BMP EFFECTIVENESS INVESTIGATION AT BRANSTEN ROAD, CITY OF SAN CARLOS

Prepared in support of provision C.8.d.ii of
NPDES Permit # CAS612008

Report

San Mateo Countywide Water Pollution Prevention Program

March 31, 2016

TABLE OF CONTENTS

FIGURES

TABLES

1.0 Introduction

Provision C.8.d.ii (BMP Effectiveness Investigation) of the San Francisco Bay Region National Pollutant Discharge Elimination System (NPDES) Municipal Regional Permit (MRP) for discharges of stormwater runoff requires that Permittees investigate the effectiveness of one best management practice (BMP) for stormwater treatment or hydrograph modification control. The MRP encourages fulfillment of the requirement via investigation of BMP(s) used to fulfill requirements of Provisions C.3.b.iii, C.11.e, and C.12.e, provided the BMP Effectiveness Investigation includes the range of pollutants generally found in urban runoff.

The San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) selected a bioretention/biofiltration facility in the City of San Carlos as the subject of the BMP Effectiveness Investigation (BMP Project). The BMP Project was coordinated with an existing study that is part of the U.S. EPA grant-funded Clean Watersheds for a Clean Bay (CW4CB) project currently being implemented by the Bay Area Stormwater Management Agencies Association (BASMAA). The CW4CB project was designed to pilot test a number of different control measures aimed at reducing polychlorinated biphenyls (PCBs) and mercury in stormwater runoff from urban areas pursuant to MRP Provisions C.11 and C.12. Additional constituents generally found in stormwater runoff (e.g., nutrients, cadmium, chromium, copper, nickel, zinc) were added by SMCWPPP to supplement the CW4CB investigation.

Results from the supplemental data collection are presented in this report, which is intended to satisfy requirements in Provision C.8.d.ii of the MRP. Monitoring results from the CW4CB project are scheduled to be reported separately in the future.

2.0 Background

In November 2013, the City of San Carlos constructed seven bioretention/biotreatment curb extension facilities (or cells) along a short section of Bransten Road. Each cell consists of a permeable strip of area consisting of rock and soil materials and planted with vegetation. The permeable area is bordered by a curb that extends into the roadway and contains openings to allow surface runoff to move through the cell. Three of the seven cells have an underdrain to transport the treated water into the storm drain pipe.

Two of the Bransten Road biofiltration facilities were selected as monitoring locations (i.e., sites PUL-3 and PUL-7) for the CW4CB project. The CW4CB project collected paired influent and effluent[1] samples and volume/flow measurements to provide data needed to calculate PCBs and mercury load reductions (BASMAA 2013). The CW4CB analytical constituents include suspended sediments, total organic carbon, lead, mercury, and PCBs. The stormwater runoff constituents (i.e., additional metals and nutrients) supplemented to the CW4CB project by SMCWPPP for Provision C.8.d.ii compliance were collected only at site PUL-7.

Recent reports regarding installation that was inconsistent with the design, resulting in localized flooding and potential system performance issues at the Bransten Road facility, may have affected its pollutant removal performance. These concerns are currently under investigation.

[1] The biofiltration facility at site PUL-3 was not constructed with an underdrain, thus no effluent samples were collected at this site.

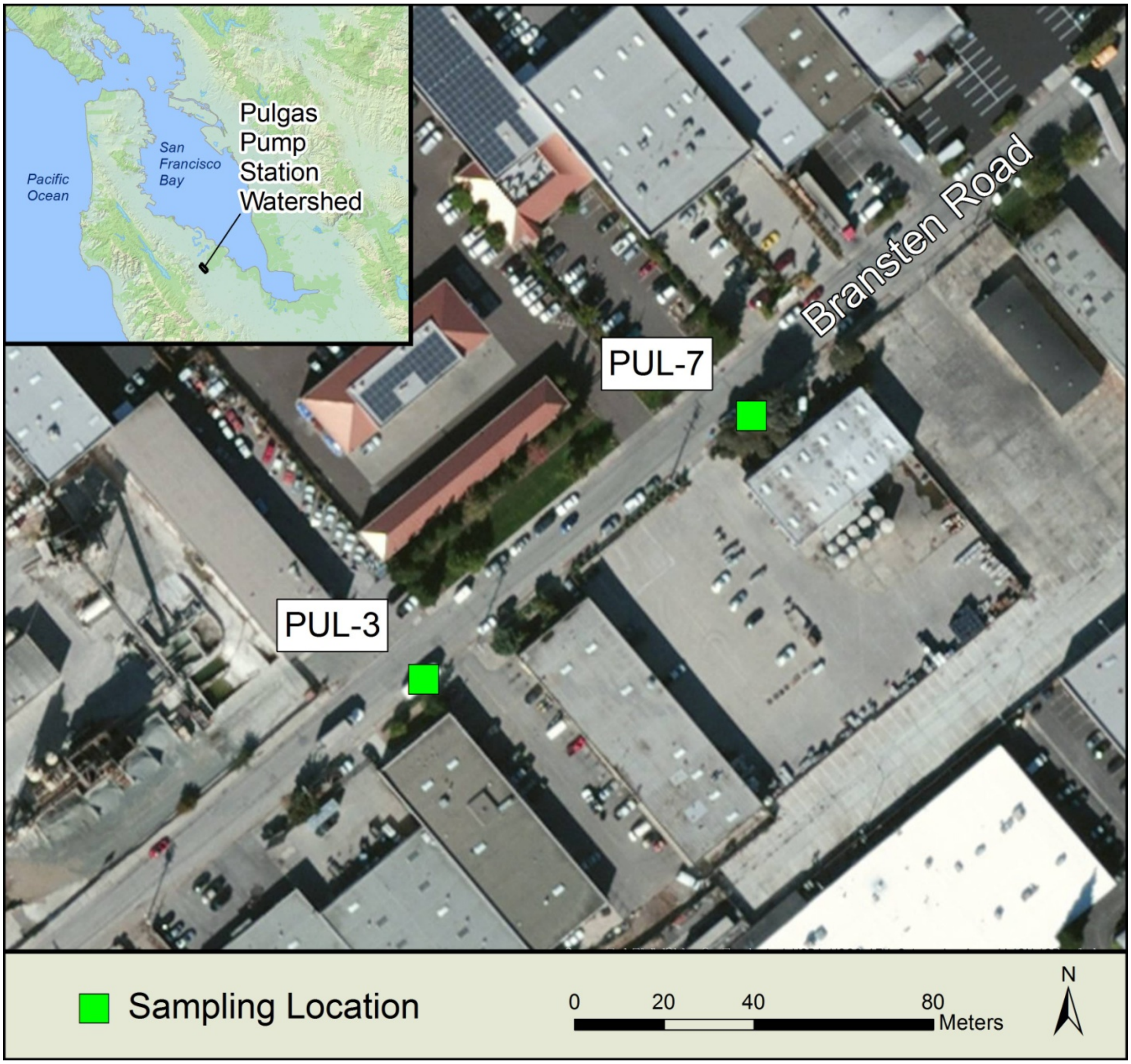

Figure 1. Location of BMP Effectiveness Monitoring for CW4CB project (sites PUL-3 and PUL-7) on Bransten Road, City of San Carlos.

3.0 Methods

3.1 Field Sampling

This section summarizes sampling procedures, as described in the Draft Field Sampling and Analysis Plan for the CW4CB Project (AMS and ADH 2014) that were applied specifically to site PUL-7 on Bransten Road. All sampling conformed to protocols identified in the Regional Monitoring Coalition (RMC) Creek Status Monitoring Standard Operating Procedure (SOP) FS-2, *Manual Collection of Water Samples for Chemical Analysis, Bacteriological Analysis, and Toxicity Testing* (EOA et al., 2014). The "clean hands / dirty hands" sampling techniques described in SOP FS-2 were used since mercury was one of the analytes to be measured. Data quality for laboratory and field sampling procedures conformed to the Clean Watersheds for a Clean Bay (CW4CB) QAPP (AMS 2012).

Water samples were collected by ADH Environmental (ADH) located in Santa Cruz, California. All samples were collected using a peristaltic pump sampler operated in manual mode. Each pump was fitted with cleaned Teflon® and C-Flex® tubing. Eight to ten discrete sample aliquots were collected in equal time intervals, targeted to coincide with the rising limb and peak of the storm hydrograph. These discrete sample aliquots were composited into one sample, per analyte, per sampling location, at the laboratory prior to analysis.

The influent sample was collected along the curb/gutter conveyance about ten feet upstream of the cell. The sample intake tubing was secured to the curb and gutter with a stainless steel rod so that the intake point was positioned in the centroid of flow (Figure 2). The effluent sample was collected from a vertical riser that provided access to the underdrain. The monitoring protocols were altered following the first sampling event to address flooding that caused the bypass flow to mingle with treated flow within the effluent stream being monitored. To avert future flooding during storm events, monitoring personnel temporarily attached a 12" PVC extension to the existing riser for each monitoring event, and removed riser at the end of each event (Figure 2).

Samples were collected and flow volumes were measured at site PUL-7 during three storm events in water year 2014 (WY2014) and one storm event in WY2015 (note: due to low precipitation in WY2014, the monitoring project was extended through WY2015).

Figure 2. Influent (left) and effluent (right) sampling locations at site PUL-7 on Bransten Road, City of San Carlos.

3.2 Laboratory Analysis

Water samples were analyzed by ALS Environmental Laboratory in Kelso, Washington. Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are presented in Appendix A. The data review for Quality Assurance/Quality Control is presented in Appendix B.

3.3 Data Analysis

For this report, a pollutant removal efficiency ratio (ER) (David et al. 2014) was used to analyze changes in concentrations between the influent samples (taken in the gutter upstream of the biofiltration facility) and the effluent samples (taken from the underdrain) as a percentage of inflow concentration using the following equation:

$$ER = (\text{influent conc.} - \text{effluent conc.}/\text{influent conc.}) \times 100$$

The ER was calculated for each storm event. Results are presented as percent difference (% Diff) in Tables 3 and 4.

Hydrologic data (i.e., flow rates) were not available (as of February 2016) to calculate flow weighted mean concentrations, loading rates, or pollutant removal efficiencies for the pollutants added by SMCWPPP for Provision C.8.d.ii compliance.

4.0 Results

The hydrologic data needed to calculate pollutant removal efficiencies of the stormwater constituents added to the CW4CB project by SMCWPPP for Provision C.8.d.ii compliance are not available at this time. Therefore, this report compares pollutant concentrations in both the paired influent and effluent samples for a given storm, and across storms using mean influent and effluent concentrations. Limitations to this approach in evaluating BMP performance include that it does not account for overall loading into and out of the BMP.

Summary statistics for analyte concentrations measured in the influent and effluent samples collected during four storm events are shown in Table 1 and Table 2. Effluent mean concentrations of total metals were consistently lower compared to the influent mean concentrations, with the exception of arsenic (Table 1). In contrast, all of the dissolved metals and nutrients had similar or higher mean concentrations in the group of effluent samples compared to the group of influent samples, with the exception of cadmium, chromium and zinc which were slightly lower (Table 2).

Table 1. Summary statistics for total metal concentrations in samples collected above (influent) and below (effluent) the biofiltration facility (PUL-7).

Total Metals	Influent (n=4)			Effluent (n=4)		
	Range	Mean	SD	Range	Mean	SD
Arsenic (ug/L)	3.5 - 6.7	4.4	1.5	3.4 - 5.2	4.4	0.8
Cadmium (ug/L)	0.16 - 0.41	0.3	0.1	0.12 - 0.24	0.2	0.1
Chromium (ug/L)	16 - 39	23.8	10.4	8.3 - 16	11.1	3.5
Copper (ug/L)	30 - 62	45.3	16.6	15 - 24	20.8	4.0
Lead (ug/L)	7.9 - 19	13.0	5.0	3.8 - 8.1	5.6	1.9
Nickel (ug/L)	15 - 39	22.8	11.0	9.3 - 16	12.1	3.1
Zinc (ug/L)	86 - 270	149	82.2	21 - 40	29.5	7.9

n = number of samples, SD = standard deviation

Table 2. Summary statistics for dissolved metal and nutrient concentrations in samples collected above (influent) and below (effluent) the biofiltration facility (PUL-7).

Dissolved Metals and Nutrients	Influent (n=4)			Effluent (n=4)		
	Range	Mean	SD	Range	Mean	SD
Metals						
Arsenic (ug/L)	0.08 - 2	1.3	1.1	0.08 - 3	1.8	1.5
Cadmium (ug/L)	0.03 - 2.6	1.3	1.8	0.04 - 1.9	0.7	1.1
Chromium (ug/L)	1.5 - 15	6.8	7.2	1.4 - 9.2	4.6	4.1
Copper (ug/L)	12 - 120	52	59.2	9.8 - 130	51.6	67.9
Hardness	0.1- 80	50	43.5	0.14 - 180	96.7	90.7
Lead (ug/L)	0.06 -1.8	0.7	1.0	0.22 - 2.4	1.1	1.2
Nickel (ug/L)	0.5 - 2.5	1.5	1.0	0.32 - 3.9	2.5	1.9
Zinc (ug/L)	6.9 - 8.3	7.6	1.0	4.7 - 6	5.4	0.9
Nutrients						
Nitrate as N (mg/L)	0.15 - 0.68	0.4	0.3	0.17 - 0.7	0.4	0.3
Orthophosphate as P (mg/L)	0.1 - 3.7	1.3	2.1	0.12 - 3.6	1.3	2.0

n = number of samples, SD = standard deviation

The total and dissolved metals, hardness, nitrate, and orthophosphate concentrations measured in water samples collected at the paired influent and effluent locations at site PUL-7 during each of the four storm events are presented in Tables 3 and 4. The change in concentration, expressed as percent difference, is presented for each analyte. Total metal concentrations for both influent and effluent samples collected over the four storm events are shown in Figure 3.

Table 3. Total metal concentrations from influent and effluent samples collected at site PUL-7 during four storm events.
"I" and "E" represents influent and effluent sample concentrations, respectively, and "% Diff" is the percent difference between samples.

Analyte	2/26/2014			3/26/2014			3/29/2014			2/6/2015		
	I	E	% Diff	I	E	% Diff	I	E	% Diff	I	E	% Diff
Arsenic (ug/L)	3.6	4.8	33%	6.7	5.2	-22%	3.9	4.1	5%	3.5	3.4	-3%
Cadmium (ug/L)	0.41	0.24	-41%	0.33	0.21	-36%	0.16	0.13	-19%	0.21	0.12	-43%
Chromium (ug/L)	21	11	-48%	39	16	-59%	19	8.9	-53%	16	8.3	-48%
Copper (ug/L)	32	21	-34%	62	24	-61%	30	15	-50%	57	23	-60%
Hardness	88	220	150%	120	130	8%	70	180	157%	80	110	38%
Lead (ug/L)	15	5.9	-61%	19	8.1	-57%	7.9	3.8	-52%	10	4.7	-53%
Nickel (ug/L)	18	13	-28%	39	16	-59%	15	9.3	-38%	19	10	-47%
Zinc (ug/L)	270	30	-89%	120	40	-67%	86	21	-76%	120	27	-78%

Table 4. Dissolved metal and nutrient concentrations from influent and effluent samples collected at site PUL-7 during four storm events.
"I" and "E" represents influent and effluent sample concentrations, respectively, and "% Diff" is the percent difference between samples.

Analyte	2/26/2014			3/26/2014			3/29/2014			2/6/2015		
	I	E	% Diff	I	E	% Diff	I	E	% Diff	I	E	% Diff
Arsenic (ug/L)	0.86	2.8	226%	2.1	3.2	52%	1.8	3	67%	2	2.3	15%
Cadmium (ug/L)	0.033	0.064	94%	0.082	0.082	0%	<0.025	0.075	300%	0.03	0.04	33%
Chromium (ug/L)	3.2	2.6	-19%	2.6	1.9	-27%	3.9	3.1	-21%	1.5	1.4	-7%
Copper (ug/L)	11	11	0%	15	9.2	-39%	12	9.8	-18%	24	15	-38%
Lead (ug/L)	0.14	0.2	43%	0.099	0.14	41%	0.061	0.62	916%	0.1	0.22	120%
Nickel (ug/L)	1.8	4.5	150%	1.8	2.4	33%	1.6	3.9	144%	2.5	3.3	32%
Zinc (ug/L)	15	4.6	-69%	3.7	3.6	-3%	8.3	6	-28%	6.9	4.7	-32%
Nitrate as N (mg/L)	0.43	0.26	-40%	0.5	0.32	-36%	0.33	0.21	-36%	0.68	0.73	7%
Orthophosphate as P (mg/L)	0.094	0.17	81%	0.15	0.17	13%	0.1	0.16	60%	0.1	0.12	20%

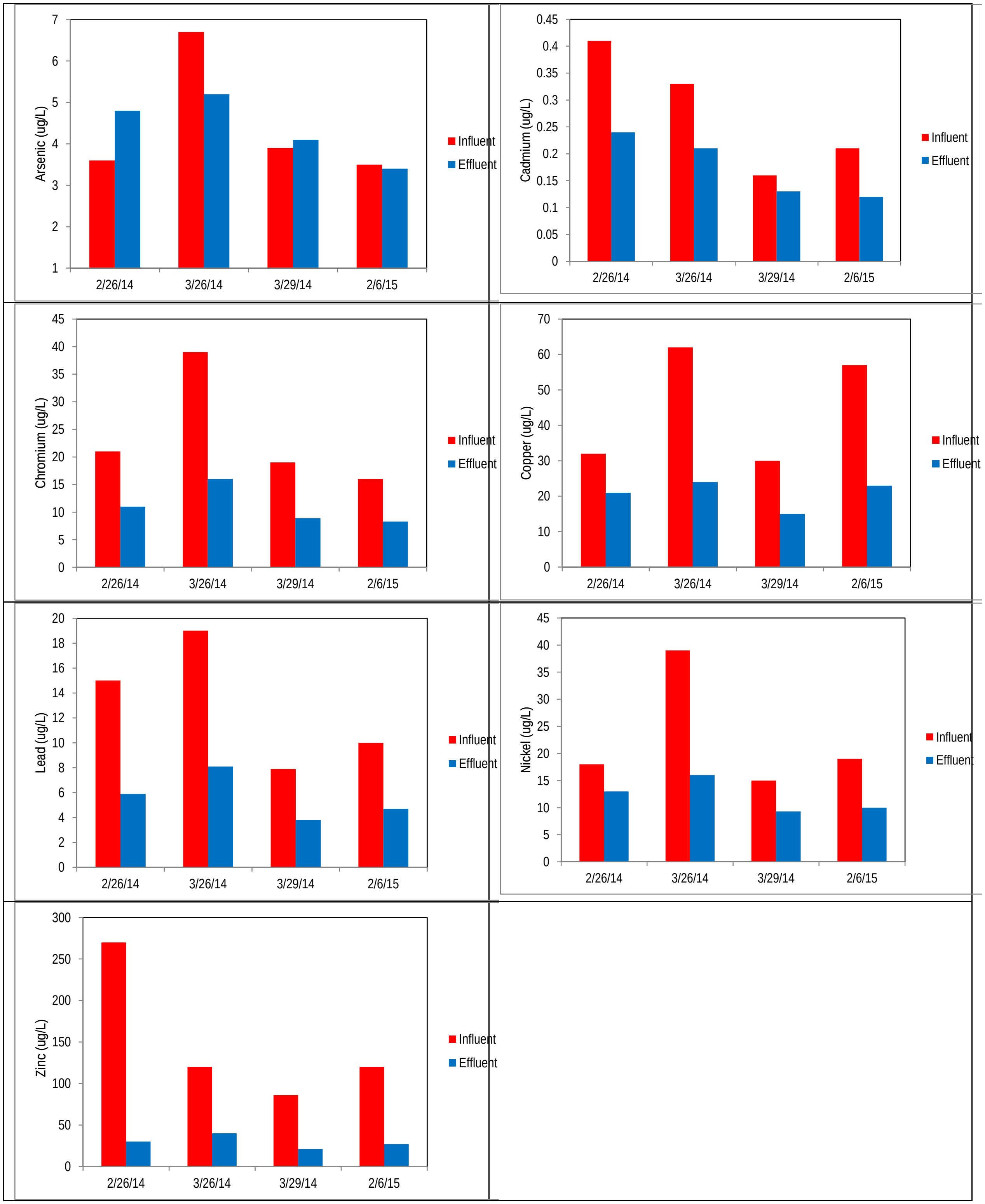

Figure 3. Total metal concentrations for influent and effluent samples collected at Bransten Road BMP during four storm events.

Total zinc concentrations had the highest percent difference for all events (-67% to -89%) (Table 3 and Figure 3). Percent difference in total copper concentrations ranged -34% to -61% across the four storm events (Table 3 and Figure 3). The dissolved metal concentrations were generally higher in the effluent samples compared to the influent samples, with the exception of chromium, copper and zinc, which had lower levels in the effluent samples at three of the four storms events (Table 4). Dissolved nitrate (as nitrogen) had lower concentrations (ranging -36% to -40%) in the effluent samples from three of the four storms events (Table 4). In contrast, dissolved orthophosphate (as phosphorus) concentrations were always higher in the water samples collected at the effluent location (Table 4).

One factor contributing to these results is that the BMP would be expected to have much lower efficiencies in removing trace metals and nutrients in the dissolved fraction compared to the total fraction because dissolved constituents are less likely to be trapped or absorbed by filtration materials or vegetation during a runoff event. These results were consistent with results from other BMP effectiveness studies reported in the International BMP Database (Geosyntec and Wright Water Engineers 2014). In general, other BMP studies showed statistically significant reductions for most trace metals in the total fraction, but not in the dissolved fraction. However, metal and nutrient concentrations in both the influent and effluent samples were generally higher at the Bransten Road BMP in comparison to the median concentrations found in other BMP studies[2]. The results suggest that observed percent removal may be more reflective of how "dirty" the influent water is than BMP performance.

Evaluation of biofiltration effectiveness for removal of contaminants is challenging due to a wide range of factors that affect removal efficiency, including variability in input concentrations and fine sediment, precipitation, and potential hydrologic losses to groundwater (David et al. 2014). Evaluation of reductions should also incorporate flow measurements associated with paired influent and effluent samples to calculate flow-weighted mean concentrations, loading estimates, and pollutant removal efficiencies.

[2] Influent/effluent concentrations measured at "bioretention" type of BMPs were used for comparison to the Bransten Road BMP.

5.0 Conclusions

Initial analyses of results presented in this report suggest that the biofiltration cell at site PUL-7 on Bransten Road was generally effective at reducing concentrations of total metals in stormwater. Reductions in mean total concentrations were observed for six of the seven metals. These results were consistent with paired influent and effluent concentrations for all four storm events. In contrast, dissolved metals and nutrients concentrations were often higher in the effluent samples compared to the influent samples. Higher concentrations for analytes in dissolved fraction have been found in other BMP effectiveness studies (Geosyntec and Wright Water Engineers 2014).

Overall efficiency of the system will be affected by factors such as the level of precipitation and associated flow volumes and rates (i.e., residence time of surface runoff in the cell) and influent pollutant and sediment concentrations. In addition, continued maintenance of the biofiltration cell (e.g., mulching) and maturation of plants will be important to maintain and potentially increase the removal efficiency over time. Plants at the Bransten Road BMP were established between 3 months and 15 months prior to four sampling events.

Recent reports regarding installation that was inconsistent with the design, resulting in localized flooding and potential system performance issues at the Bransten Road facility, may have affected its pollutant removal performance. These concerns are currently under investigation. If appropriate, SMCWPPP will calculate loadings and removal efficiencies for the constituents after the concerns at the site are better understood and resolved and any CW4CB hydrologic data are published. However, any assessment of overall BMP effectiveness should be interpreted with caution due to a limited number of samples that were collected soon after construction of the bioretention facility.

6.0 References

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AMS and ADH (2014). Field Sampling and Analysis Plan Clean Watersheds for a Clean Bay – Implementing the San Francisco Bay's PCBs and Mercury TMDLs with a Focus on Urban Runoff, Task 5, Phase II, EPA San Francisco Bay Water Quality Improvement Fund Grant # CFDA66.202. Prepared for Bay Area Stormwater Management Agencies Association.

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Bay Area Stormwater Management Agencies Association (BASMAA), 2014. *BASMAA Regional Monitoring Coalition Creek Status Monitoring Program Standard Operating Procedures*. Prepared for Bay Area Stormwater Management Agencies Association. Version 2, January 28, 2014.

David, N. and J. Leatherbarrow, D. Yee and L. McKee. 2014. Removal Efficiencies of a Bioretention System for Trace Metals, PCBs, PAHs, and Dioxins in a Semiarid Environment. J. Environ. Eng., 10-1061/(ASCE)EE.1943-7870.0000921.

Geosyntec Consultants and Wright Water Engineers, 2014. International Stormwater Best Management Practices (BMP) Database Pollutant Category Statistical Summary Report. December 2014.

APPENDIX A

Analytes, Methods and Detection Limits

Table 1. Analytes, Methods and Reporting Limits.

Analyte	Method	Reporting Limit
Total phosphorus	SM4500-P E	0.01 mg/L as P
Dissolved orthophosphate*	SM4500-P E	0.01 mg/L as P
Nitrate	EPA 300.0	0.1 mg/L as N
Ammonia	EPA 350.1	0.1 mg/L as N
TKN	EPA 351.3	0.5 mg/L as N
Total metals **	EPA 200.8	See Table 2
Dissolved metals ***	EPA 200.8	See Table 2
Hardness	SM 2340B	5 mg/L as $CaCO_3$

*Dissolved orthophosphate is to be filtered by the lab
**Total metals (arsenic, cadmium, chromium, copper, lead, nickel, and zinc)
***Dissolved metals (arsenic, cadmium, chromium, copper, lead, nickel, and zinc) – to be filtered by the lab

Table 2. Reporting Limits for metals.

Analyte	RL	Units
Arsenic	0.5	ug/L
Cadmium	0.2	ug/L
Chromium	0.5	ug/L
Copper	0.5	ug/L
Lead	0.2	ug/L
Nickel	0.5	ug/L
Zinc	1.0	ug/L

APPENDIX B

QA Data Analysis

ALS Environmental Laboratories analyzed all water chemistry samples for the project and performed all internal QA/QC requirements for Inorganic Analytes in Water as specified in the CW4CB QAPP (BASMAA 2014a). The lab MQO for RPDs was 20% and for the QAPP it was 25%. Summary results of QA are shown in Table 1.

Table 1. QA Results.

Analyte	Method Used	Target RL	RL	MDL	PR	RPD
Lead	EPA 200.8	0.01 ug/L	0.2 ug/L	0.032 ug/L	75-125%	25
Arsenic	EPA 200.8	None		0.050	75-125%	25
Cadmium	EPA 200.8	None		0.025	75-125%	25
Chromium	EPA 200.8	None		0.050	75-125%	25
Copper	EPA 200.8	None		0.084	75-125%	25
Hardness	SM 2340 B	None	5.0	0.50	80-120%	25
Nickel	EPA 200.8	None		0.050	75-125%	25
Nitrate	EPA 200.8	None		0.020	80-120%	25
Orthophosphate	EPA 200.8	None		0.0010	80-120%	25
Zinc	EPA 200.8	None		0.10	75-125%	25

A limited number of lab sample results for inorganic analytes in water were flagged due to minor QA/QC issues. These results were not thought to affect the validity of sample results and were not rejected. Included were the following:

- There were no RPD or PR problems for LCS, LCD, Reference, MS, MSD, or duplicate samples. Two blanks were above the method detection limit for several metals, but all were below reporting limits. One duplicate sample exceeded the MQO for RPD (28%), but concentrations were far below the reporting limit (for nickel).