™-lined intake lines into 1-gallon glass jars with Teflon™-lined lids. This approach was used because these materials are known to be the most inert in terms of adsorption and desorption of organic compounds (CDOT, 2000). Sample bottles were cleaned by the analytical laboratory using a diluted sulfuric acid rinse followed by a deionized (DI) water rinse.

During the study period, equipment rinsate blanks were collected at the inlet sampler on three occasions. Each blank was collected by pumping DI water through the strainer and Teflon™-lined intake line into a clean 1-gallon glass sample bottle. Two blanks were collected at the start and one midway through the study. Blanks were collected to estimate bias, that is to determine if any of the sample containers, preservation methods, handling procedures, or sampling equipment contributed constituents to the sample. Field duplicates were collected at the inlet sampler during nine storms (ten percent of the total stormwater samples) and submitted blind to the laboratory to provide estimates of field variability.

RESULTS AND DISCUSSION

This study produced thousands of analytical results, the presentation of which would be far beyond the format of this document. The reader is encouraged to contact the Taylor Associates, Inc. authors for a copy of a final report for access to the full data set. A summary of influent mean concentration (MC) results for the data set used for analysis is shown in Table 1.

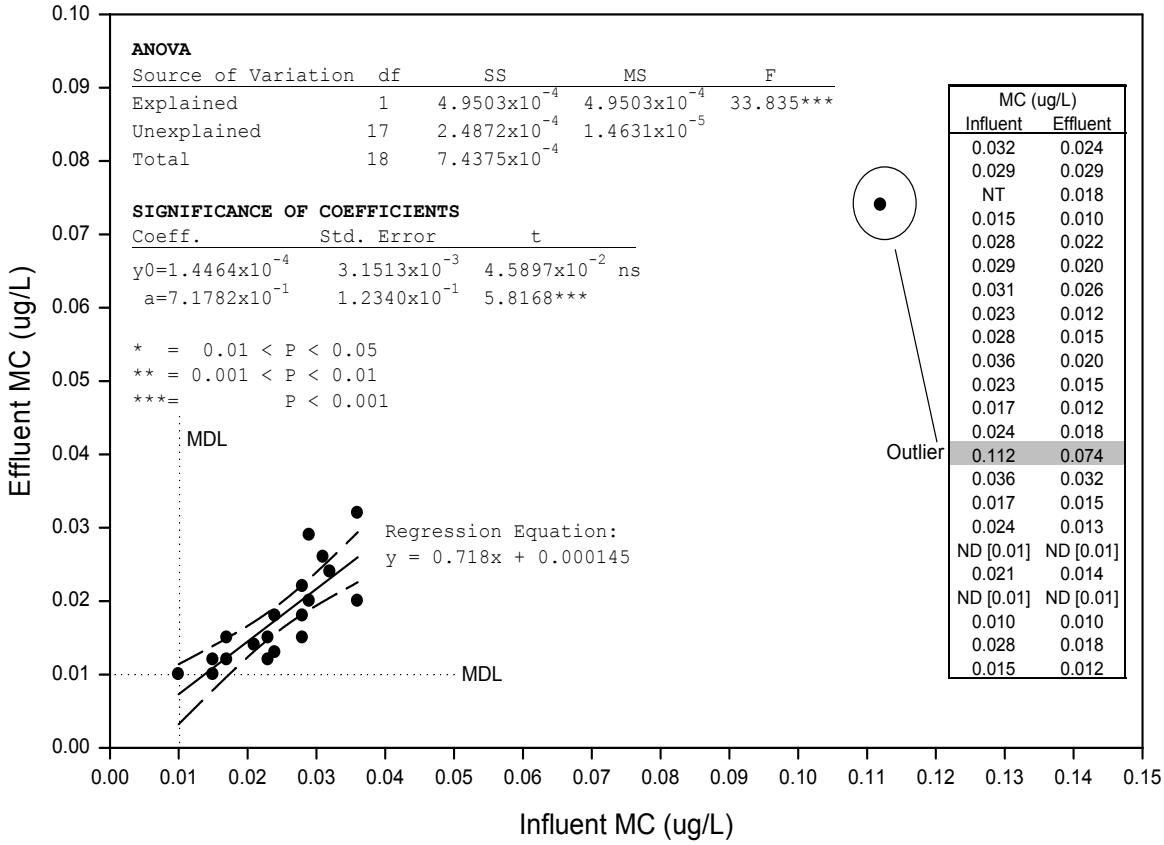
		Descriptive Statistics			ZPG Performance			GAC Performance		
	Analyte	*n*	Range of Influent MCs (µg/L)	Median Influent MC (µg/L)	Mean Removal Efficiency Estimate (%)	SE	95% Confidence Interval for the Mean Removal Efficiency Estimate (%)	Mean Removal Efficiency Estimate (%)	SE	95% Confidence Interval for the Mean Removal Efficiency Estimate (%)
	Total Suspended Solids	23	12.2 to 174	49.3	68***	7	54 to 83	73***	6	60 to 86
Poly Aromatic Hydrocarbons (PAHs)	Naphthalene	21	0.0180 to 0.175	0.0470	34***	11	12 to 57	47***	9	27 to 67
	2-Methylnaphthalene	20	0.0100 to 0.112	0.0260	28***	12	2 to 54	54***	11	29 to 78
	Acenaphthylene	10	0.0110 to 0.0180	0.0130	---	---	--- to ---	---	---	--- to ---
	Acenaphthene	11	0.0100 to 0.0860	0.0160	75*	8	56 to 94	---	---	--- to ---
	Fluorene	21	0.0130 to 0.591	0.0250	15***	6	3 to 28	60***	2	56 to 64
	Anthracene	18	0.0100 to 0.132	0.0155	---	---	--- to ---	68***	5	57 to 78
	Phenanthrene	22	0.0180 to 0.902	0.0990	33***	6	20 to 46	53***	4	44 to 62
	Fluoranthene	22	0.0450 to 0.955	0.178	44***	6	33 to 56	61***	5	51 to 71
	Pyrene	22	0.0570 to 1.08	0.248	52***	6	40 to 64	61***	5	50 to 72
	Benzo(a)anthracene	22	0.0130 to 0.591	0.0555	42***	8	26 to 58	62***	3	55 to 68
	Chrysene	22	0.0320 to 0.573	0.122	52***	6	40 to 63	63***	4	55 to 71
	Benzo(a)pyrene	22	0.0140 to 0.616	0.0565	38***	6	26 to 50	62***	3	55 to 69
	Benzofluoranthenes	22	0.0400 to 1.39	0.140	40***	6	28 to 51	61***	3	54 to 68
	Benzo(g,h,i)perylene	22	0.0260 to 0.419	0.100	41***	8	25 to 57	57***	6	44 to 69
	Indeno(1,2,3-cd)pyrene	22	0.0110 to 0.413	0.0440	33***	7	20 to 47	60***	4	52 to 69
	Dibenz(a,h)anthracene	16	0.0100 to 0.126	0.0175	36***	11	12 to 61	76**	8	59 to 93
Phthalates	Dimethyl phthalate	22	0.0180 to 0.150	0.0665	23***	10	2 to 43	35***	8	17 to 52
	Diethyl phthalate	12	0.250 to 0.690	0.380	---	---	--- to ---	---	---	--- to ---
	Di-n-butyl phthalate	12	0.240 to 0.550	0.360	---	---	--- to ---	---	---	--- to ---
	Butyl benzyl phthalate	12	0.260 to 0.850	0.430	---	---	--- to ---	81**	6	69 to 94
	Di-n-octyl phthalate	22	1.27 to 59.8	2.96	38***	12	13 to 62	52***	12	28 to 77
	bis(2-Ethylhexyl)phthalate	22	9.20 to 42.7	18.2	40***	11	17 to 64	54***	11	30 to 78

Table 1. Summary of influent observations and treatment performance. Descriptive Statistics include outliers. Asterisks indicate the significance of the underlying regression: * = 0.05 > P > 0.01, ** = 0.01 > P > 0.001, *** = P < 0.001. Regressions that were not significant at the 95% confidence level or better are indicated by "---". SE = Standard Error of the Mean Removal Efficiency Estimate.

Regression analysis was used to characterize the influent/effluent MC relationship for each analyte (univariate analysis). Since this relationship is a reflection of performance, it can be used to compare media treatments. Regression analysis is especially well suited for this purpose since it is more immune to the normality issues typical of water quality data and thus provides more meaningful statistics. An example of a single regression analysis is shown in Figure 1 with the result of all regression analyses shown in Table 1.

As is typical of water quality data, many suspected outliers were observed on the basis of their uncharacteristically high MCs (Figure 1) and had to be addressed prior to data analysis. Due to sample size and normality constraints, no conventional methods of outlier analysis could be employed (Robinson et al., 2005), thus to mitigate the effects of these outliers on data analysis, a systematic solution was employed. Given the healthy size of the data set, the data pairs with the highest influent and effluent MCs within the data set for each individual analyte were excluded from the analysis. This ensured that the most extreme outliers were excluded from analysis in a non-selective fashion.

Graphical presentation of the data shown in Table 1 highlights instances where a significant difference was observed between the two treatments. This is shown in Figure 2, where the dark bars represent the 95% confidence intervals for the performance of the baseline media (ZPG) and the light bars represent the 95% confidence intervals for the performance of the alternative treatment (GAC). The mean removal efficiency estimate for the GAC treatment is indicated by a horizontal bar, with a significant difference at the 95% confidence level indicated when the bar lies outside the 95% confidence range for the mean removal efficiency estimate of the ZPG treatment. A sense of statistical power can also be gained from the figures, with less overlap between confidence intervals indicating greater statistical power.



MC (ug/L) Influent	MC (ug/L) Effluent
0.032	0.024
0.029	0.029
NT	0.018
0.015	0.010
0.028	0.022
0.029	0.020
0.031	0.026
0.023	0.012
0.028	0.015
0.036	0.020
0.023	0.015
0.017	0.012
0.024	0.018
0.112	0.074
0.036	0.032
0.017	0.015
0.024	0.013
ND [0.01]	ND [0.01]
0.021	0.014
ND [0.01]	ND [0.01]
0.010	0.010
0.028	0.018
0.015	0.012

Figure 1. An example of regression analysis of the 2-Methylnaphthalene results for the ZPG data including the ANOVA table used to assess the significance of the regression and the error statistics of regression coefficients. Note that the indicated outlier is not included in the regression analysis (see Results and Discussion section). MDL = Method Detection Limit.

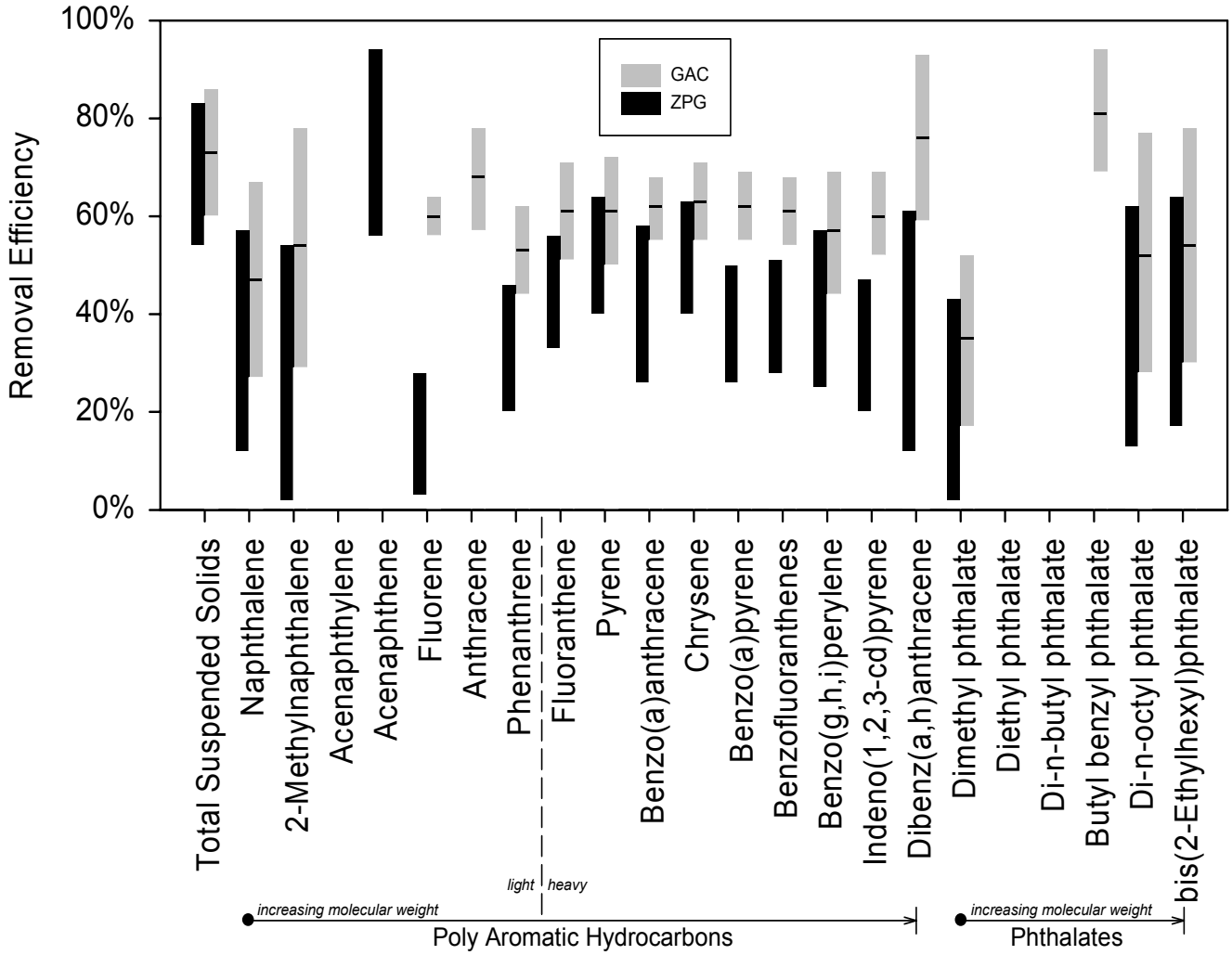


Figure 2. Graphical comparison of ZPG and GAC treatment performance. Absent bars indicate a regression that was not significant at the 95% confidence level or better.

CONCLUSION

Comparison of the two treatments suggests that the GAC treatment performed significantly (P=0.05) better than the ZPG treatment for many PAHs, with statistical power >80% observed for several analytes. On the other hand, no significant difference was observed between the two treatments for phthalates. While the variance of the observations was too great to allow the two treatments to be statistically distinguishable, removal of some phthalates was still observed to be significant at the 95% level.

While both media treatments appear to be capable of PAH and phthalate removal, GAC appears to be the better media for these contaminants. The observation of no significant difference (P=0.05) between the two media for Total Suspended Solids removal suggests that this difference is due in some part to the composition of the two media types as opposed to an artifact of improved suspended solids removal. This supports the hypothesis that the use of GAC enhances the removal of anthropogenic organic contaminants.

REFERENCES

City of Tacoma, 2005. 2003-2004 Stormwater Source Control Report, Thea Foss and Wheeler-Osgood Waterways, City of Tacoma, March 2005.

CDOT. 2000. Guidance Manual: Stormwater Monitoring Protocols, second edition. CTSW-RT-00-005. California Department of Transportation.

Ecology. 2004. Guidance for Evaluating Emerging Stormwater Treatment Technologies. Technology Assessment Protocol – Ecology (TAPE). Publication no. 02-10-037. Water Quality Program, Washington State Department of Ecology

EPA. 1983. Results of the Nationwide Urban Runoff Program. U.S. Enviornmental Protection Agency,Water Planning Division, PB 84-185552, Washington, D.C.

EvTEC. 2001. Environmental Technology Evaluation Center. EvTEC Evaluation Plan for Ultra-urban Stormwater Technologies. Prepared for: Washington State Department of Transportation. Prepared by: The Environmental Technology Evaluation Center and David Evans and Associates, Inc.

Hoffman, E.J., G.L. Mills, J.S. Latimer, and J.G. Quinn. 1984 "Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters." *Environment Science and Technology*, 18:580-587.

King County and Seattle Public Utilities. 2004. King County And Seattle Public Utilities Source Control Program for the Lower Duwamish Waterway, June 2004 Progress Report.

Pitt, R., R. Field, M. Lalor and M. Brown. 1995. "Urban stormwater toxic pollutants: assessment, sources and treatability." *Water Environment Research*. Vol. 67, No. 3, pp. 260-275.

Pitt, Robert and Melinda Lalor. 2000. "The Role of Pollution Prevention in Stormwater Management." *Models and Applications to Urban Water Systems, Monograph 9.*

Robinson, R. B., C. D. Cox, and K. Odom. 2005. "Identifying Outliers in Correlated Water Quality Data." *Journal of Environmental Engineering*. pp. 651-657.

Taylor Associates, Inc. 2005. EvTec Ultra-urban Stormwater Technology Evaluation, Stormwater 360 StormFilter® Quality Assurance Project Plan.

Parameter Brief

The Stormwater Management StormFilter® for Removal of Dissolved Metals

Introduction

Urban Stormwater often contains high levels of soluble and particulate heavy metals. Generated from traffic, industrial facilities, and sometimes residential sources, these metals are frequently found in concentrations that are deleterious to aquatic life and other biota that are dependent on aquatic life as a food sources. Two of the most common metals found both in the water column and sediments are zinc and copper. Zinc tends to exhibit toxicity effects in the fresh water environment and copper exhibits toxicity characteristics in the marine environment.

Metals are measured as both total metals and soluble metals. Total metals are the sum of dissolved metals and those metals associated with particulates. Soluble metals are commonly defined as those metals that pass through a 0.45 micron filter. Frequently the soluble metals are in a cationic form in that they posses a net positive charge. However, sometimes the charge of the soluble metal has been satisfied in that it could be associated with sub-micron particles such as ligands or colloids. In this event, the metal may not have a net positive charge.

Cation Exchange

Cation exchange is the exchange of a cation (positively charged atom) for another cation. The process involves the displacement of an atom within the media matrix by an atom within the water column. The displacement occurs if the incoming atom's affinity for the exchange site is higher than that of the current occupying atom. In general, the physically smaller the ion (when hydrated) and the greater the positive charge the more tightly it will be held by the media.

Predictions can be made using a periodic table of elements for commonly found metals in stormwater runoff. Staying within the same row of the table and proceeding left to right produces an increasing affinity for cation exchange. This trend is promoted due to the metal atom remaining in the same valence state (charge) while the overall diameter of the atom decreases. Since the diameter decreases, the "apparent charge" of the atom increases, thus producing the driving mechanism for cation exchange. For most purposes the following affinity series is true:

$$Al^{3+} > H^{+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Fe^{2+} > Cr^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$$

Primary Exchange Ions within CONTECH Stormwater Solutions Filtration Media

The media-bound ions utilized with cation exchange filtration are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) with calcium and magnesium being the primary exchange ions due to their abundance within the media matrix.

As presented above, zinc, copper and iron (as well as others) will force the displacement of the calcium and magnesium ions from the media.

Media promoting cation exchange and measured cation exchange capacity (CEC):

- CSF® media (93.8 meq/100-grams)
- Zeolite (125 meq/100 grams)

Performance Summary

Table 1. Soluble Metals Removal using organic media (CSF®, Metal Rx).

		Soluble Copper		Soluble Zn	
Site	**Media**	**Removal**	**Influent (ug/l)**	**Removal**	**Influent (ug/l)**
Nassco Shipyard	CSF	54%	61-401	64%	191-124
Charleston Boatyard	CSF	49%	11,000 (Total)	48%	3,560 (Total)
East Side Plating	Metal Rx	92%	58-268	43%	ND-569 (Total)

Table 2. Total Metals Removal

		Configuration (Removal efficiency)			
Parameter	**Influent (mg/l)**	**CSF Standard Grade 15 gpm**	**CSF Standard Grade 7.5 gpm**	**Perlite/Zeolite Coarse Grade 15 gpm**	**Perlite/Zeolite Fine Grade 15 gpm**
Total Copper	11	42%	49%	41%	54%
Total Lead	0.096	43%	47%	42%	60%
Total Zinc	3.56	41%	48%	31%	51%
Total Chromium	0.0384	49%	61%	57%	67%

Performance data has been summarized from field investigations (Table 1) and from laboratory (Table 2) investigations using captured stormwater runoff from the Charleston Boatyard.

References

Stormwater Management, Inc. (2001). Comparison of CSF and XFCSF StormFilter Cartridges for Zinc and Total Suspended Solids Removal. Stormwater Management Inc., Technical Update. Portland, OR.

Lenhart, James, Scott de Ridder, Paula Calvert, Calvin Noling. (2003). The Removal of Soluble Heavy Metals From Non-Point Source Runoff Originating From Industrial Sources by Leaf Compost Media. Portland, OR.

Noling, Calvin. (2002). The Road to Environmental Performance: A Small Shipyards Experience. 2nd Annual Shipyard Environmental Issues Conference. Portland, OR.

Minton, Gary. (2002). Stormwater Treatment: Biological, Chemical, & Engineering Principles. Resource Planning Associates. Seattle, WA.

Tobiason, Scott, et.al. (2002). Stormwater Metals Removal Testing at Seattle-Tacoma International Airport. Proceedings Water Environment Federation, Watershed 2002 Conference.

Hart Crowser. (2002). Final Report (Deliverable 5) Demonstration of Enhanced Filtration for Stormwater Treatment of Shipyard Stormwater San Diego, California. June 2002, 7374-03.

Hart Crowser. (1997) Shipyard AKART Analysis for Treatment of Stormwater. Final Report Prepared for Maritime Environmental Coalition, May 7, 1997.