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NBSD Commissary Bioinfiltration System Stormwater Monitoring Data Analysis for WinSLAMM Modeling

Contents

Summary

The monitored Naval Base San Diego (NBSD) Commissary parking lot site described in this memo has a drainage area of about 0.38 acres. The bioinfiltration system treating the stormwater runoff from this area has a storage capacity of about 600 ft^3, and a surface area of about 400 ft^2 (about 2.4% of the paved drainage area).

Three events were sampled at this location during this project. The PAHs and metals were evaluated by particle size range, while the PFAS were only evaluated for particulate bound and filtered fractions, due to low concentrations.

The reductions reported were only for inlet vs. outlet concentrations and did not reflect mass reductions that would also be affected by runoff infiltration losses with the bioinfiltration system. The modeled system had about 70% runoff volume reductions.

Many of the outlet metal concentrations for the smallest particle size range show negative removals (increasing concentrations) likely due to washout of media fines or previously captured material. In all cases, the metal removals associated with particles greater than 20 µm are large. The overall total sample reductions are low to moderate for most of the metals, while arsenic and mercury outlet concentrations for the total samples indicate increases after the bioinfiltration system treatment.

The median size associated with TSS was about 20 µm for the inlet samples, which was reduced to about 10 µm for the effluent samples. Typical sizes associated with the inlet median metal concentrations ranged from about 15 to 50 µm, while the sizes associated with the outlet median concentrations ranged from about 2 to 15 µm. Overall, the Commissary bioinfiltration system was most effective in removing the larger particles, while being less effective with removal of the small particles. All of the metals, except for chromium and arsenic, had larger particulate strengths associated with the large particles (>63 µm) compared to the other size ranges.

Many of the PAH removals associated with the smallest particle size range could not be calculated due to missing (non-detected) values. Overall, the PAH concentration reductions were moderate to high. The total PAH reductions were 91% for the total sample, 94% for the particulate bound sample fraction, and 60% for the filtered sample fraction. In general, the removals for the individual PAHs were greatest for the largest particles compared to the smallest particles, but there was substantial variability in the removals. In all cases, the inlet samples were associated with larger particle sizes (20 to >80 µm) associated with the median concentrations, compared to the outlet samples (7 to 20 µm). The bioinfiltration system preferentially removed the larger particles, with the smaller particles less effectively removed. In most cases, the particulate strengths were highest for the largest (>63 µm) particle size range.

PFAS data were only available for the total sample, filtered sample, and particulate sample fractions. The particulate bound concentrations were too small to be analyzed for different particle size ranges. The PFAS concentration removal performance was highly variable.

When compared to historical site stormwater concentrations, the averages of the three inlet samples analyzed during this project were mostly within the range of the prior observed values. The recent TSS values were slightly larger than the prior maximum observed TSS concentration, while the recent metal concentration data are within the range of the prior observed values.

The preliminary WinSLAMM model calculations indicated about 70% reductions in runoff volume, the main purpose of bioinfiltration systems. The mass reductions associated with the bioinfiltration system are the joint reductions associated with concentrations and the runoff volume. As an example, while the TSS concentrations were only reduced from about 75 to 60 mg/L (a 20% reduction), the TSS mass reductions were about 77%. The observed concentrations were higher than the modeled calculated concentrations for TSS, filtered copper and total copper concentrations, while the other observed concentrations were within the calculated range.

None of the outlet conditions indicated large (>70%) fractions of the pollutants associated with possible near-field deposition, while many of the metals and PAHs would likely have most of their mass widely dispersed upon discharge, depending on water depth and velocities.

Site and Monitoring Description

The following is the site and data description provided by the Texas Tech research group: “This spreadsheet contains the sampling and analytical data for NBSD - commissary site. The parking lot site has a drainage area of 0.38 acres and runoff enters the bioinfiltration system (storage capacity of ~ 600 cf) through two curb inlets under normal conditions. For the purpose of our sampling, we closed the inlet furthest away from the BMP device with landscape edging and foam sealant. The other inlet was provided with a H-flume for ease of sampling the incoming runoff. This also turned out to be useful for flow measurements as in some cases the area-velocity flow meter stopped working during sampling. In such cases, we estimated the flow values using the level and bioinfiltration capacity as detailed below. A total of 3 events were sampled for both flow and contaminant of concern (CoC) analysis."

Three events were sampled at this location. The PAHs and metals were evaluated by particle size range, while the PFAS were only evaluated for particulate bound and filtered fractions, due to low concentrations. The following describe the three monitored events.

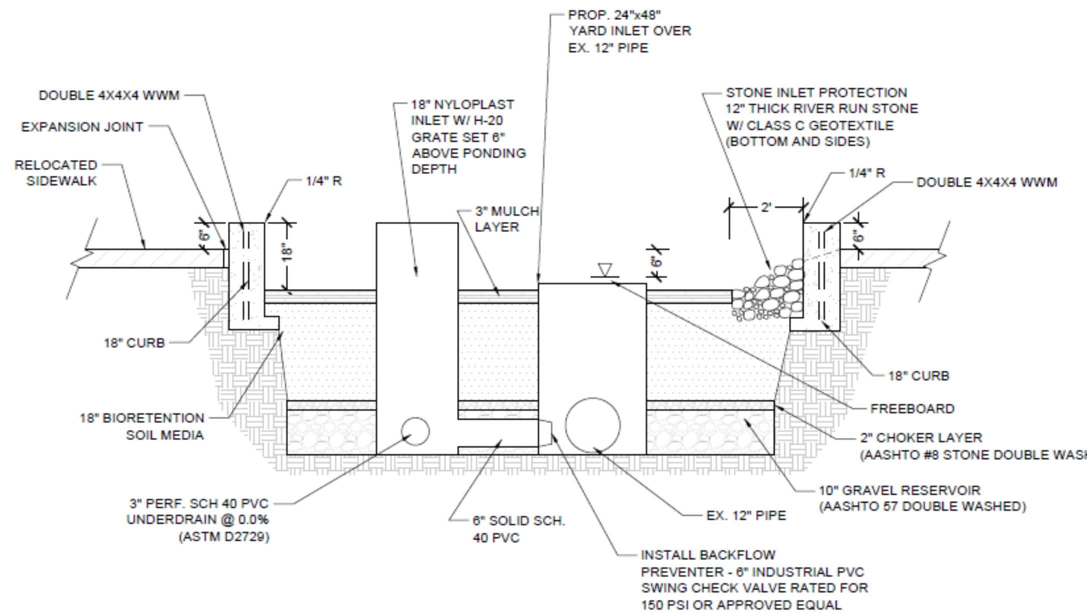
		Rain depth	Rain duration (hrs)
Event 1	February 22, 2020	0.29	1.25
Event 2	March 3, 2020	0.14	13.8
Event 3	March 10, 2020	n/a	n/a

Note: rain gauge for event 3 did not record the rain depth due to clogging

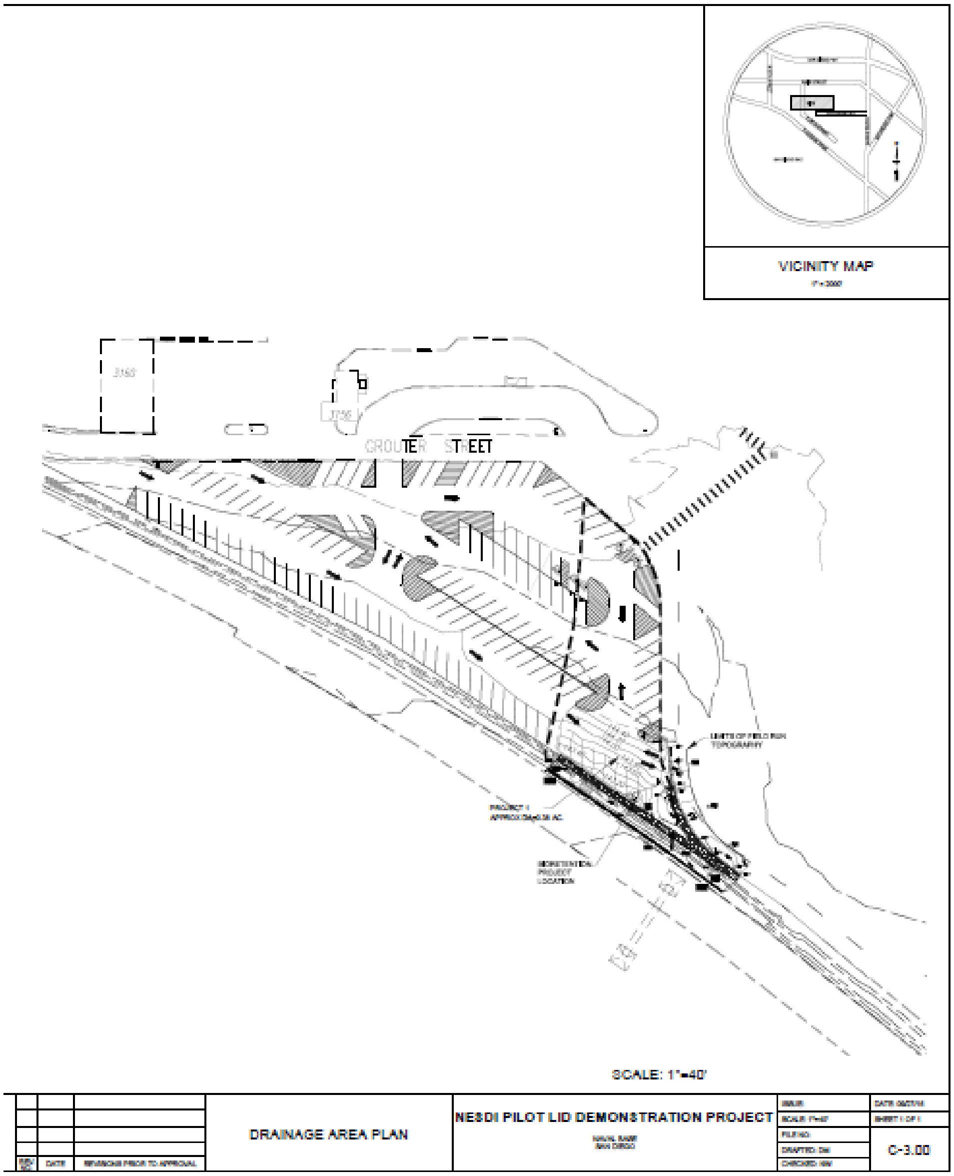
The following table and figures were provided by the Low Impact Development Center during the earlier project for the Navy that constructed the bioinfiltration system and conducted initial stormwater monitoring. These were used to prepare the WinSLAMM input files.

Drainage Area (ac)	Drainage Area (sf)	Surface Area (sf)	Ponding Depth (ft)	Ponding Storage (cf)	Mulch Depth (ft)
0.38	16,550	400	0.5	200	0.17

Mulch Storage (cf)	Media Depth (ft)	Media Storage (cf)	Gravel Depth (ft)	Gravel Storage (cf)	Total Storage (cf)
27	1.5	240	0.83	133	600



Bioinfiltration System Details (Low Impact Development Center).



Bioinfiltration System Drainage Area

Stormwater Monitoring Data Summaries for use in WinSLAMM Modeling

TSS and Heavy Metals

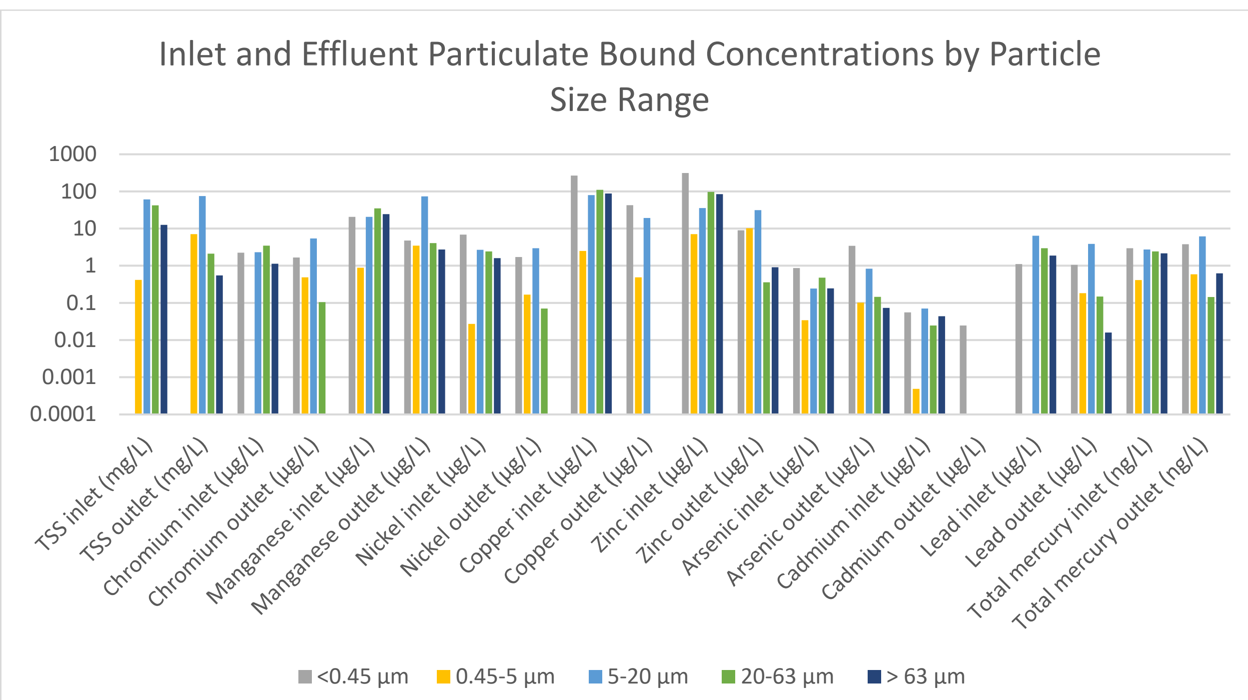
The following tables summarize the average inlet and outlet concentrations for TSS and heavy metals at the Commissary bioinfiltration system location. These summarizes show the total sample bulk concentrations, along with the total particulate and filterable forms, along with concentrations associated with different particle size ranges. These data are also shown in figures contrasting the concentrations by size.

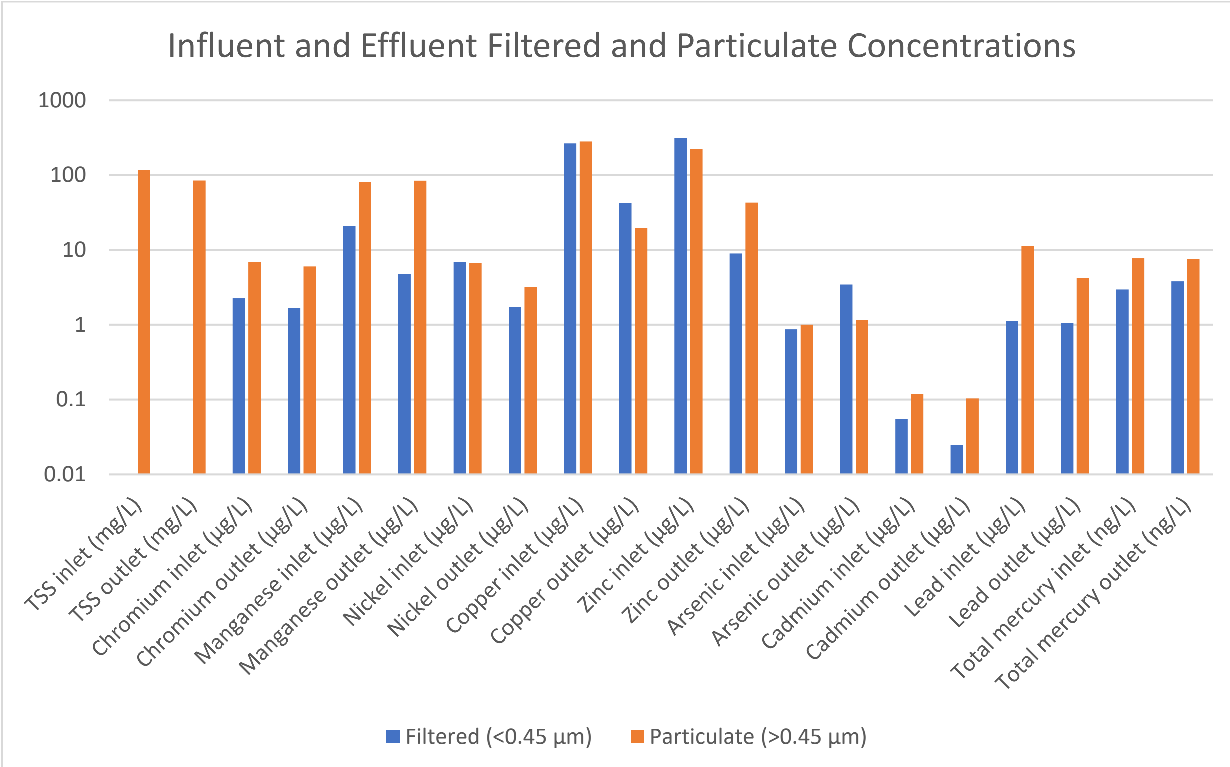
TSS and Metal Concentrations at Bioinfiltration System Inlet (average of 3 events)

Size Interval	TSS inlet (mg/L)	Chromium inlet (µg/L)	Manganese inlet (µg/L)	Nickel inlet (µg/L)	Copper inlet (µg/L)	Zinc inlet (µg/L)	Arsenic inlet (µg/L)	Cadmium inlet (µg/L)	Lead inlet (µg/L)	Total mercury inlet (ng/L)
Bulk		9.2	101.8	13.6	547.7	538.2	1.9	0.2	12.4	10.7
Total particulates (>0.45 µm)	116.4	6.9	81.0	6.7	281.7	224.6	1.0	0.1	11.3	7.7
<0.45 µm		2.3	20.8	6.9	266.0	313.6	0.9	0.1	1.1	3.0
0.45-5 µm	0.4		0.9	0.0	2.5	7.1	0.0	0.0		0.4
5-20 µm	61.0	2.3	20.7	2.7	79.9	35.6	0.2	0.1	6.4	2.7
20-63 µm	42.3	3.5	34.9	2.4	110.9	97.2	0.5	0.0	3.0	2.4
> 63 µm	12.6	1.1	24.5	1.6	88.4	84.7	0.2	0.0	1.9	2.2
% filtered		24.6	20.4	50.4	48.6	58.3	46.5	28.5	9.0	27.7
% particulate		75.4	79.6	49.6	51.4	41.7	53.5	61.2	91.0	72.3

TSS and Metal Concentrations at Bioinfiltration System Outlet (average of 3 events)

Size Interval	TSS outlet (mg/L)	Chromium outlet (µg/L)	Manganese outlet (µg/L)	Nickel outlet (µg/L)	Copper outlet (µg/L)	Zinc outlet (µg/L)	Arsenic outlet (µg/L)	Cadmium outlet (µg/L)	Lead outlet (µg/L)	Total mercury outlet (ng/L)
Bulk		7.7	88.9	4.9	62.2	51.9	4.6	0.1	5.3	11.3
Total particulates (>0.45 µm)	84.6	6.0	84.1	3.2	19.7	42.9	1.2	0.1	4.2	7.5
<0.45 µm		1.7	4.8	1.7	42.5	9.0	3.4	0.0	1.1	3.8
0.45-5 µm	7.1	0.5	3.5	0.2	0.5	10.3	0.1		0.2	0.6
5-20 µm	74.8	5.4	73.8	2.9	19.2	31.4	0.8		3.9	6.2
20-63 µm	2.1	0.1	4.1	0.1		0.4	0.1		0.1	0.1
> 63 µm	0.5		2.7			0.9	0.1		0.0	0.6
% filtered		21.7	5.4	35.1	68.3	17.3	74.9	21.0	20.1	33.5
% particulate		78.3	94.6	64.9	31.7	82.7	25.1	88.2	79.9	66.5



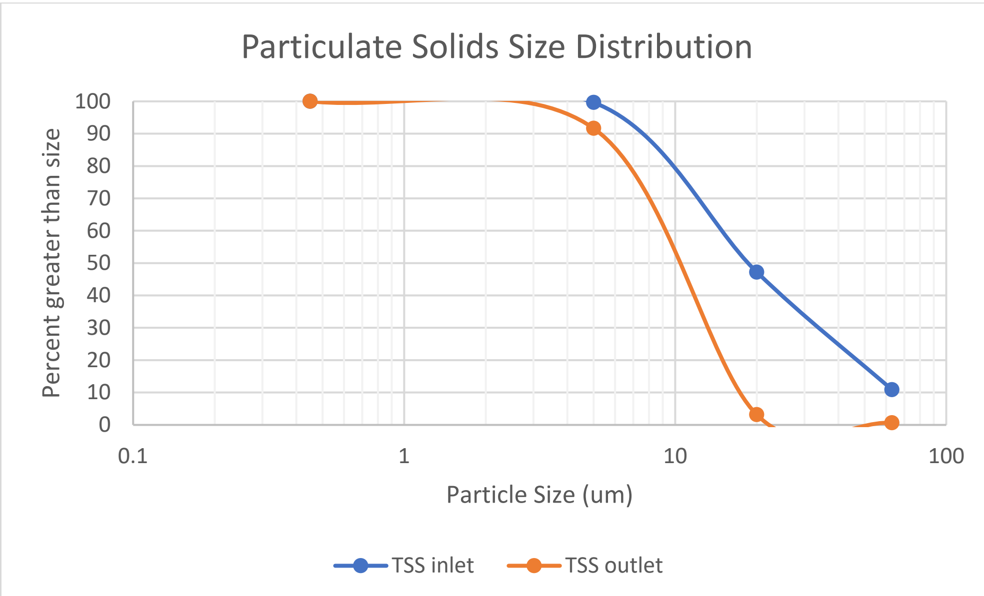


The following table summarizes the percentage reductions of TSS and heavy metal concentrations for the total sample, particulate bound, and filterable fractions, along with the removal by particle size range. These are averages for the three events. These are concentrations reductions only and do not reflect mass reductions that would also be affected by runoff infiltration losses with the bioinfiltration system (the modeled system had about 70% runoff volume reductions). Many of the outlet concentrations for the smallest particle size range show negative removals (increasing concentrations) likely due to washout of media fines. In all cases, the removals associated with particles greater than 20 µm were large. The overall total sample reductions were low to moderate for most of these constituents, while arsenic and mercury outlet concentrations for the total samples indicated increases after the bioinfiltration system treatment.

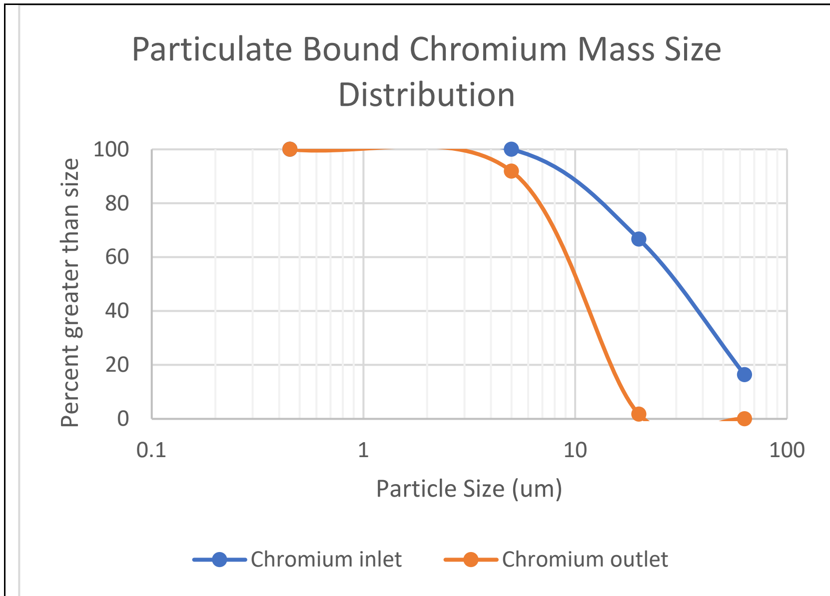
Percentage Reductions in Concentrations Associated with Commissary Bioinfiltration System by Particle Size Range

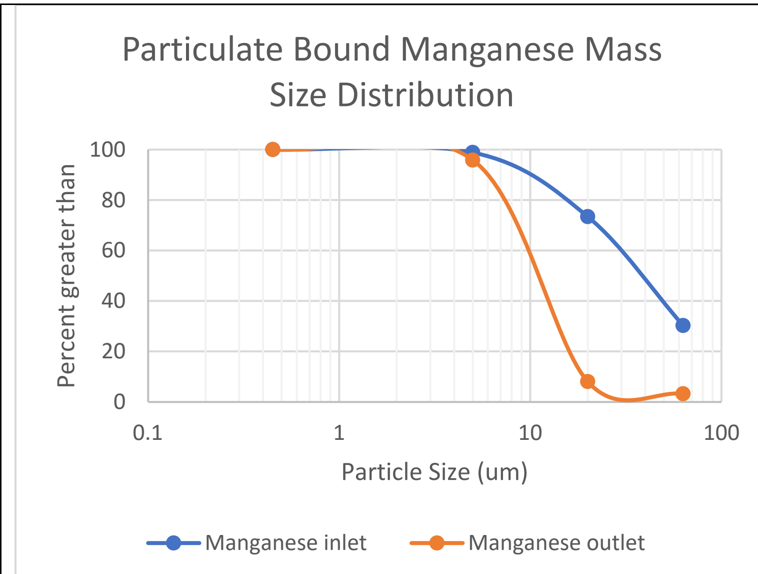
Size Interval	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead	Mercury
Total sample	n/a	16.4	12.7	63.9	88.6	90.4	-145.9	39.7	57.6	-5.8
>0.45 µm (particulate bound)	27.3	13.1	-3.8	52.7	93.0	80.9	-15.3	13.1	62.8	2.7
<0.45 µm (filtered)	n/a	26.3	77.0	74.9	84.0	97.1	-295.9	55.6	4.8	-28.1
0.45-5 µm	-1601.7		-292.6	-520.0	80.6	-45.2	-197.4			-43.6
5-20 µm	-22.7	-135.1	-257.4	-10.0	75.9	11.7	-240.4		40.2	-125.3
20-63 µm	95.0	97.0	88.4	97.1		99.6	69.4		95.0	94.0
> 63 µm	95.7	100.0	88.8			98.9	70.2		99.2	71.3

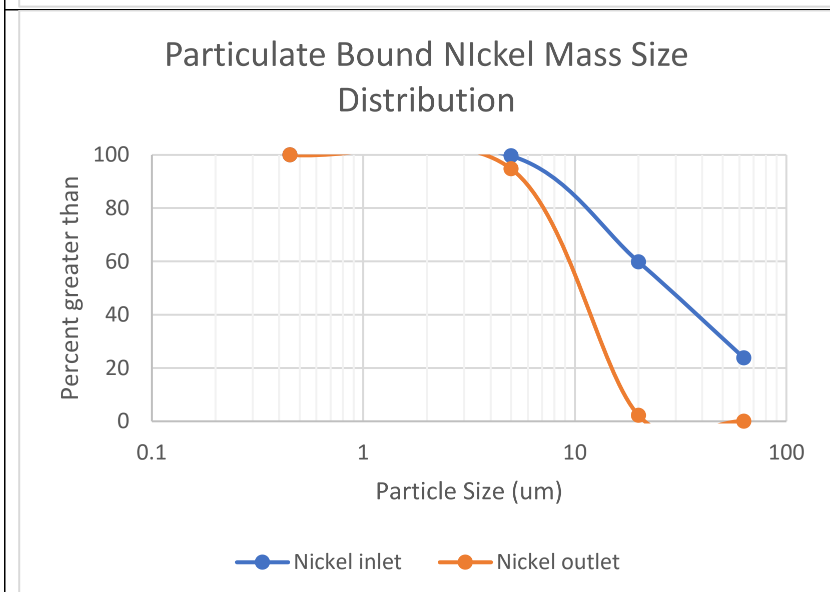
The following plots show the particle size distributions for the TSS and metal concentrations. The median size associated with TSS was about 20 µm for the inlet samples, which was reduced to about 10 µm for the effluent samples.

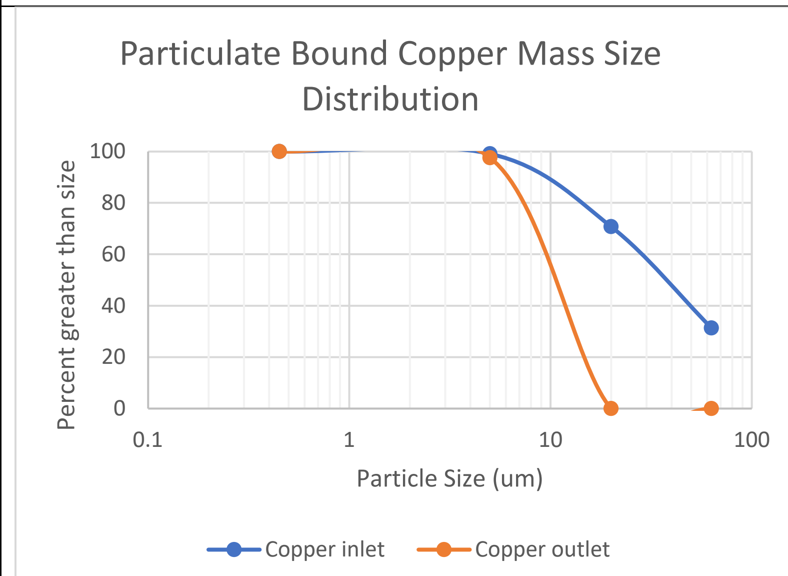


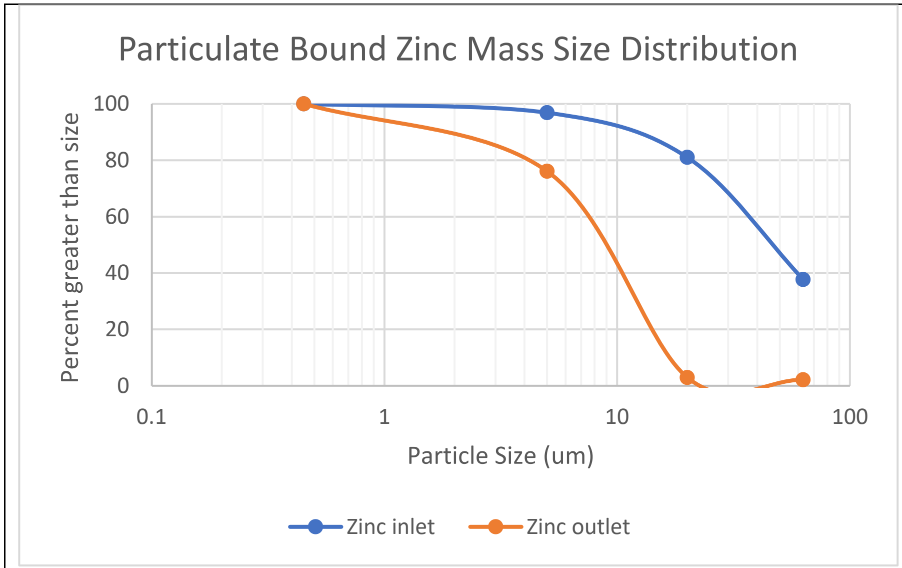
The following are similar particulate bound concentration plots by particle size for the monitored metals. As for the TSS values, all of the sizes associated with the median concentrations were reduced with treatment. Typical sizes associated with the inlet median concentrations ranged from about 15 to 50 µm, while the sizes associated with the outlet median concentrations ranged from about 2 to 15 µm. Overall, the Commissary bioinfiltration system was most effective in removing the larger particles, while being less effective with removal of the small particles.

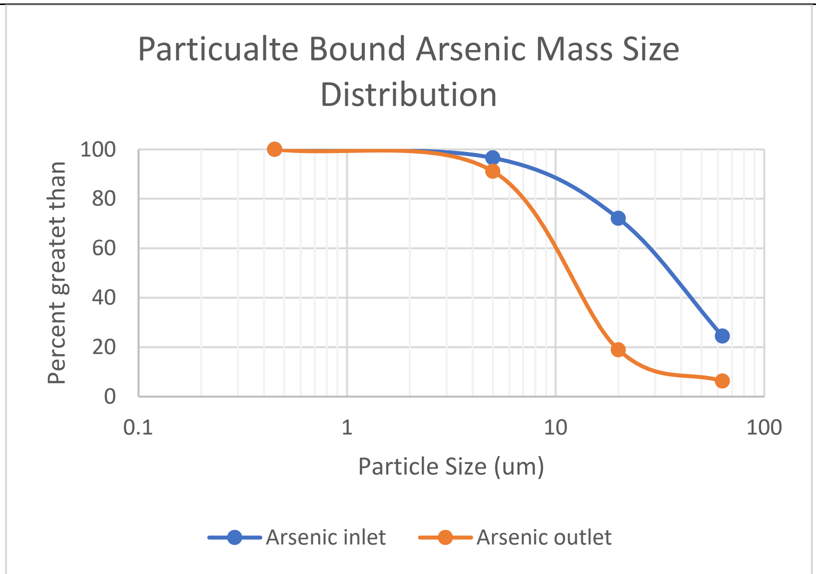

Particulate Bound Chromium Mass Size Distribution
Percent greater than size
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Chromium inlet
Chromium outlet

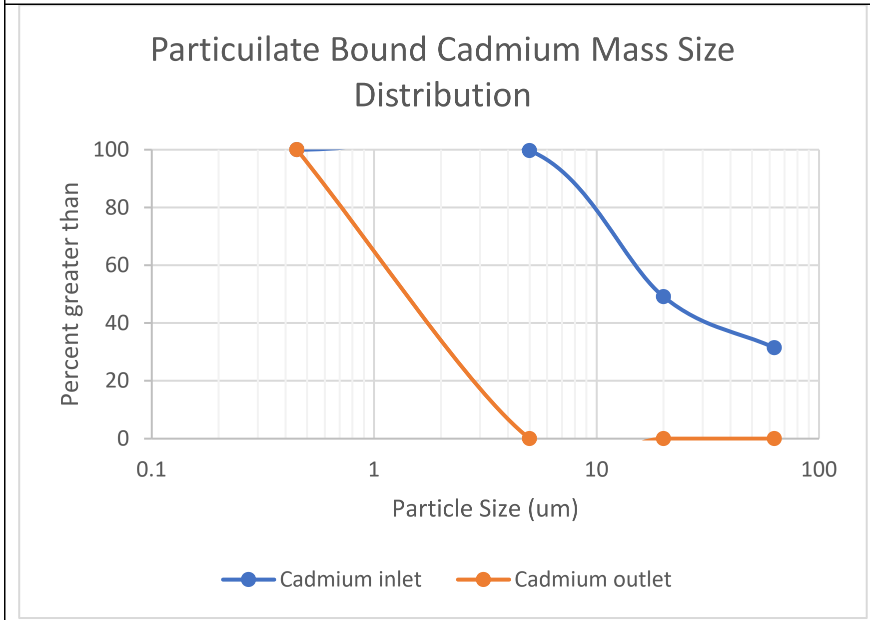

Particulate Bound Manganese Mass Size Distribution
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Manganese inlet
Manganese outlet

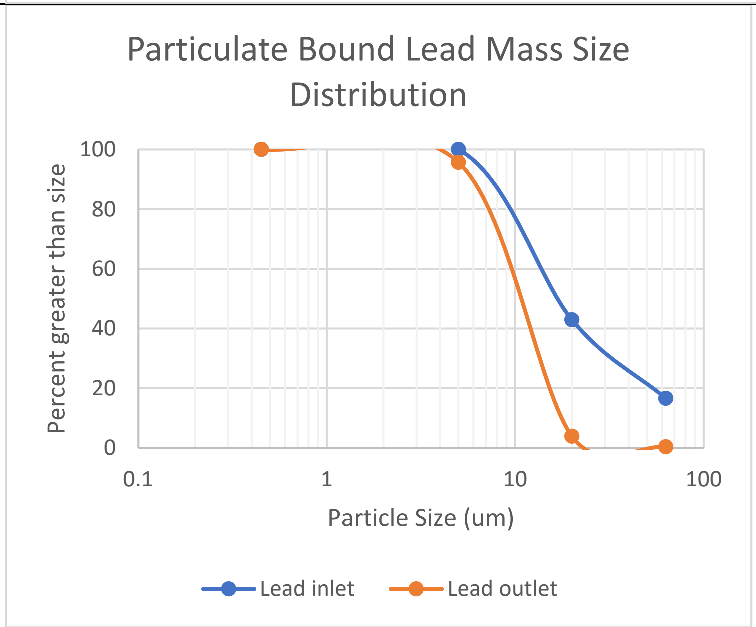

Particulate Bound NIckel Mass Size Distribution
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Nickel inlet
Nickel outlet

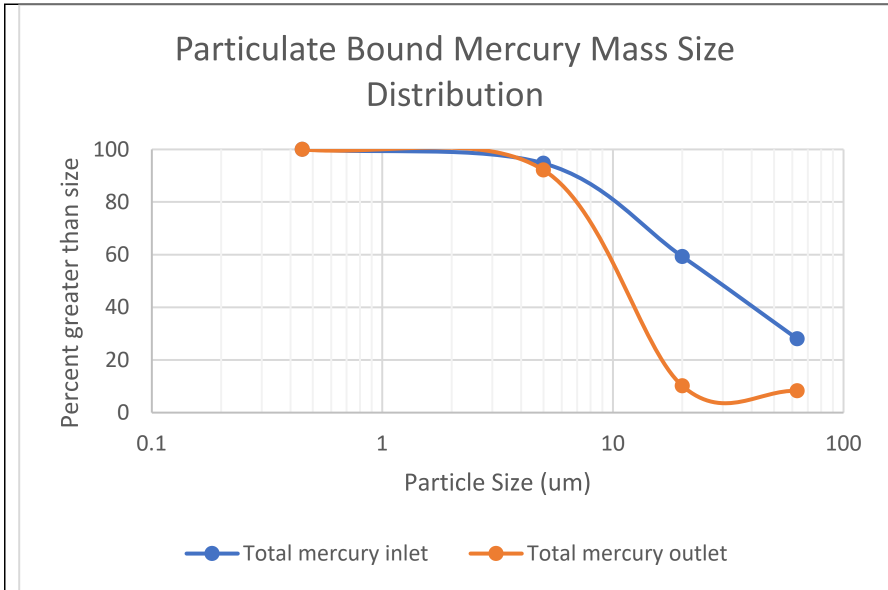

Particulate Bound Copper Mass Size Distribution
Percent greater than size
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Copper inlet
Copper outlet


Particulate Bound Zinc Mass Size Distribution
Percent greater than size
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Zinc inlet
Zinc outlet


Particualte Bound Arsenic Mass Size Distribution
Percent greatet than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Arsenic inlet
Arsenic outlet


Particuilate Bound Cadmium Mass Size Distribution
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Cadmium inlet
Cadmium outlet

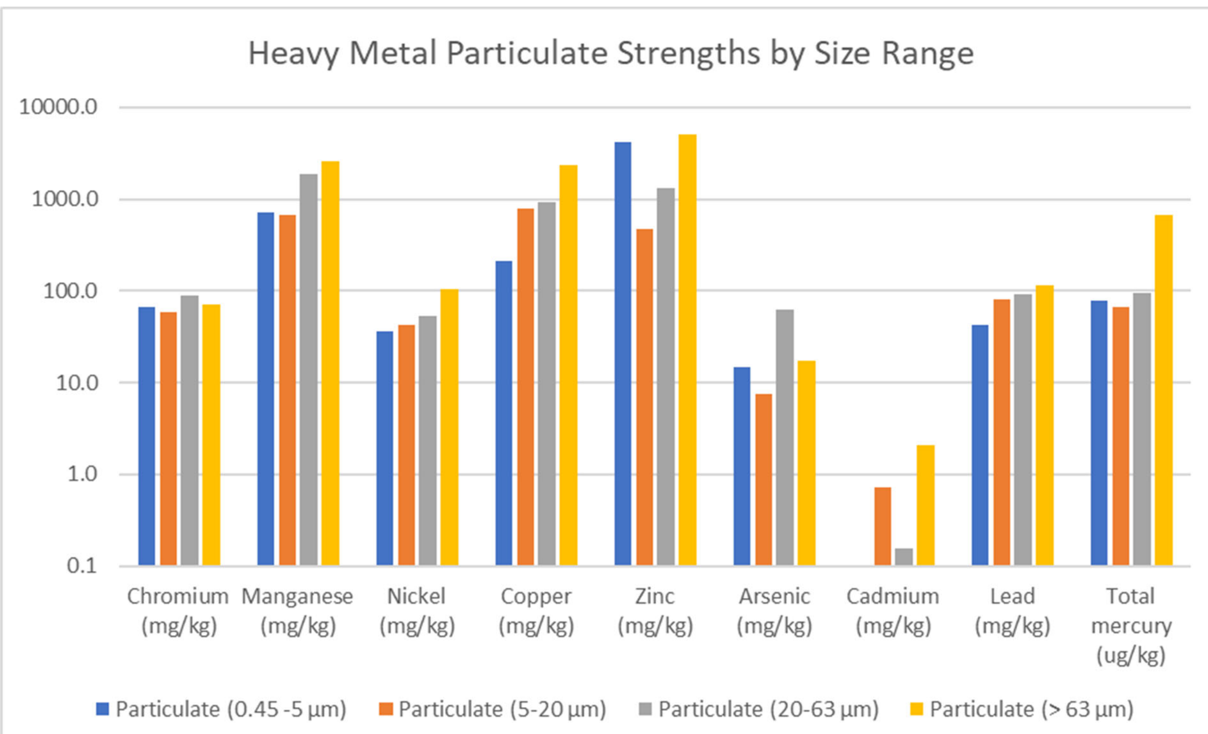

Particulate Bound Lead Mass Size Distribution
Percent greater than size
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Lead inlet
Lead outlet


Particulate Bound Mercury Mass Size Distribution
Percent greater than size
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Total mercury inlet
Total mercury outlet

The following table and figure illustrate the particulate strengths for the metals for the different particle sizes. These are averages of all detected particulate strengths for inlet and outlet samples combined, as the treatment process would not affect the particulate strengths, but just the mass of particles in each size range. All of the metals, except for chromium and arsenic, had larger particulate strengths associated with the large particles (>63 µm) compared to the other size ranges.

Metal Particulate Strengths by Particle Size

size interval	Chromium (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Copper (mg/kg)	Zinc (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Mercury (ug/kg)
Particulate (0.45 -5 µm)	65.8	706.3	36.0	210.2	4179.4	14.7	n/a	42.8	77.6
Particulate (5-20 µm)	58.6	664.3	42.7	780.3	476.1	7.4	0.7	80.9	65.6
Particulate (20-63 µm)	88.9	1863.8	53.3	918.9	1326.7	62.1	0.2	92.0	93.8
Particulate (> 63 µm)	71.2	2540.0	104.6	2367.3	4991.8	17.0	2.1	114.7	680.0



PAHs

The following tables and figures summarize the inlet and outlet PAH concentrations for the Commissary bioinfiltration system for the three monitored events. As for the TSS and metals, these are shown for the bulk (total sample) in addition to the filterable and particulate bound concentrations, and particulate concentrations for different particle size ranges. Many of the smallest particle size analyses resulted in non-detected results.

Inlet PAH Concentrations (average of 3 events), ng/L

Size Interval	Naphthalene	2-methylnaphthalene	1-methylnaphthalene	2-ethylnaphthalene	1-ethylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	2-isopropylnaphthalene	acenaphthylene	1.2-dimethylnaphthalene
Filtered (<0.7µm)	6.375	6.194	3.241	0.865	0.142	2.072	1.655	0.055	0.161	0.456
0.7-2.7 µm	n/a	n/a	n/a	n/a	0.067	0.122	0.339	n/a	n/a	0.103
2.7-20 µm	0.612	0.951	0.560	0.138	0.047	0.291	0.266	0.013	0.009	0.058
20-63 µm	1.710	1.671	0.897	0.256	0.049	0.535	0.323	n/a	0.049	0.068
>63 µm	3.704	1.748	0.971	0.134	0.014	0.519	0.506	0.008	0.014	0.099
Total Particulate (>0.7 µm)	6.026	4.370	2.429	0.528	0.176	1.467	1.433	0.021	0.071	0.328
Bulk	12.401	10.564	5.670	1.393	0.318	3.539	3.088	0.076	0.232	0.784
% filt	51.4	58.6	57.2	62.1	44.6	58.6	53.6	72.9	69.4	58.2
% part	48.6	41.4	42.8	37.9	55.4	41.4	46.4	27.1	30.6	41.8

Note: n/a indicates concentrations not available as they were less than the detection limits

Inlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	1.8-dimethylnaphthalene	acenaphthene	2.3.5-trimethylnaphthalene	fluorene	1-methylfluorene	phenanthrene	anthracene	2-methylphenanthrene	2-methylanthracene	1-methylphenanthrene
Filtered (<0.7µm)	0.041	1.263	0.895	5.193	2.265	25.206	0.954	5.484	0.149	2.355
0.7-2.7 µm	0.011	0.476	n/a	n/a	n/a	n/a	0.003	n/a	n/a	n/a
2.7-20 µm	0.002	0.589	0.173	0.798	0.338	22.216	0.868	3.925	0.234	1.716
20-63 µm	0.002	0.379	0.276	1.857	0.218	39.555	2.209	7.614	0.780	3.610
>63 µm	0.001	0.814	0.184	0.791	0.312	45.038	1.530	6.332	0.396	2.866
Total Particulate (>0.7 µm)	0.016	2.258	0.633	3.446	0.868	106.809	4.610	17.872	1.410	8.192
Bulk	0.057	3.520	1.528	8.639	3.133	132.014	5.564	23.355	1.559	10.546
% filt	72.5	35.9	58.5	60.1	72.3	19.1	17.1	23.5	9.6	22.3
% part	27.5	64.1	41.5	39.9	27.7	80.9	82.9	76.5	90.4	77.7

Inlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	9-methylanthracene	2-ethylanthracene	fluoranthene	pyrene	9.10-dimethylanthracene	2-tertbutylanthracene	1-methylpyrene	benz(a)anthracene	chrysene	benzo(b)fluoranthene
Filtered (<0.7µm)	0.064	1.148	7.928	26.908	0.128	0.040	0.208	0.419	1.614	0.690
0.7-2.7 µm	0.003	0.072	5.796	0.303	n/a	0.000	0.009	0.036	0.407	0.159
2.7-20 µm	0.010	1.603	30.151	21.042	0.013	0.014	1.030	3.720	16.899	9.339
20-63 µm	0.057	2.669	76.410	34.958	0.040	0.065	2.642	10.549	38.737	16.196
>63 µm	0.053	2.261	79.971	77.257		0.142	3.208	8.065	32.242	11.314
Total Particulate (>0.7 µm)	0.124	6.605	192.327	133.561	0.053	0.222	6.890	22.371	88.285	37.007
Bulk	0.188	7.753	200.255	160.468	0.180	0.262	7.098	22.790	89.899	37.697
% filt	33.9	14.8	4.0	16.8	70.8	15.4	2.9	1.8	1.8	1.8
% part	66.1	85.2	96.0	83.2	29.2	84.6	97.1	98.2	98.2	98.2

Inlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	7.12-methylbenz(a)anthracene	benzo(k)fluoranthene	benzo(a)pyrene	benzo(e)pyrene	perylene	Indeno(123-cd)pyrene	Dibenzo(ah)anthracene	benzo(ghi)perylene	Total corrected PAH ng/L
Filtered (<0.7µm)	0.062	0.506	0.207	0.633	0.148	0.210	0.148	0.408	93.355
0.7-2.7 µm	0.006	0.100	0.112	0.224	0.000	0.212	0.037	0.437	9.034
2.7-20 µm	0.370	6.699	9.371	9.501	1.195	6.375	1.648	17.258	170.041
20-63 µm	0.575	13.079	12.975	16.022	3.666	10.769	3.869	30.111	335.448
>63 µm	0.446	9.197	4.628	8.535	1.629	1.338	0.972	7.425	314.665
Total Particulate (>0.7 µm)	1.398	29.075	27.086	34.282	6.490	18.694	6.525	55.231	829.187
Bulk	1.460	29.581	27.293	34.915	6.639	18.904	6.673	55.639	935.678
% filt	4.2	1.7	0.8	1.8	2.2	1.1	2.2	0.7	10.0
% part	95.8	98.3	99.2	98.2	97.8	98.9	97.8	99.3	88.6

Outlet PAH Concentrations (average of 3 events), ng/L

	Naphthalene	2-methylnaphthalene	1-methylnaphthalene	2-ethylnaphthalene	1-ethylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	2-isopropylnaphthalene	acenaphthylene	1.2-dimethylnaphthalene
Filtered (<0.7µm)	1.599	1.924	1.031	0.373	0.058	1.223	0.912	0.011	0.112	0.233
0.7-2.7 µm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.002	n/a
2.7-20 µm	0.308	1.105	0.430	0.059	0.030	0.192	0.161	0.007	0.015	0.058
20-63 µm	0.045	0.040	0.004	0.000	0.002	0.013	0.000	0.000	0.035	0.005
>63 µm	0.332	0.475	0.093	0.103	0.015	0.321	0.231	0.005	0.000	0.071
Total Particulate (>0.7 µm)	0.684	1.621	0.527	0.161	0.047	0.526	0.392	0.012	0.051	0.134
Bulk	2.284	3.544	1.559	0.535	0.105	1.749	1.304	0.023	0.163	0.367
% filt	70.0	54.3	66.2	69.8	55.4	69.9	69.9	46.9	68.4	63.5
% part	30.0	45.7	33.8	30.2	44.6	30.1	30.1	53.1	31.6	36.5

Outlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	1.8-dimethylnaphthalene	acenaphthene	2.3.5-trimethylnaphthalene	fluorene	1-methylfluorene	phenanthrene	anthracene	2-methylphenanthrene	2-methylanthracene	1-methylphenanthrene
Filtered (<0.7µm)	0.022	0.213	0.609	2.389	1.235	12.714	0.775	3.165	0.094	1.176
0.7-2.7 µm		0.049	0.034	0.176	0.077	1.119	0.047	0.338	0.012	0.082
2.7-20 µm	0.003	0.047	0.080	0.319	0.042	2.214	0.227	0.480		0.199
20-63 µm	0.001	0.002	0.017	0.055	0.005	0.349	0.081	0.053	0.049	0.017
>63 µm	0.004	0.159	0.201	0.815	0.364	2.823	0.097	0.531	0.008	0.279
Total Particulate (>0.7 µm)	0.007	0.256	0.332	1.364	0.488	6.506	0.452	1.403	0.070	0.578
Bulk	0.028	0.470	0.940	3.754	1.723	19.219	1.227	4.567	0.164	1.754
% filt	75.8	45.4	64.7	63.7	71.7	66.2	63.2	69.3	57.3	67.1
% part	24.2	54.6	35.3	36.3	28.3	33.8	36.8	30.7	42.7	32.9

Outlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	9-methylanthracene	2-ethylanthracene	fluoranthene	pyrene	9.10-dimethylanthracene	2-tertbutylanthracene	1-methylpyrene	benz(a)anthracene	chrysene	benzo(b)fluoranthene
Filtered (<0.7μm)	0.056	0.779	2.847	1.859	0.097	0.013	0.026	0.191	0.594	0.310
0.7-2.7 μm	0.002	0.131	0.607	0.303	n/a	0.004	0.106	0.122	0.376	0.227
2.7-20 μm	n/a	0.022	5.310	2.601	0.041	0.000	0.167	0.913	2.500	1.757
20-63 μm	0.012	0.063	0.501	0.542	n/a	0.003	0.014	0.115	0.417	0.184
>63 μm	0.004	0.133	1.603	1.707	n/a	0.002	0.057	0.180	0.946	0.437
Total Particulate (>0.7 μm)	0.019	0.349	8.020	5.152	0.041	0.008	0.344	1.329	4.239	2.605
Bulk	0.075	1.128	10.867	7.011	0.138	0.021	0.370	1.521	4.832	2.915
% filt	75.0	69.1	26.2	26.5	70.3	61.1	7.0	12.6	12.3	10.6
% part	25.0	30.9	73.8	73.5	29.7	38.9	93.0	87.4	87.7	89.4

Outlet PAH Concentrations (average of 3 events), ng/L (continued)

Size Interval	7.12-methylbenz(a)anthracene	benzo(k)fluoranthene	benzo(a)pyrene	benzo(e)pyrene	perylene	Indeno(123-cd)pyrene	Dibenzo(ah)anthracene	benzo(ghi)perylene	Total corrected PAH ng/L
Filtered (<0.7μm)	0.032	0.192	0.133	0.284	0.066	0.218	0.096	0.137	37.797
0.7-2.7 μm	0.001	0.159	0.041	0.194	0.001	0.015	0.017	0.088	4.325
2.7-20 μm	0.010	1.276	1.629	1.588	0.051	1.086	0.263	1.588	26.775
20-63 μm	0.037	0.173	0.049	0.213	0.055	0.038	0.013	0.195	3.398
>63 μm	0.016	0.311	0.108	0.390	0.042	0.043	0.001	0.070	12.976
Total Particulate (>0.7 μm)	0.063	1.918	1.826	2.384	0.149	1.182	0.294	1.940	47.475
Bulk	0.095	2.110	1.959	2.668	0.215	1.400	0.390	2.077	85.271
% filt	33.7	9.1	6.8	10.6	30.6	15.6	24.7	6.6	44.3
% part	66.3	90.9	93.2	89.4	69.4	84.4	75.3	93.4	55.7

The following tables show the percentage concentration reductions for the PAH compounds associated with the Commissary bioinfiltration system. Reduction values are shown for the bulk (total) sample, the filtered and particulate-bound portions, and the particulate removals by particle size range. Many of the removals associated with the smallest particle size range cannot be calculated due to missing (non-detected) values. Overall, the reductions were moderate to high. The total PAH reductions were shown to be 91% for the total sample, 94% for the particulate bound sample fraction, and 60% for the filtered sample fraction. In general, the removals for the individual PAHs were greatest for the largest particles compared to the smallest particles, but there was substantial variability in the removals.

PAH Concentration Reductions by Particle Size (%)

	Naphthalene ng/L	**2-methylnaphthalene ng/L**	**1-methylnaphthalene ng/L**	**2-ethylnaphthalene ng/L**	**1-ethylnaphthalene ng/L**	**2.6-dimethylnaphthalene ng/L**	**1.3-dimethylnaphthalene ng/L**	**2-isopropylnaphthalene**	**acenaphthylene**	**1.2-dimethylnaphthalene**
Filtered (<0.7µm)	74.9	68.9	68.2	56.8	59.0	41.0	44.9	80.6	30.7	48.9
0.7-2.7 µm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2.7-20 µm	49.8	-16.3	23.3	57.5	36.4	34.0	39.5	48.4	-76.6	1.3
20-63 µm	97.4	97.6	99.5	n/a	95.4	97.5	n/a	n/a	28.8	92.5
>63 µm	91.0	72.8	90.4	23.4	-8.6	38.2	54.3	31.4		28.1
Total Particulate (>0.7 µm)	88.6	62.9	78.3	69.4	73.4	64.2	72.7	40.7	27.5	59.1
Bulk	81.6	66.4	72.5	61.6	66.9	50.6	57.8	69.8	29.7	53.2

PAH Concentration Reductions by Particle Size (%) (continued)

Size Interval	1.8-dimethylnaphthalene	acenaphthene	2.3.5-trimethylnaphthalene	fluorene	1-methylfluorene	phenanthrene	anthracene	2-methylphenanthrene	2-methylanthracene	1-methylphenanthrene
Filtered (<0.7µm)	47.8	83.1	32.0	54.0	45.5	49.6	18.8	42.3	37.3	50.1
0.7-2.7 µm	n/a	89.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2.7-20 µm	-9.1	92.0	54.1	60.1	87.5	90.0	73.9	87.8		88.4
20-63 µm	67.9	99.4	94.0	97.0	97.9	99.1	96.3	99.3	93.7	99.5
>63 µm	-457.3	80.5	-9.3	-3.1	-16.5	93.7	93.7	91.6	97.9	90.2
Total Particulate (>0.7 µm)	55.9	88.6	47.6	60.4	43.8	93.9	90.2	92.2	95.0	92.9
Bulk	50.0	86.7	38.5	56.5	45.0	85.4	78.0	80.4	89.5	83.4

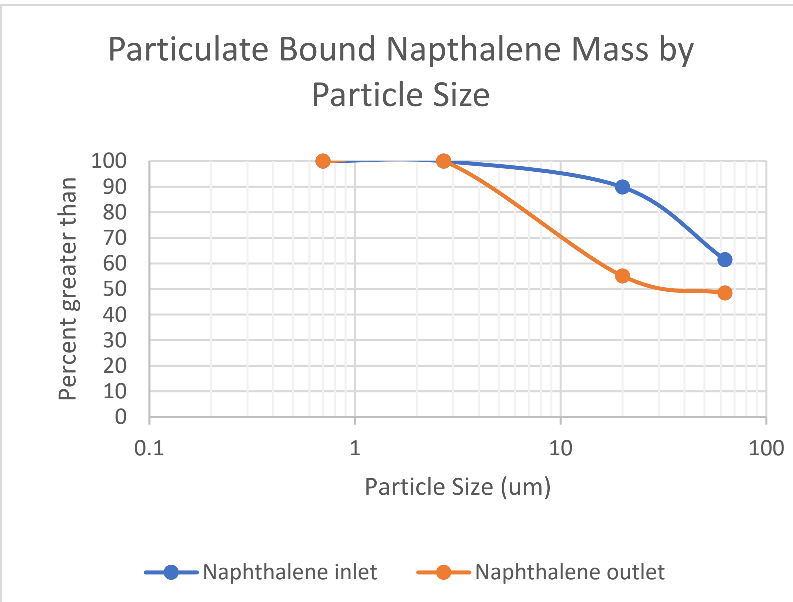
PAH Concentration Reductions by Particle Size (%) (continued)

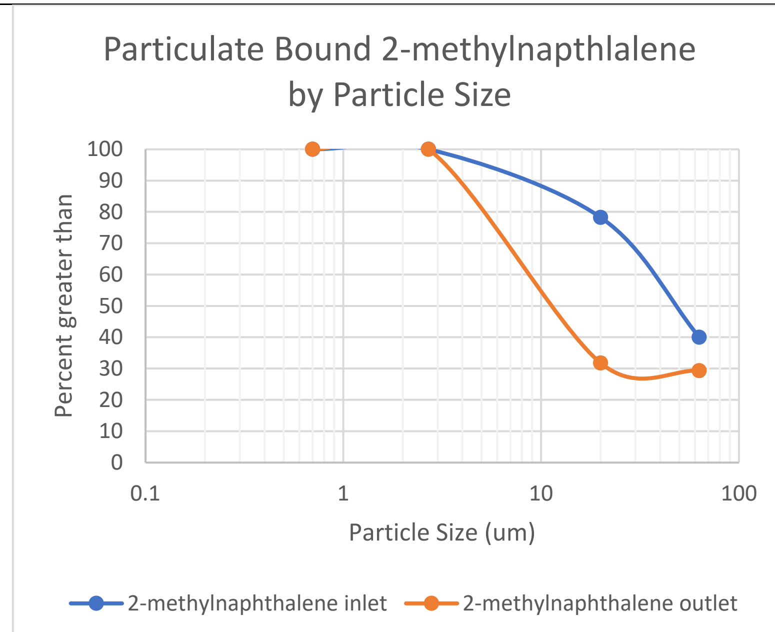
Size Interval	9-methylanthracene	2-ethylanthracene	fluoranthene	pyrene	9.10-dimethylanthracene	2-tertbutylanthracene	1-methylpyrene	benz(a)anthracene	chrysene	benzo(b) fluoranthene
Filtered (<0.7µm)	11.7	32.1	64.1	93.1	23.9	68.7	87.6	54.3	63.2	55.1
0.7-2.7 µm	51.4	-82.4	89.5	0.0	n/a	n/a	-1052.7	-234.7	7.8	-43.0
2.7-20 µm		98.6	82.4	87.6	-218.7	n/a	83.8	75.5	85.2	81.2
20-63 µm	78.5	97.6	99.3	98.4	n/a	95.7	99.5	98.9	98.9	98.9
>63 µm	92.0	94.1	98.0	97.8	n/a	98.8	98.2	97.8	97.1	96.1
Total Particulate (>0.7 µm)	84.9	94.7	95.8	96.1	21.9	96.4	95.0	94.1	95.2	93.0
Bulk	60.1	85.4	94.6	95.6	23.3	92.1	94.8	93.3	94.6	92.3

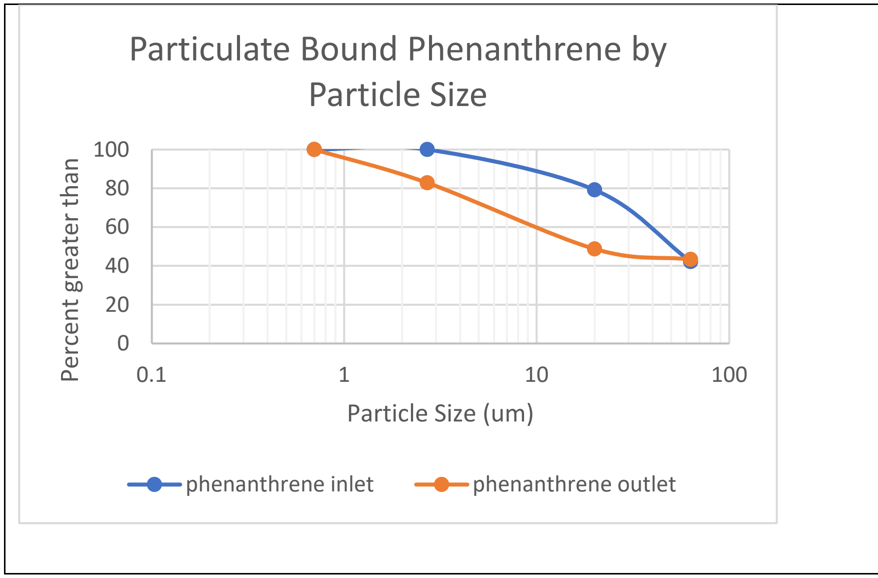
PAH Concentration Reductions by Particle Size (%) (continued)

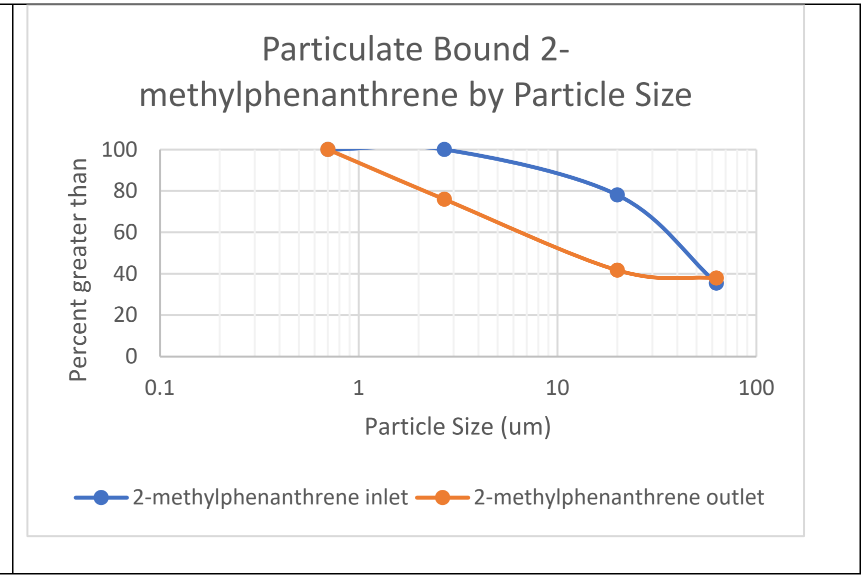
Size Interval	7.12-methylbenz(a) anthracene	benzo(k) fluoranthene	benzo(a) pyrene	benzo(e) pyrene	perylene	Indeno(123-cd) pyrene	Dibenzo(ah) anthracene	benzo(ghi) perylene	Total corrected PAH
Filtered (<0.7µm)	47.9	62.1	35.8	55.2	55.8	-3.7	34.9	66.3	59.5
0.7-2.7 µm	91.2	-58.5	63.6	13.7	n/a	93.0	54.4	79.9	52.1
2.7-20 µm	97.2	81.0	82.6	83.3	95.8	83.0	84.0	90.8	84.3
20-63 µm	93.6	98.7	99.6	98.7	98.5	99.6	99.7	99.4	99.0
>63 µm	96.5	96.6	97.7	95.4	97.4	96.8	99.9	99.1	95.9
Total Particulate (>0.7 µm)	95.5	93.4	93.3	93.0	97.7	93.7	95.5	96.5	94.3
Bulk	93.5	92.9	92.8	92.4	96.8	92.6	94.1	96.3	90.9

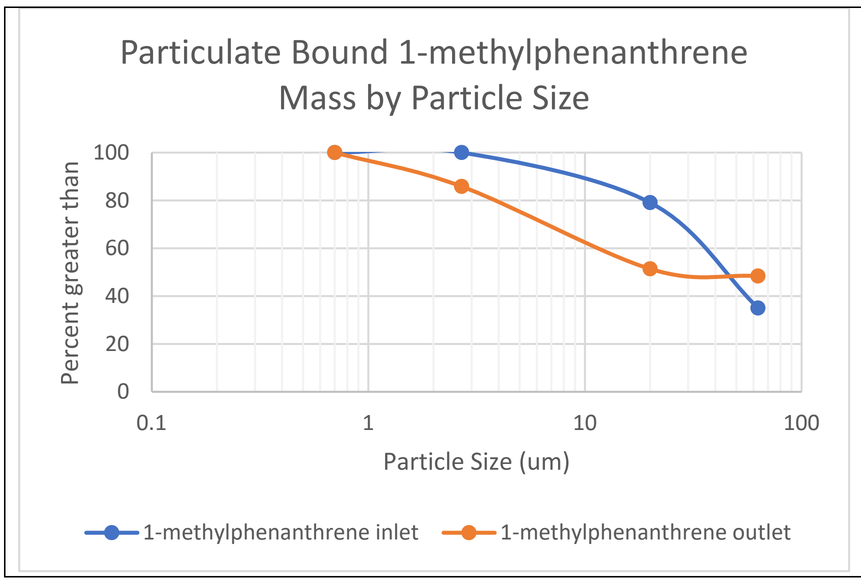
The following figures are particle size distributions of the PAH concentrations for the inlet and outlet samples. In all cases, the inlet samples are associated with larger particle sizes (20 to >80 µm) associated with the median concentrations, compared to the outlet samples (7 to 20 µm). The bioinfiltration system is preferentially removing the larger particles, with the smaller particles less effectively removed.

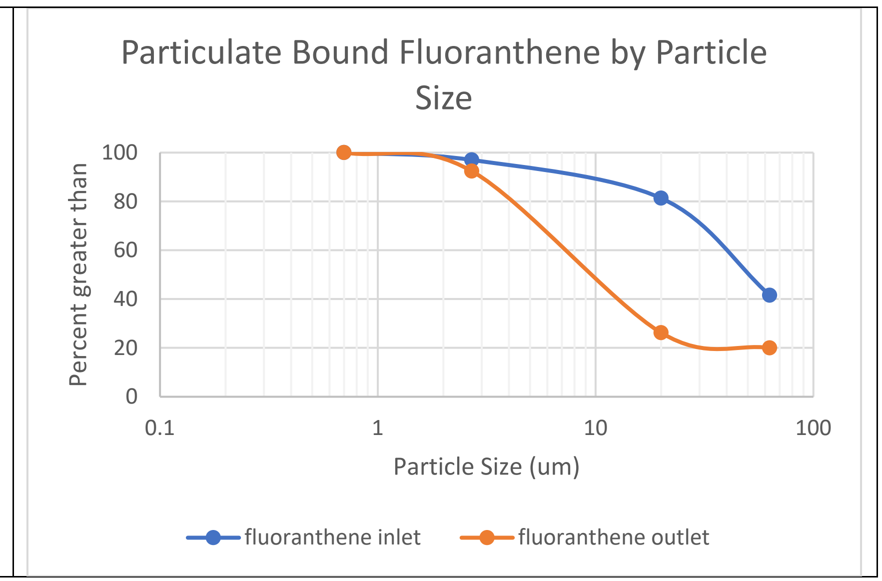


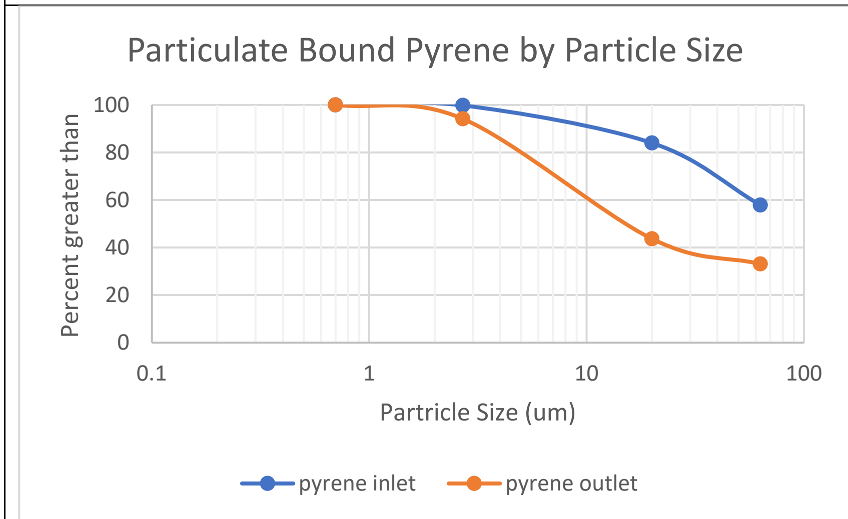


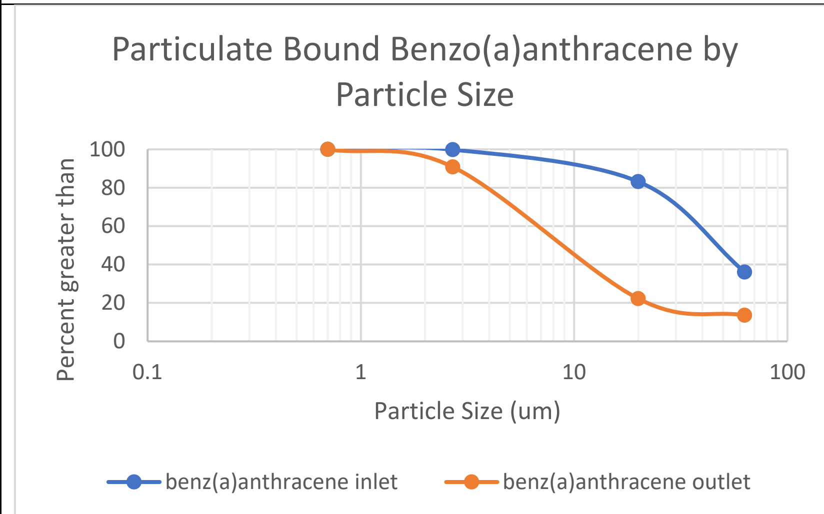

Particulate Bound Phenanthrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
phenanthrene inlet
phenanthrene outlet

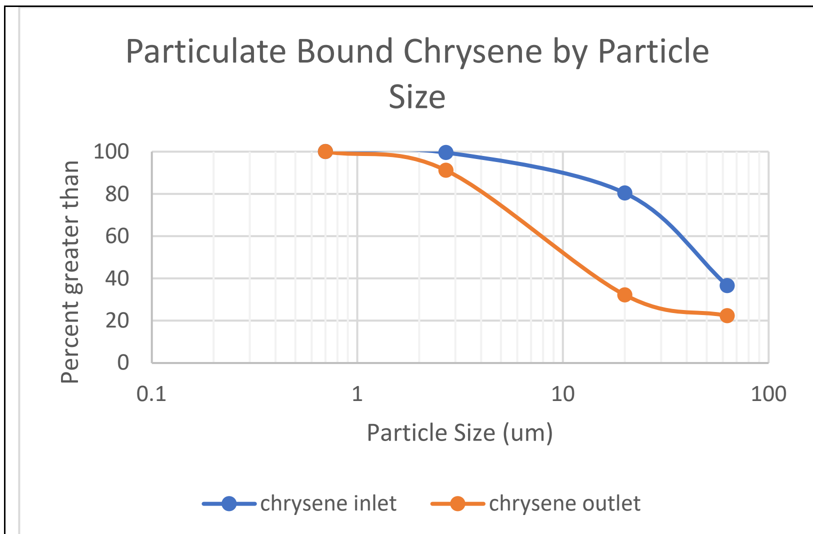

Particulate Bound 2-methylphenanthrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
2-methylphenanthrene inlet
2-methylphenanthrene outlet

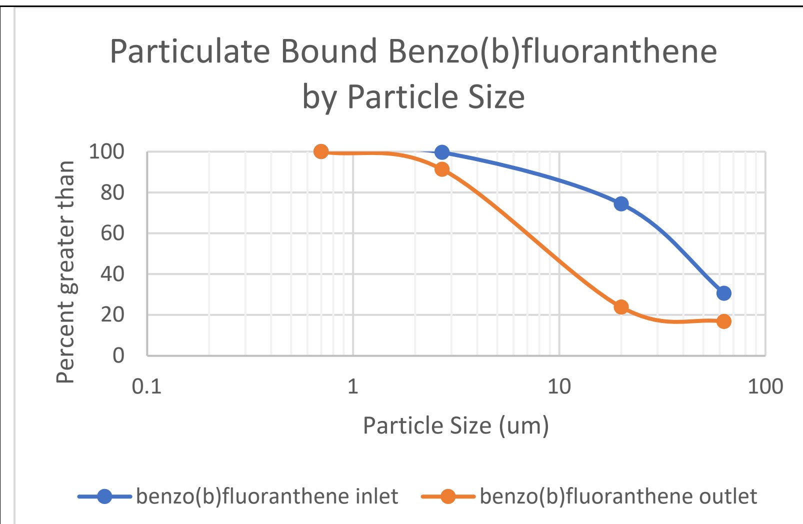

Particulate Bound 1-methylphenanthrene Mass by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
1-methylphenanthrene inlet
1-methylphenanthrene outlet

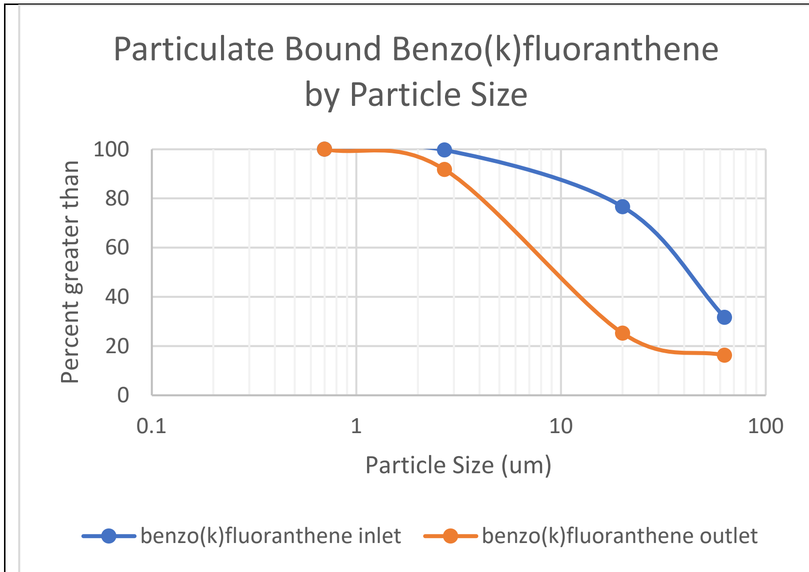

Particulate Bound Fluoranthene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
fluoranthene inlet
fluoranthene outlet

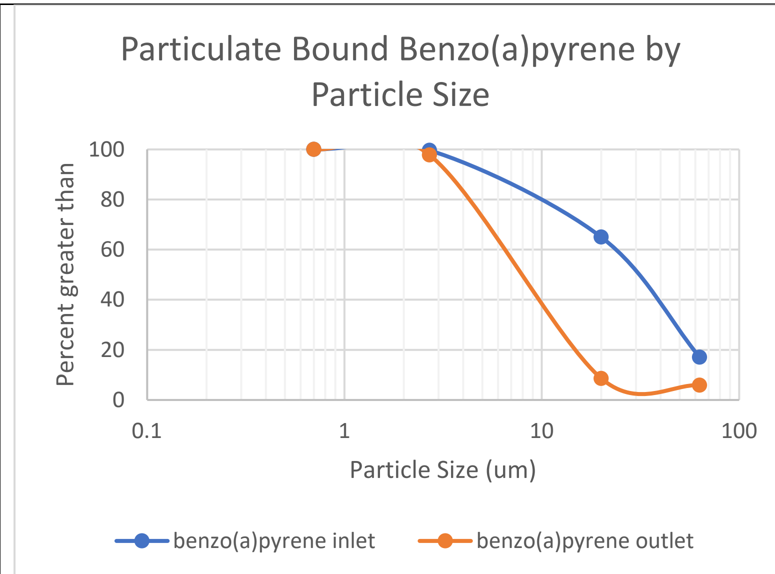

Particulate Bound Pyrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Partricle Size (um)
pyrene inlet
pyrene outlet

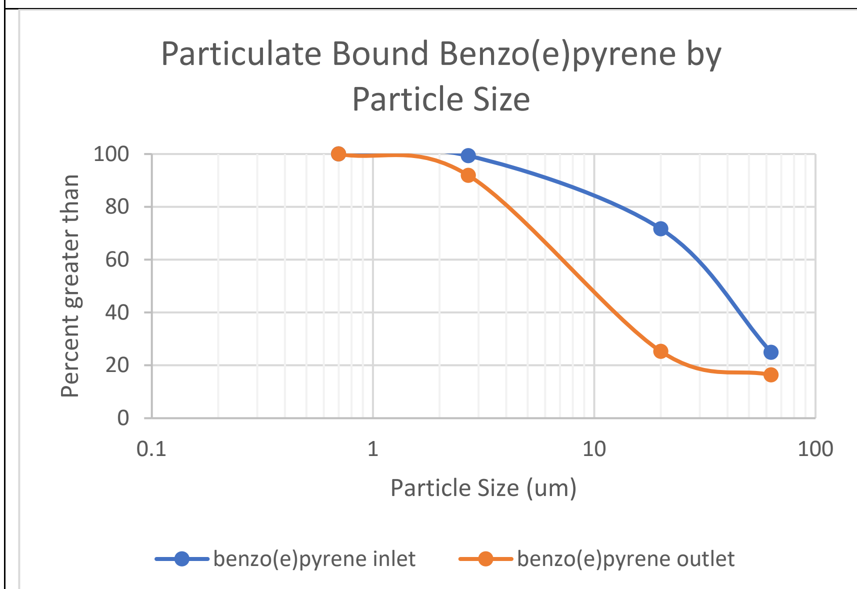

Particulate Bound Benzo(a)anthracene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
benz(a)anthracene inlet
benz(a)anthracene outlet

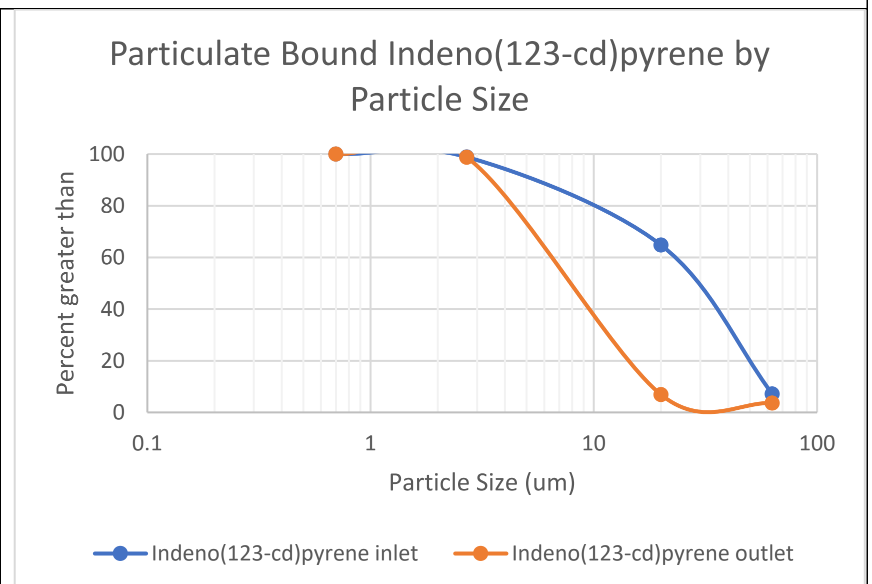

Particulate Bound Chrysene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
chrysene inlet
chrysene outlet

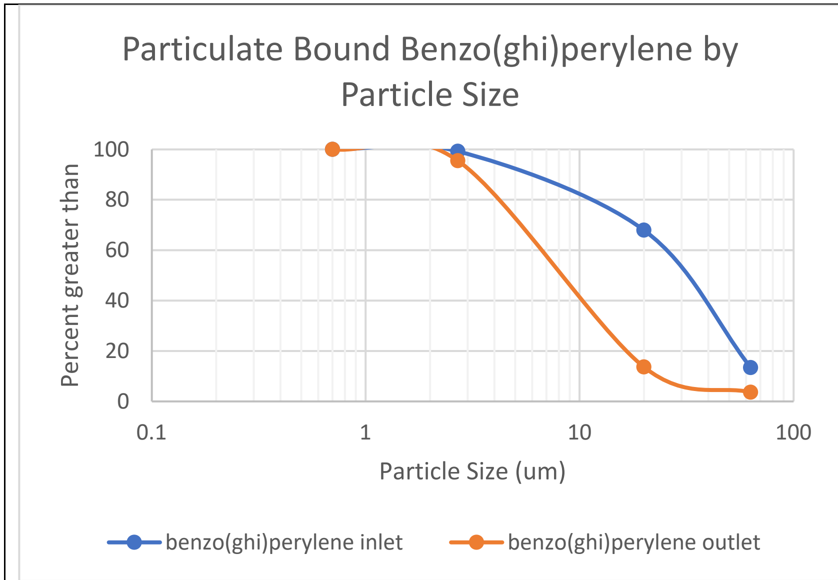

Particulate Bound Benzo(b)fluoranthene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
benzo(b)fluoranthene inlet
benzo(b)fluoranthene outlet

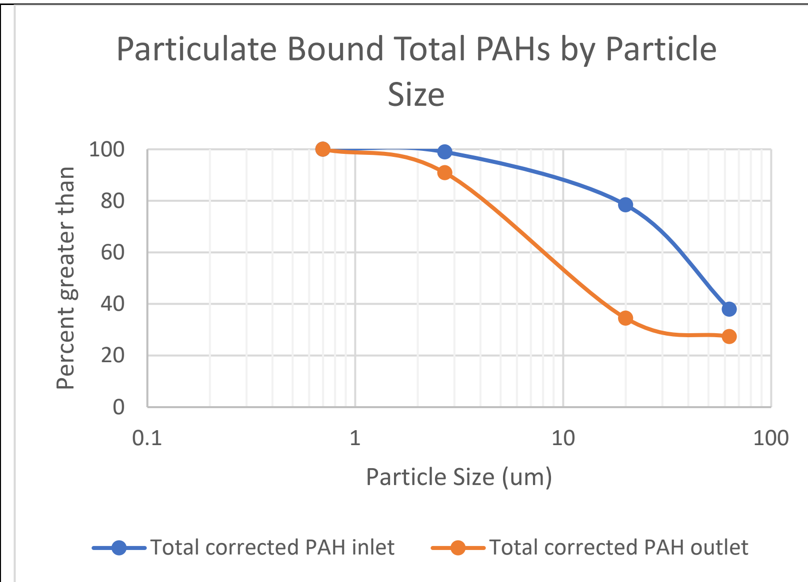

Particulate Bound Benzo(k)fluoranthene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
benzo(k)fluoranthene inlet
benzo(k)fluoranthene outlet


Particulate Bound Benzo(a)pyrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
benzo(a)pyrene inlet
benzo(a)pyrene outlet


Particulate Bound Benzo(e)pyrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
benzo(e)pyrene inlet
benzo(e)pyrene outlet


Particulate Bound Indeno(123-cd)pyrene by Particle Size
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (um)
Indeno(123-cd)pyrene inlet
Indeno(123-cd)pyrene outlet





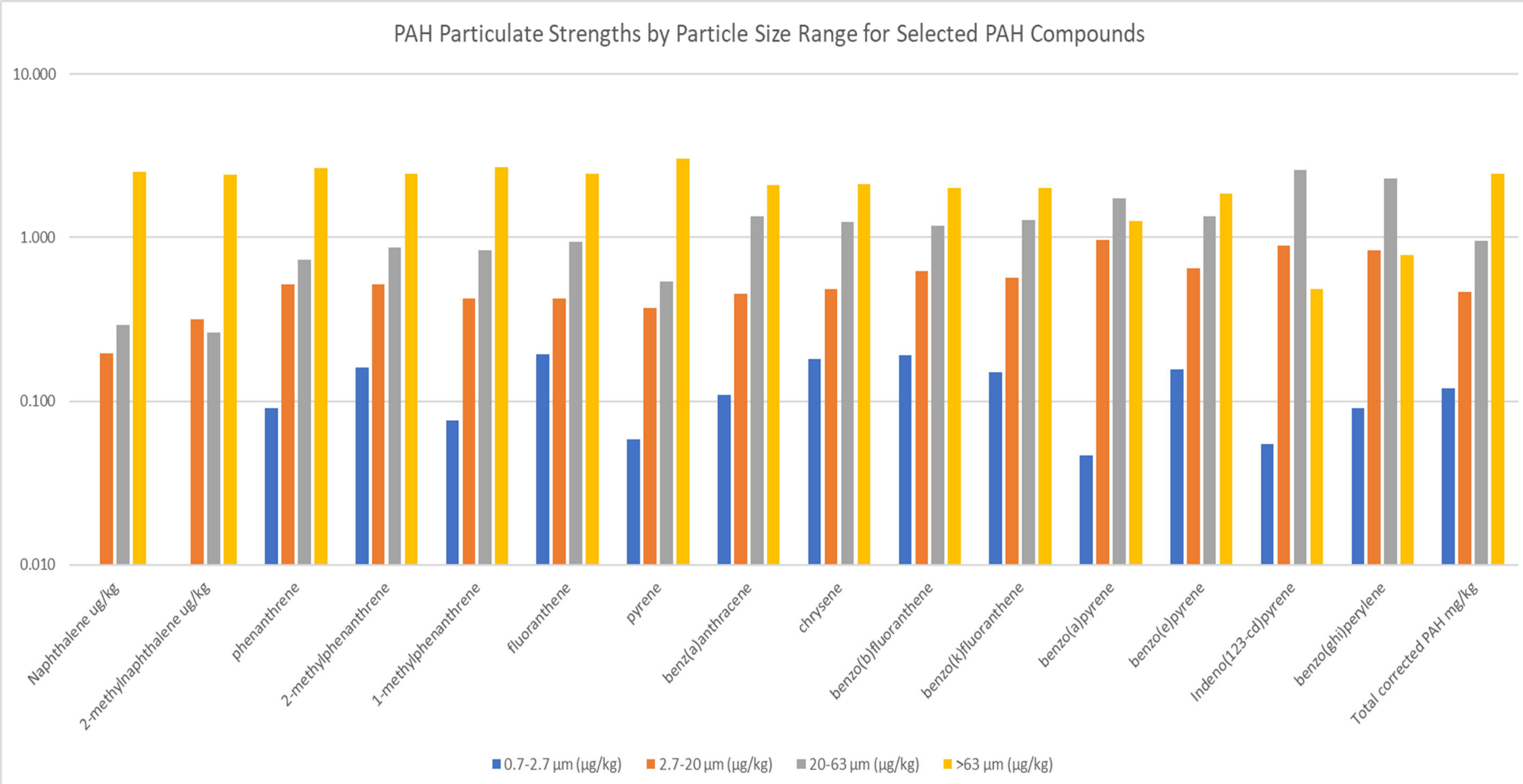
The following tables and figure show the particulate strengths for selected PAHs by particle size. In most cases, the particulate strengths are highest for the largest (>63 µm) particle size range.

Average PAH Particulate Strengths for Inlet and Outlet Samples by Particle Size (µg/kg)

size interval	Naphthalene	2-methylnaphthalene	phenanthrene	2-methylphenanthrene	1-methylphenanthrene	fluoranthene	pyrene	benzo(a)anthracene
0.7-2.7 µm (µg/kg)	n/a	n/a	0.091	0.160	0.076	0.194	0.059	0.110
2.7-20 µm (µg/kg)	0.196	0.318	0.519	0.520	0.422	0.426	0.370	0.453
20-63 µm (µg/kg)	0.290	0.263	0.734	0.869	0.831	0.935	0.539	1.338
>63 µm (µg/kg)	2.514	2.419	2.657	2.451	2.670	2.445	3.032	2.099

Average PAH Particulate Strengths for Inlet and Outlet Samples by Particle Size (µg/kg) (continued)

size interval	chrysene	benzo(b)fluoranthene	benzo(k)fluoranthene	benzo(a)pyrene	benzo(e)pyrene	Indeno(123-cd)pyrene	benzo(ghi)perylene	Total PAH
0.7-2.7 µm (µg/kg)	0.181	0.192	0.151	0.047	0.156	0.055	0.091	0.121
2.7-20 µm (µg/kg)	0.481	0.621	0.564	0.965	0.647	0.894	0.836	0.467
20-63 µm (µg/kg)	1.236	1.171	1.279	1.724	1.345	2.569	2.295	0.958
>63 µm (µg/kg)	2.102	2.016	2.006	1.264	1.852	0.482	0.778	2.454

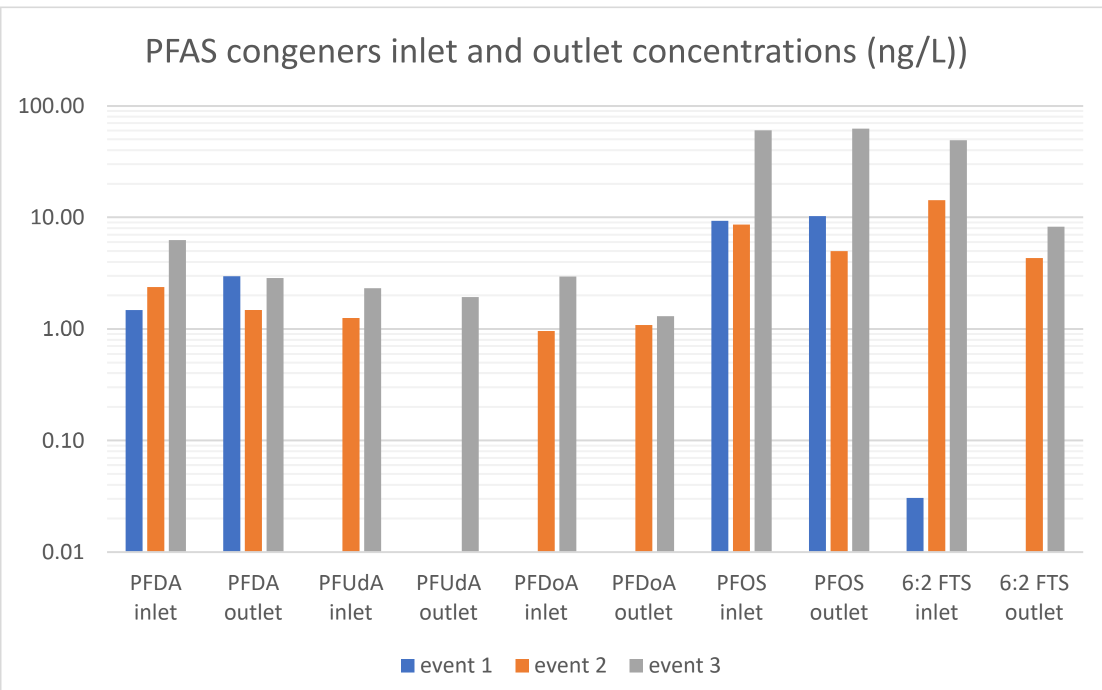

PAH Particulate Strengths by Particle Size Range for Selected PAH Compounds
10.000
1.000
0.100
0.010
Naphthalene ug/kg
2-methylnaphthalene ug/kg
phenanthrene
2-methylphenanthrene
1-methylphenanthrene
fluoranthene
pyrene
benz(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(a)pyrene
benzo(e)pyrene
Indeno(123-cd)pyrene
benzo(ghi)perylene
Total corrected PAH mg/kg
0.7-2.7 µm (µg/kg)
2.7-20 µm (µg/kg)
20-63 µm (µg/kg)
>63 µm (µg/kg)

PFAS

PFAS data were only available for the total samples along with filtered sample and particulate sample fractions. The particulate bound concentrations were too small to analyze for different particle size ranges.

Inlet and Outlet PFAS Concentrations (ng/L)

average if all samples	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUdA	PFDoA	PFBS	PFOS	6:2 FTS
Inlet filtered (<0.7)	n/a	1.48	10.05	4.76	28.98	2.52	2.45	0.91	1.20	n/a	26.39	28.77
inlet particulates (>0.7)	n/a	0.06	0.76	1.30	1.55	0.96	1.86	0.87	0.76	n/a	8.03	2.86
Inlet total sample	3.07	1.53	8.58	4.63	21.12	2.66	3.36	1.79	1.96	n/a	26.06	21.10
outlet filtered (<0.7)	n/a	2.73	3.23	1.46	14.87	1.89	1.47	0.23	0.61	2.23	16.25	8.44
outlet particulates (>0.7)	n/a	-0.35	0.12	0.12	1.31	0.25	0.70	1.46	0.58	-1.41	17.46	-2.16
Outlet total sample	2.47	2.59	3.86	1.60	11.62	1.83	2.44	1.92	1.19	0.82	25.89	6.28
inlet percentage filtered	n/a	96.25	117.02	102.73	137.24	94.62	72.94	51.13	61.38	n/a	101.28	136.39
inlet percentage particulates	n/a	3.75	-17.02	-2.73	-37.24	5.38	27.06	48.87	38.62	n/a	-1.28	-36.39
outlet percentage filtered	n/a	105.39	83.70	91.25	127.91	103.25	60.43	12.10	51.49	n/a	62.76	134.36
outlet percentage particulates	n/a	-5.39	16.30	8.75	-27.91	-3.25	39.57	87.90	48.51	n/a	37.24	-34.36



The following table summarizes the Commissary bioinfiltration system removals of the PFAS compounds for the total samples, along with the filtered and particulate sample fractions. The removal performance was highly variable, as also illustrated in the above plot of inlet vs. outlet concentrations.

PFAS Removals (percentage)

average if all samples	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUdA	PFDoA	PFBS	PFOS	6:2 FTS
Total sample percentage reduction	19.30	-68.90	55.07	65.47	44.96	31.28	27.53	-7.80	39.16	n/a	0.63	70.22
particulate percentage reduction	n/a	710.68	84.68	91.03	15.54	73.69	62.22	-67.24	23.57	n/a	-117.48	175.62
Filtered percentage reduction	n/a	-84.95	67.87	69.33	48.70	25.01	39.96	74.50	48.97	n/a	38.42	70.66

The following table shows the calculated particulate strengths for the PFAS compounds for the total particulate fractions of the samples. These are averages of all detected inlet and outlet samples combined.

Selected PFAS Particulate Strengths for Observed Inlet and Outlet Samples Combined

overall PFAS particulate strengths (µg/kg)	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUdA	PFDoA	PFOS	6:2 FTS
detected only	11.5	2.1	21.5	3.8	11.3	11.8	6.8	189.5	31.3

Comparisons with Historical Monitoring Data

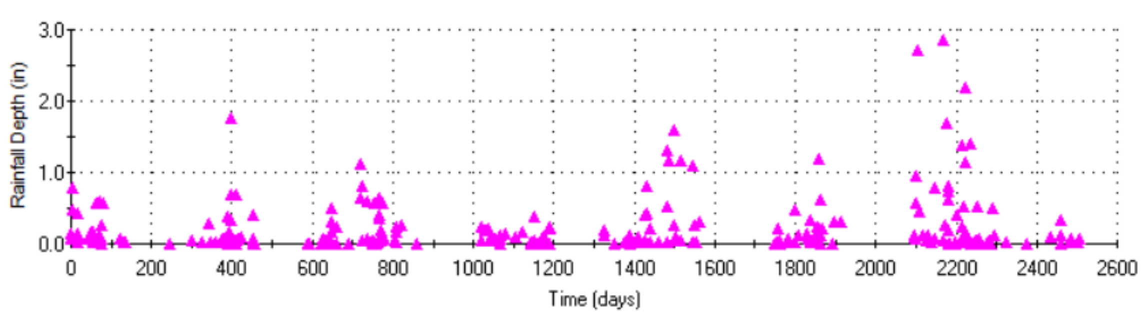
The following table compares the historical stormwater data for NBSD commercial areas as summarized by Katz, *et al*. (2018) with the average concentrations observed at the Commissary location for TSS, copper, lead, and zinc. The averages of the three inlet samples were mostly within the range of the prior observed values. The recent TSS values were slightly larger than the prior maximum observed TSS concentration. The recent metal concentration data were within the range of the prior observed values.

Comparisons of Recent Commissary Inlet TSS and Metal Concentrations with Prior Data

	historical data (9 reference samples)			Commissary Location (average of 3 inlet samples)
	average	minimum	maximum	
TSS, mg/L	58	23	104	116
total Cu, µg/L	258	29	711	548
filt Cu, µg/L	100	10	330	266
partic Cu, µg/L	158	13	544	282
% filterable Cu	46	16	94	49
% partic. Cu	54	6	84	51
overall partic strgth Cu, mg/kg	2,100	325	5,551	1,132
total Pb, µg/L	7.1	0.5	20.0	12.4
filt Pb, µg/L	2.2	1.0	5.0	1.1
partic Pb, µg/L	4.7	1.0	19.0	11.3
% filterable Pb	36	5	73	9
% partic. Pb	64	27	95	91
overall partic strgth Pb, mg/kg	104	23	250	76
total Zn, µg/L	226	80	472	538
filt Zn, µg/L	123	45	205	314
partic Zn, µg/L	104	20	267	225
% filterable Zn	61	37	90	58
% partic. Zn	39	10	63	42
overall partic strgth Zn, mg/kg	1,582	377	3,513	1,202

Preliminary WinSLAMM Modeling

The following scatterplot shows the rain pattern used in the preliminary WinSLAMM calculations for the Commissary bioinfiltration system. The seven years of data (from 1/20/1999 to 12/2/2005) included 248 rains that ranged from 0.01 to 2.85 inches (0.25 in average; 60.97 inches total).



The following discussion, from the prior Commissary modeling report prepared for the Navy, summarizes how bioinfiltration system are evaluated in WinSLAMM.

Biofilters/bioinfiltration systems are similar in function to rain gardens but have more complex cross-sections with increased water volume storage that enhances their performance. They are excavations to collect runoff and allow infiltration. They are usually filled with a rock storage layer, a media treatment layer, and most have underdrains to prevent excessive ponding for extended times. Because of the increased amount of storage compared to a simple rain garden, bioinfiltration system can better handle short periods of increased rainfall and larger amounts of runoff.

Bioinfiltration system performance is based on the characteristics of the flow entering the device, the infiltration rate into the native soil, the filtering capacity and infiltration rate of the engineered media fill if used, the amount of rock fill storage, the size of the device and the outlet structures for the device. Pollutant filtering by the engineered media (usually containing amendments) is based on the engineered media type and the particle size distribution of the particulates in the inflowing water. If the engineered media flow rate is lower than the flow rates entering the device, the engineered media will affect the device performance by forcing the excess water to bypass the device through surface discharges, if the storage capacity above the engineered media is inadequate.

The device operation is modeled using the Modified Puls Storage-Indication method and is analyzed differently depending on whether rock and engineered media layers are in the model. The model simulates the inflow and outflow hydrographs using a time interval selected by the user (typically 6 minutes), although this interval is reduced automatically by the program if the simulation calculations approach becoming unstable.

The inflow hydrograph is divided into the selected time intervals, which are routed to the surface of the bioinfiltration system. The bioinfiltration system is evaluated in two basic sections: the above-ground section (or above the engineered media) and the below-ground section (below the surface of the engineered media). If there is a rock layer and an engineered media layer, separate details are entered for each. The available surface outflow devices include broad crested weirs (required to have at least one as the surface overflow outlet), and optional crested weirs, vertical standpipes, and evaporation/ET. An underdrain is also optional that discharges back to the drainage system (but with “filtered” water).

As water enters the device, the water infiltrates through the media to the below-ground section if the engineered media infiltration rate is greater than the inflowing water rate. If the inflow rate increases to be greater than the media infiltration rate, the above-ground storage begins to fill. If the inflowing rate is high enough and the excess runoff volume exceeds the available storage, the water discharges from the device through the above-ground surface broad crested weir outflow, and any other surface outlet. As water enters the below-ground section of the device, it passes through the native soil and, as the bottom section fills, it may enter an underdrain (if used). All water that flows through the underdrain is assumed to be filtered by the engineered media. The filtering performance changes based on the type of engineered media and varies by the particle size of the particulates in the water. If the water level in the below-ground section of the device reaches the top of the engineered media layer, infiltration from the surface layer into the below-ground layer stops until the water level in the below-ground section is below the top of the engineered media layer. If there are no rock and engineered media layers, flow into the native soil is considered to be an outflow: there is no below-ground section, and all treatment by the device is assumed to be through volume loss by infiltration into the native soil (this is the typical way rain gardens operate, since they have no media or underdrain, but do have surface storage).

The following figures are the data entry forms used for bioinfiltration systems. To model bioinfiltration systems, the geometry and other characteristics of the bioinfiltration system are described, or of a typical bioinfiltration system if modeling a set of bioinfiltration systems for, say, roofs or parking lot source areas. The number of bioinfiltration systems to be modeled in the source area is also entered on the form. The model divides the total source area runoff volume by the number of bioinfiltration systems in the source area, creates a complex triangular hydrograph for that representative flow fraction that is then routed through that bioinfiltration system. It then multiplies the resulting runoff pollutant and flow reductions by the number of bioinfiltration systems for the total source area effects.

Device Geometry:

Top Area (square feet): Enter the top area of the bioinfiltration system

Bottom Area (square feet): Enter the bottom area of the bioinfiltration system

Total Depth (feet): Enter the depth of the bioinfiltration system.

Typical Width (ft): If you intend to perform a cost analysis of the bioinfiltration system practices listed in the .mdb file, you must enter the typical bioinfiltration system width (ft) of a bioinfiltration system you are modeling. This value is not used for a hydraulic or water quality analysis; it is relevant only for the cost analysis.

Native Soil Infiltration Rate (in/hr): Enter the infiltration rate or select a typical infiltration rate based on soil type from the provided list in the lower left-hand corner of the window. The native soil infiltration rate value is supplied if you select the typical seepage rate provided by the model.

Native Soil Infiltration Rate COV (Coefficient of Variation): If you want to consider the typical variabilities in the infiltration rates, select the "Use Random Number Generation to Account for Uncertainty in Infiltration Rate" checkbox and then accept or enter another seepage rate COV value in the cell below the native soil infiltration rate. This is optional and uses a Monte Carlo simulation built into the model. If selected, the infiltration rates are randomly varied for each event based on a log-normal probability distribution of actual measured infiltration rate variabilities.

Infiltration Rate Fraction - Bottom (0-1): Enter the seepage rate multiplier for bottom flow (from 0 to 1) to reduce the seepage rate through the bottom of the bioinfiltration system. This option can be useful if you want to evaluate the effects of complete clogging on the bottom of the device.

Infiltration Rate Fraction - Side (0-1): Enter the seepage rate multiplier for side flow (from 0 to 1) to reduce the seepage rate through the sides of the bioinfiltration system. This option can be useful if you want to ignore the benefits of seepage out of the sides of the device, as required by some regulatory agencies.

Rock Filled Depth (ft): This is the depth of the bioinfiltration system that is rock filled. This must be less than or equal to the bioinfiltration system depth and may be zero if there is no rock fill. Water is assumed to flow through the rock storage layer very quickly.

Rock Fill Porosity: Enter the fraction of rock fill that is voids as a value from zero to one. If you have both rock fill and engineered soil, the model sums the total pore volume available in the bioinfiltration system. If you are using an underdrain, a rock storage layer will be required (and the underdrain is usually located near the top of this storage layer but can be at the bottom if there is no natural infiltration, or for a sealed system).

Engineered Media Type. If the device has an engineered soil layer, the program uses an infiltration rate depending on the type of engineered media, based on extensive media tests in laboratory columns and in the field. Select the 'Media Data' button to enter media type information including the media porosity, infiltration rate, field moisture capacity and permanent wilting point.

Engineered Media Infiltration Rate (in/hr): If you have selected a specific engineered media type, the program uses an infiltration rate for that media type, or if you selected a user defined media type, you may enter your own engineered media infiltration rate.

Engineered Media Depth (ft). This must be less than or equal to the bioinfiltration system depth and may be zero if there is no engineered media fill.

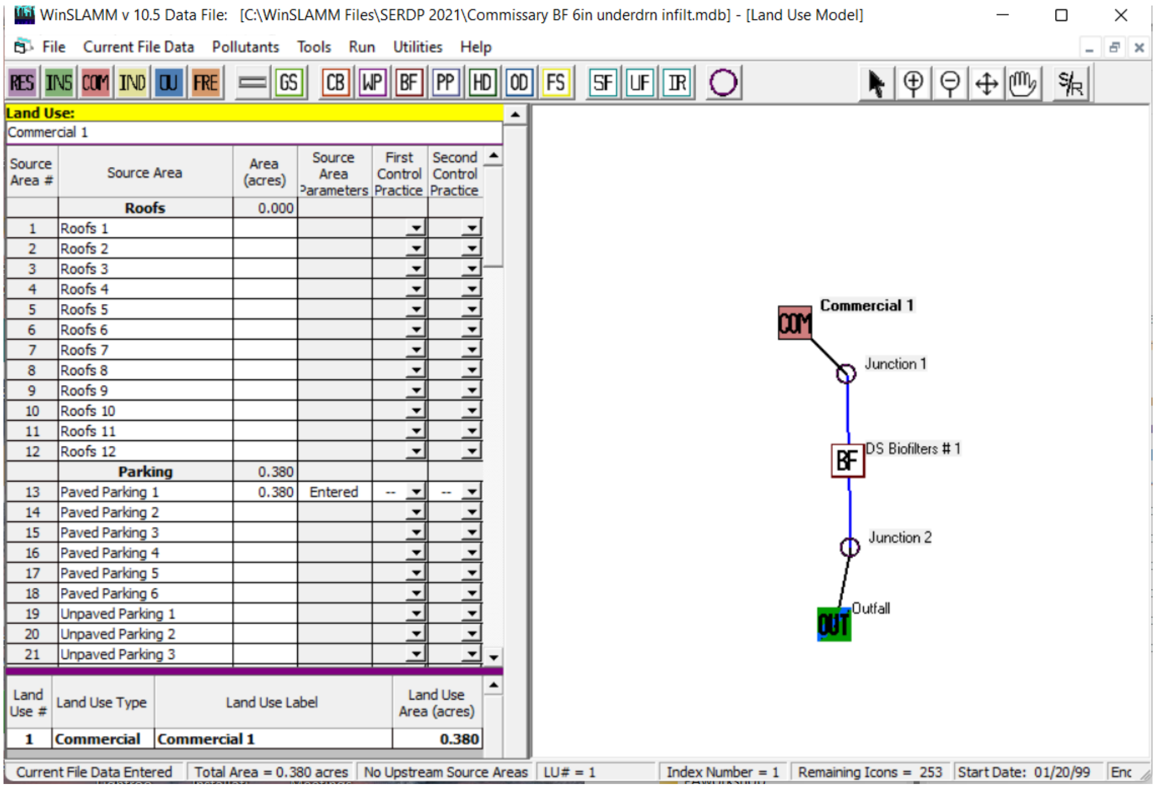
Engineered Media Porosity (0-1): This is the fraction of engineered media that is voids - enter the porosity of the engineered media as a value from zero to one. If you have both rock fill and engineered media, the model sums the total pore volume from all layers.

Inflow Hydrograph Peak Flow to Average Flow Ratio. This value is used to determine the shape of the complex triangular unit hydrograph that is routed through the device. A typical value of the peak to average flow ratio is 3.8. However, short duration events in small areas may have larger ratios and similarly, long duration events in large areas may have smaller ratios. In version 10 and later, the routed hydrograph from upgradient areas and controls is used instead of setting this value to 3.8.

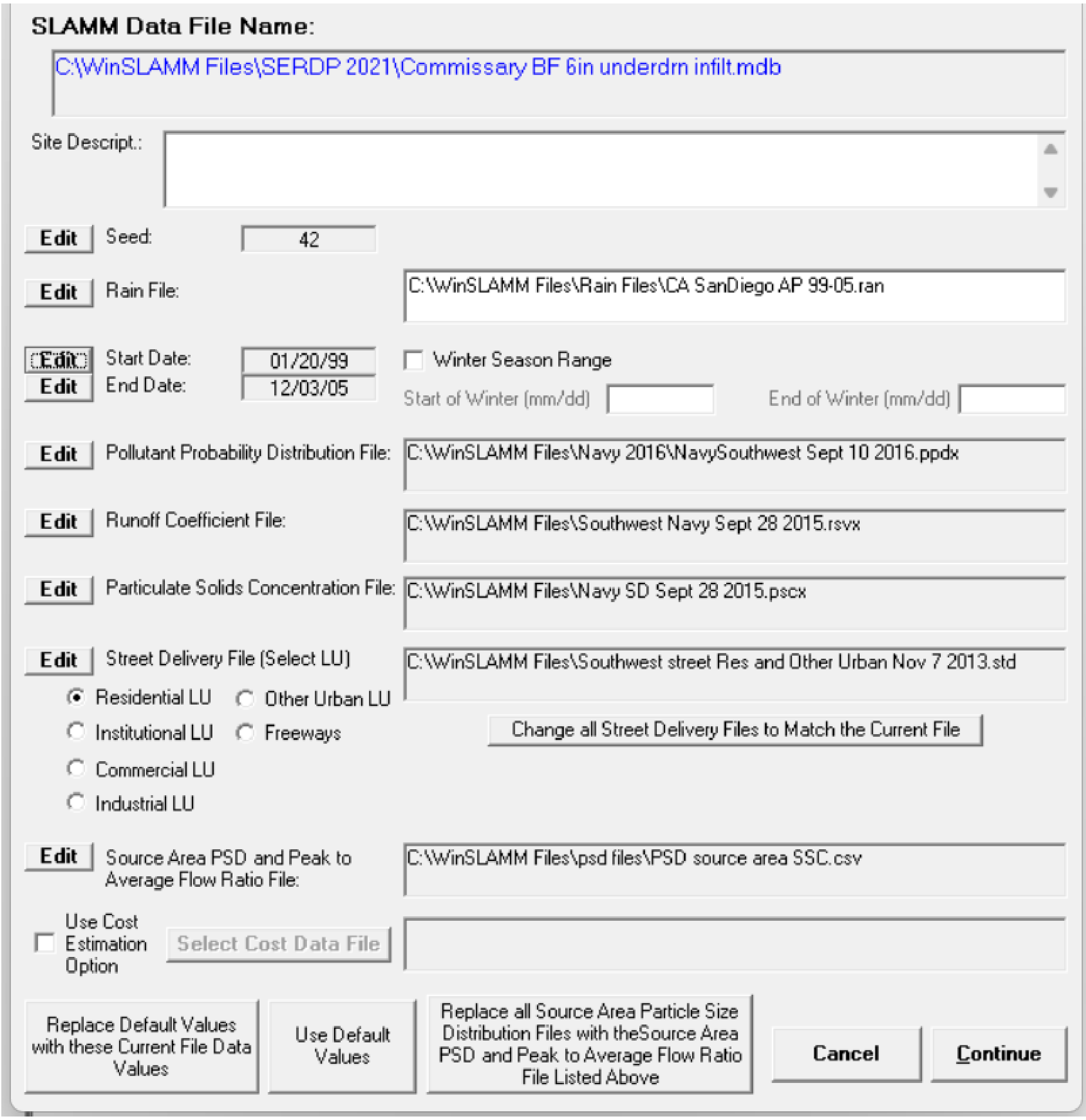
Number of Devices in the Source Area or Upstream Drainage System (all assumed to be similar with similar drainage areas, otherwise enter them separately). The model divides the runoff volume by the number of bioinfiltration systems in the source area or land use, creates a complex triangular hydrograph that it routes through that bioinfiltration system, and then multiplies the resulting losses by the number of bioinfiltration systems to apply the results to the source area.

Particle Size Distribution File. The particle size distribution of the particulates in the runoff affects the percent solids reduction of the engineered media layer. If you select the 'Route Hydrographs and Particle Sizes between Control Devices' checkbox in Program Options/Default Model Options (recommended), the program uses the routed particle size distributions from upgradient source areas. The particle size distribution entering the control device is modified by whatever practices are upstream of the control practice. If the practice is the most upstream practice, the initial particle size distribution is used.

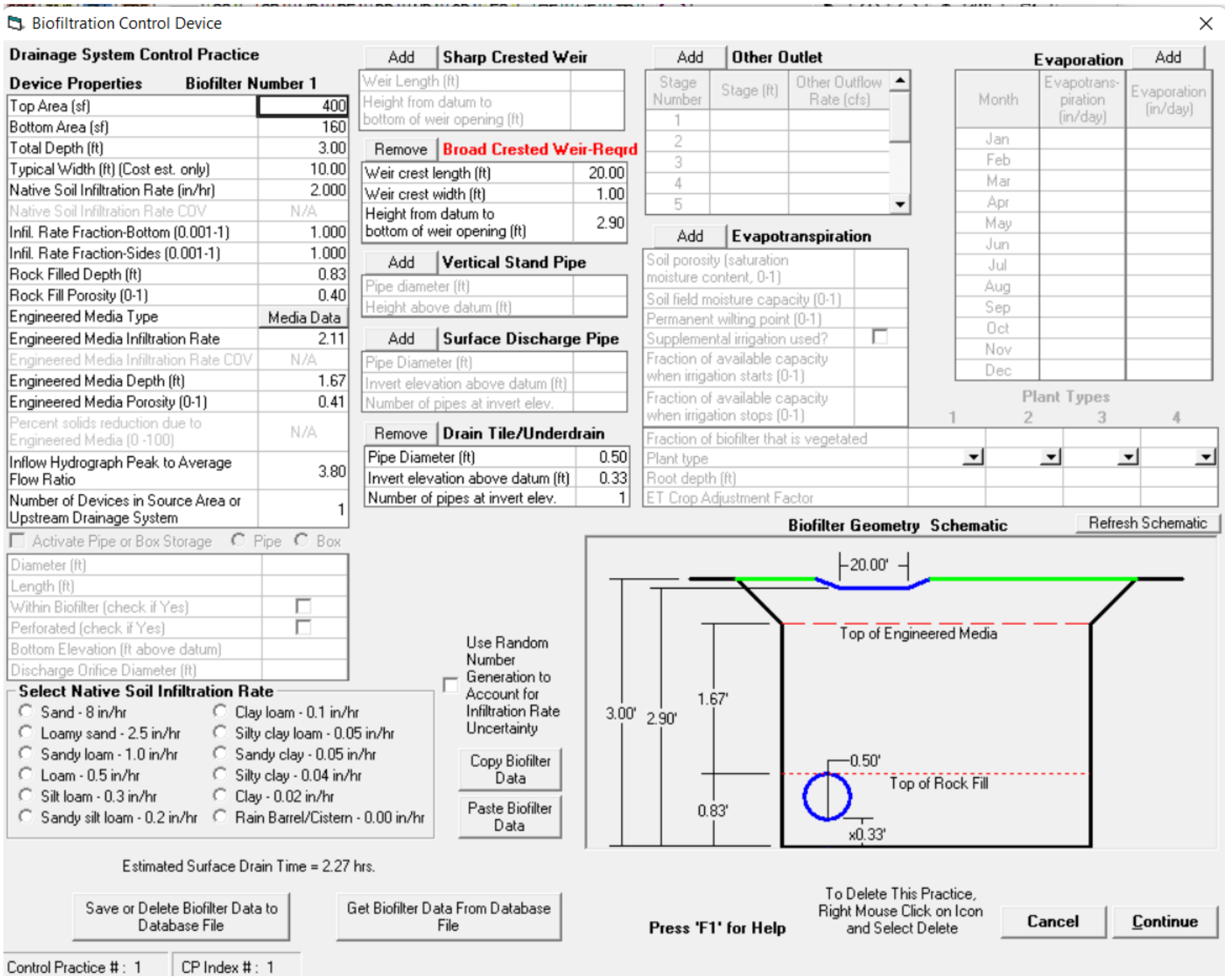
The following screen images show the various WinSLAMM forms used for the Commissary bioinfiltration system analysis.



Layout of stormwater system from 0.38 ac paved parking source area, the bioinfiltration system, and the outfall.

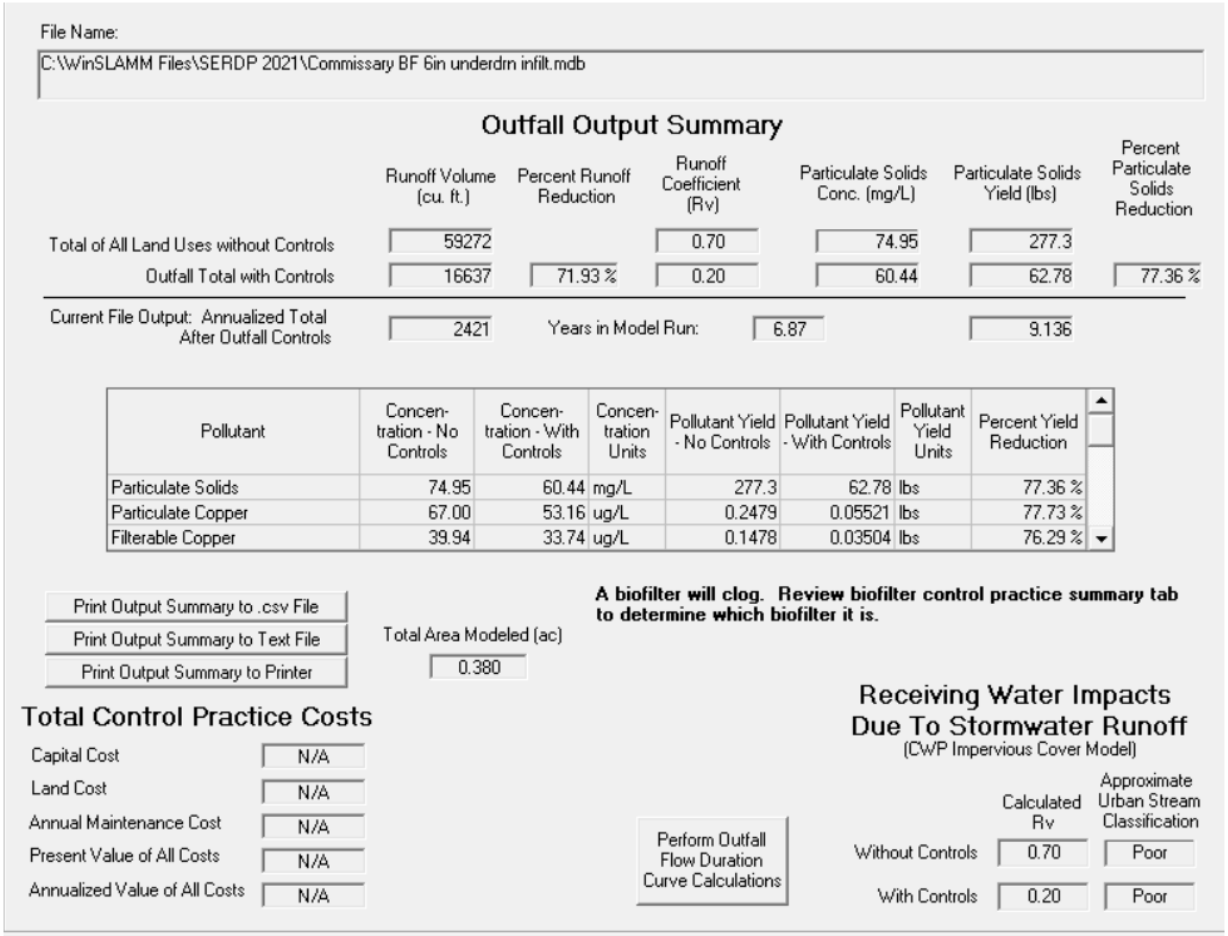


Parameter files used for Naval Base San Diego evaluations from prior Navy project.



Bioinfiltration system form showing cross-section with entered dimensions.

The following form shows the modeled results (more detailed results are available with other output options). Besides the influent and effluent concentration changes with treatment, the model analysis also indicated about 70% reductions in runoff volume, the main purpose of bioinfiltration systems. The mass reductions associated with the bioinfiltration system are the joint reductions associated with concentrations and the runoff volume. As an example, while the TSS concentrations were only reduced from about 75 to 60 mg/L (20% reduction), the TSS mass reductions were about 77%.



File Name:

C:\WinSLAMM Files\SERDP 2021\Commissary BF 6in underdrn infilt.mdb

Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	59272		0.70	74.95	277.3	
Outfall Total with Controls	16637	71.93 %	0.20	60.44	62.78	77.36 %
Current File Output: Annualized Total After Outfall Controls	2421	Years in Model Run:	6.87		9.136	

Pollutant	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Solids	74.95	60.44	mg/L	277.3	62.78	lbs	77.36 %
Particulate Copper	67.00	53.16	ug/L	0.2479	0.05521	lbs	77.73 %
Filterable Copper	39.94	33.74	ug/L	0.1478	0.03504	lbs	76.29 %

Print Output Summary to .csv File

Print Output Summary to Text File

Print Output Summary to Printer

Total Area Modeled (ac): 0.380

A biofilter will clog. Review biofilter control practice summary tab to determine which biofilter it is.

Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

Perform Outfall Flow Duration Curve Calculations

Receiving Water Impacts Due To Stormwater Runoff

(CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.70	Poor
With Controls	0.20	Poor

Model output summary form after analysis.

Land Uses | Junctions | Control Practices | Outfall

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L)

Data File: C:\WinSLAMM Files\Srn infilt.mdb											
Rain File: CA SanDiego AP 99-05											
Date: 09-22-22 Time: 10:56:19 F											
Site Description:											
Col. #:	2	4	5	6	7	8	9	10	11	12	13
Control Practice No.	Control Practice Type	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Total Influent Load (lbs)	Total Effluent Load (lbs)	Percent Load Reduction	Flow Weighted Influent Conc (mg/L)	Flow Weighted Effluent Conc (mg/L)	Percent Conc. Reduction	Influent Median Part. Size (microns)
1	Biofilter	59272	16637	71.93	277.3	62.77	77.36	74.95	60.44	19.365	40.00

Land Uses | Junctions | Control Practices | Outfall | Output Summ

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | Summary Table

Data File: C:\WinSLAMM Files\S												
Rain File: CA SanDiego AP 99-05												
Date: 09-22-22 Time: 10:56:19 F												
Site Description:												
Col. #:	2	14	15	18	19	23	27	28	29	30	31	32
Control Practice No.	Control Practice Type	Effluent Median Part. Size (microns)	Notes	Maximum Stage (ft)	Hydraulic Volume Out (cf)	Treated Volume (cf)	Maximum Surface Ponding Time (hrs)	Maximum Subsurface Ponding Time (hrs)	Volume Infiltrated (cf)	Underdrain Discharge Vol. (cf)	Evapo-Transpir. Vol. (cf)	Minimum Soil Moist. (frac)
1	Biofilter	40.00	No Biofilter Overflows	2.92	16634	42638	38.0	6.85	42526.68	0		

Land Uses | Junctions | Control Practices | Outfall | Output Summary

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | Summary Table

Data File: C:\WinSLAMM Files\S													
Rain File: CA SanDiego AP 99-05													
Date: 09-22-22 Time: 10:56:19 F													
Site Description:													
Col. #:	2	33	34	35	36	39	54	61	62	63	64	65	91
Control Practice No.	Control Practice Type	Surface Discharge Bypass Vol. (cf)	Evap. Vol. (cf)	Volume Supplemtl. Irrig.(cf)	Final Surface Infiltration Rate (in/hr)	Surface Ponding Events >72 hrs (Count)	Residence Time in Media (hrs)	Ttl. Mass Trapped in Media (lbs)	Ttl. Mass Infiltrated (lbs)	Annual Allowable Clog Rate (lbs/yr)	First Year Cum. Load (lbs)	Time Until Clogging Failure (yrs)	Runoff Producing Events/ Ttl. Rains
1	Biofilter	16633.96			0.941	0	8.74	197.96	385.15	0.223	0.159	14.07	48/248

Additional control practice performance information (bioinfiltration system results shown).

The following table compares the modeled concentrations with the recent monitored results. The observed values were higher than the modeled results for the influent concentrations for TSS, filtered copper and total copper concentrations. The other observed concentrations were within the calculated range.

Comparisons of Modeled Concentrations with SERDP Monitored Concentrations

	Influent min conc	Influent max conc	Influent average conc	Observed SERDP monitoring (average of 3 inlet samples)
TSS, mg/L	47	115	75	116
Cu filtered, ug/L	7.7	186	40	266
Cu particulate, ug/L	6.2	404	67	282
Cu total, ug/L	29	437	107	548
Pb filtered, ug/L	0.6	3.9	1.5	1.1
Pb particulate, ug/L	6.7	91	23	11.3
Pb total, ug/L	8.4	94	24	12.4
Zn filtered, ug/L	8.6	1,360	302	314
Zn particulate, ug/L	106	1,684	383	225
Zn total, ug/L	174	2,212	685	538

Characteristics Affecting Fate and Transport

The following tables show the amounts of TSS, heavy metals, and PAHs associated with the particle size ranges related to near field, far field, and widely dispersed expected conditions. None of the outlet conditions show large (>70%, high-lighted in yellow on the tables) fractions of the pollutants associated with possible near-field deposition, while many of the metals and PAHs would likely have most of their mass widely dispersed upon discharge, depending on water depth and velocities.

TSS and Metal Fates after Discharge for Untreated Samples

inlet	TSS inlet	Chromium inlet	Manganese inlet	Nickel inlet	Copper inlet	Zinc inlet	Arsenic inlet	Cadmium inlet	Lead inlet	Mercury inlet
>63 µm (near field)	10.9	16.4	30.3	23.8	31.4	37.7	24.5	31.4	16.6	28.0
20 to 63 µm (far field)	36.4	50.3	43.1	36.0	39.4	43.3	47.6	17.7	26.3	31.3
<20 µm (widely dispersed)	52.8	33.3	26.6	40.2	29.3	19.0	27.9	50.9	57.1	40.7

TSS and Metal Fates after Discharge for Treated Samples

outlet	TSS outlet	Chromium outlet	Manganese outlet	Nickel outlet	Copper outlet	Zinc outlet	Arsenic outlet	Cadmium outlet	Lead outlet	Mercury outlet
>63 µm (near field)	0.6	0.0	3.3	0.0	0.0	2.1	6.3	n/a	0.4	8.3
20 to 63 µm (far field)	2.5	1.7	4.8	2.2	0.0	0.8	12.6	n/a	3.5	1.9
<20 µm (widely dispersed)	96.9	98.3	91.9	97.8	100.0	97.0	81.0	n/a	96.1	89.8

PAH Fates after Discharge for Untreated Samples

inlet	Naphthalene inlet	2-methylnaphthalene inlet	phenanthrene inlet	2-methylphenanthrene inlet	1-methylphenanthrene inlet	fluoranthene inlet	pyrene inlet	benzo(a)anthracene inlet
>63 µm (near field)	61.5	40.0	42.2	35.4	35.0	41.6	57.8	36.1
20 to 63 µm (far field)	28.4	38.2	37.0	42.6	44.1	39.7	26.2	47.2
<20 µm (widely dispersed)	10.2	21.8	20.8	22.0	20.9	18.7	16.0	16.8

PAH Fates after Discharge for Untreated Samples (continued)

inlet	chrysene inlet	benzo(b)fluoranthene inlet	benzo(k)fluoranthene inlet	benzo(a)pyrene inlet	benzo(e)pyrene inlet	Indeno(123-cd)pyrene inlet	benzo(ghi)perylene inlet	PAH inlet
>63 µm (near field)	36.5	30.6	31.6	17.1	24.9	7.2	13.4	37.9
20 to 63 µm (far field)	43.9	43.8	45.0	47.9	46.7	57.6	54.5	40.5
<20 µm (widely dispersed)	19.6	25.7	23.4	35.0	28.4	35.2	32.0	21.6

PAH Fates after Discharge for Treated Samples

outlet	Naphthalene outlet	2-methylnaphthalene outlet	phenanthrene outlet	2-methylphenanthrene outlet	1-methylphenanthrene outlet	fluoranthene outlet	pyrene outlet	benzo(a)anthracene outlet
>63 um (near field)	48.4	29.3	43.4	37.9	48.4	20.0	33.1	13.5
20 to 63 um (far field)	6.6	2.5	5.4	3.8	3.0	6.3	10.5	8.7
<20 um (widely dispersed)	44.9	68.2	51.2	58.3	48.6	73.8	56.4	77.8

PAH Fates after Discharge for Treated Samples (continued)

outlet	chrysene outlet	benzo(b)fluoranthene outlet	benzo(k)fluoranthene outlet	benzo(a)pyrene outlet	benzo(e)pyrene outlet	Indeno(123-cd)pyrene outlet	benzo(ghi)perylene outlet	PAH outlet
>63 µm (near field)	22.3	16.8	16.2	5.9	16.3	3.6	3.6	27.3
20 to 63 µm (far field)	9.8	7.0	9.0	2.7	8.9	3.2	10.0	7.2
<20 µm (widely dispersed)	67.8	76.2	74.8	91.4	74.7	93.1	86.4	65.5