Effectiveness Assessment Monitoring
Newport Coast ASBS
Reef Point Parking Lot at Crystal Cove

Draft Report

Prepared For:

Proposition 84 Grant Administrator
City of Newport Beach
3300 Newport Boulevard
Newport Beach, CA 92663

January 2014

WESTON SOLUTIONS®

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1.0 INTRODUCTION

The purpose of this study was to perform an effectiveness assessment of the best management practices (BMPs) recently implemented at the Reef Point parking lot at Crystal Cove State Park in Newport Beach, CA. These BMPs were implemented to reduce pollutant loading during rain events to an Area of Special Biological Significance (ASBS) designated as ASBS 33, located along the Newport Coast. Two of the BMPs are bioretention type BMPs (sometimes called rain gardens) with the primary treatment mechanism being evapotranspiration, while a third BMP includes a treatment system that is designed to capture runoff, attenuate peak flows, and provide treatment prior to discharge into the existing catch basin located at the southern corner of the Reef Point parking lot.

To assess effectiveness of the Reef Point parking lot BMPs, wet weather monitoring was performed at two stations, one located above/upstream of the treatment BMP, and one located below, or downstream of the BMP. Flow data and water quality samples were collected and observations were recorded during sampling events at each of the monitoring locations. Results from chemical analyses of collected samples and flow data were used to estimate pollutant load reductions following treatment by the BMPs.

1.1 Background

The Newport Coast Watershed covers approximately 10 square miles and is located within the city limits of Newport Beach in Orange County, California. In recent years, urbanization within the Newport Coast Watershed has led to increased runoff in canyon streams and storm drain outfalls that drain to designated Areas of Special Biological Significance (ASBS). The southernmost ASBS on the Newport Coast, ASBS 33, receives freshwater flows from several canyon creeks, and from numerous outfalls that drain excess runoff from communities and individual residences located along the coastal bluffs to the sea.

Since 1983, the California Ocean Plan has prohibited the discharge of waste into ASBS along the California Coast, unless the State Water Resources Control Board (State Board) grants an exception to dischargers. As part of the exception process, the State Board has produced a guidance document for monitoring discharges to ASBS entitled Attachment B - Special Protections for Areas of Special Biological Significance, Governing Point Source Discharges of Storm Water and Nonpoint Source Waste Discharges (State Board, 2012) (Appendix A). The Special Protections document is intended to define the terms and conditions that limit storm water discharges to the ASBS along the California Coast (34 ASBS have been designated throughout the state). Storm drain discharge pipes along the Newport Coast fall under the jurisdiction of the City of Newport Beach (City).

In 2006, the City was informed that an exception to the ASBS discharge requirements would require the City to continue to plan for and eliminate all dry weather flows and to reduce pollutants in stormwater runoff. To this end, the City has participated in the Southern California Bight 2008 Regional Monitoring Program (Bight 2008) and Southern California Bight 2013 Regional Monitoring Program (Bight 2013) ASBS Planning Committee with the State Board, the Southern California Coastal Water Research Project (SCCWRP), and other ASBS dischargers in southern California. Together, the Committee developed a Regional ASBS Work Plan as part of the Southern California Bight 2008 and Bight 2013 Regional Monitoring Surveys. The Regional

ASBS Work Plan is based on the Special Protections document and is intended to provide compliance guidance for the majority of ASBS dischargers in southern California that wish to be part of a regional monitoring effort.

In recent years, development and urbanization within the Newport Coast Watershed has led to increased runoff in canyon streams and storm drain outfalls that drain to designated ASBS. Currently, nuisance flows near the Reef Point parking lot in Crystal Cove State Park (CCSP) have created ponded, stagnant water with limited mixing and degraded habitat. To improve conditions, parking lot BMPs were designed to reduce runoff and pollutant flows from the parking lot to the ASBS. The parking lot improvements consisted of replacing one half of the existing impervious pavement parking lot with porous pavers and re-landscaping island areas as bioretention cells with native vegetation planted along the cells' outer edges. These modifications are designed to increase infiltration, and reduce erosion and pollutant loading to the ASBS.

The effectiveness assessment for the Reef Point parking lot at CCSP consisted of wet weather monitoring at two locations. The two monitoring locations were located upstream and downstream of the BMPs, and represented runoff into and out of the Reef Point parking lot project area. Composite samples were collected upstream and downstream of the BMP. The runoff volumes (flow) were modeled using sheet flow assumptions and data from the rain gauge installed at Buck Gully. Flow measurements were measured at the downstream catch basin of the BMP following treatment. Photo documentation and visual observations were integrated into all monitoring activities in order to monitoring site conditions.

1.2 Newport Coast Watershed – Reef Point Parking Lot Design

Reef Point parking lot is located within CCSP, and consists of a two adjoining large open parking lots surrounded by open space areas with beach access to the Pacific Ocean via paved walkways and dirt trails (Figure 1-1). The BMPs at Reef Point are located in the southwestern corner of the northern parking lot. Both lots maintain a high volume of traffic on weekends, and low to moderate volume of traffic on weekdays. Due to the limited street parking in the area, contractors frequently use the lot as a meeting place and/or area from which to carpool to a job site.

The Reef Point parking lot project at CCSP was designed to address the problems of stormwater runoff and pollutant discharges to the ASBS. The final design for the project included installing BMPs to capture and treat storm water runoff from the site. A total of three BMPs were implemented: two bioretention BMPs (sometimes called rain gardens) that utilize evapotranspiration as their primary treatment mechanism, and a third treatment BMP that was designed to capture runoff, attenuate peak flows, and reduce pollutant loads prior to discharge into the existing catch basin located at the south corner of the parking lot.

Figure 1-1. Location of Reef Point Parking Lot Monitoring Stations

The bioretention BMPs were constructed in two existing planter areas (parking lot islands) on site (Figure 1-2). The two pre-existing planters were excavated such that they have a lower elevation than the adjacent asphalt surface, and curb openings were installed so that runoff is able to flow from the parking lot directly into the planter areas. On the down gradient side of the planters additional curb openings were installed to allow surplus runoff during larger rainfall events (runoff in excess of the BMP capacity) to exit the BMP. The finished grade surface of each planter was approximately 1.5 inches lower than the asphalt surface adjacent to where the overflow curb cuts were installed. This was designed to allow only minor ponding of runoff in the bioretention BMPs to occur during larger events. All runoff captured in these BMPs ultimately will infiltrate into the soil substrata or evapotranspirate into the atmosphere.

Figure 1-2. Southwest Bioretention Planter BMP

The majority of the parking lot drains to the area where porous pavement and a modular wetland system treatment train were installed (Figure 1-3). This system is designed to capture and slowly treat runoff generated by up to a 1.25-inch design storm. During installation of the BMP, the pre-existing asphalt, concrete curb and gutter in the south corner of the parking lot (an area equivalent to approximately 6.5 parking spaces) were removed and replaced with a porous pavement (pavers) surface and porous concrete curb and gutter. Beneath the porous surface a rock reservoir was installed, which was designed to temporarily store runoff. The porous pavement and rock reservoir will provide pollutant removal, especially for total suspended soils (TSS) and pollutants bound to those removed soil particles. Perforated PVC pipe then drains the water from the rock reservoir into a modular wetland system (MWS), which provides additional pollutant removal. The MWS was designed with an orifice that restricts the discharge rate from the rock reservoir, proving a slow release of the temporarily stored water, which will attenuate peak flows of storm events.

Figure 1-3. Porous Pavers and Modular Wetland System Treatment BMPs

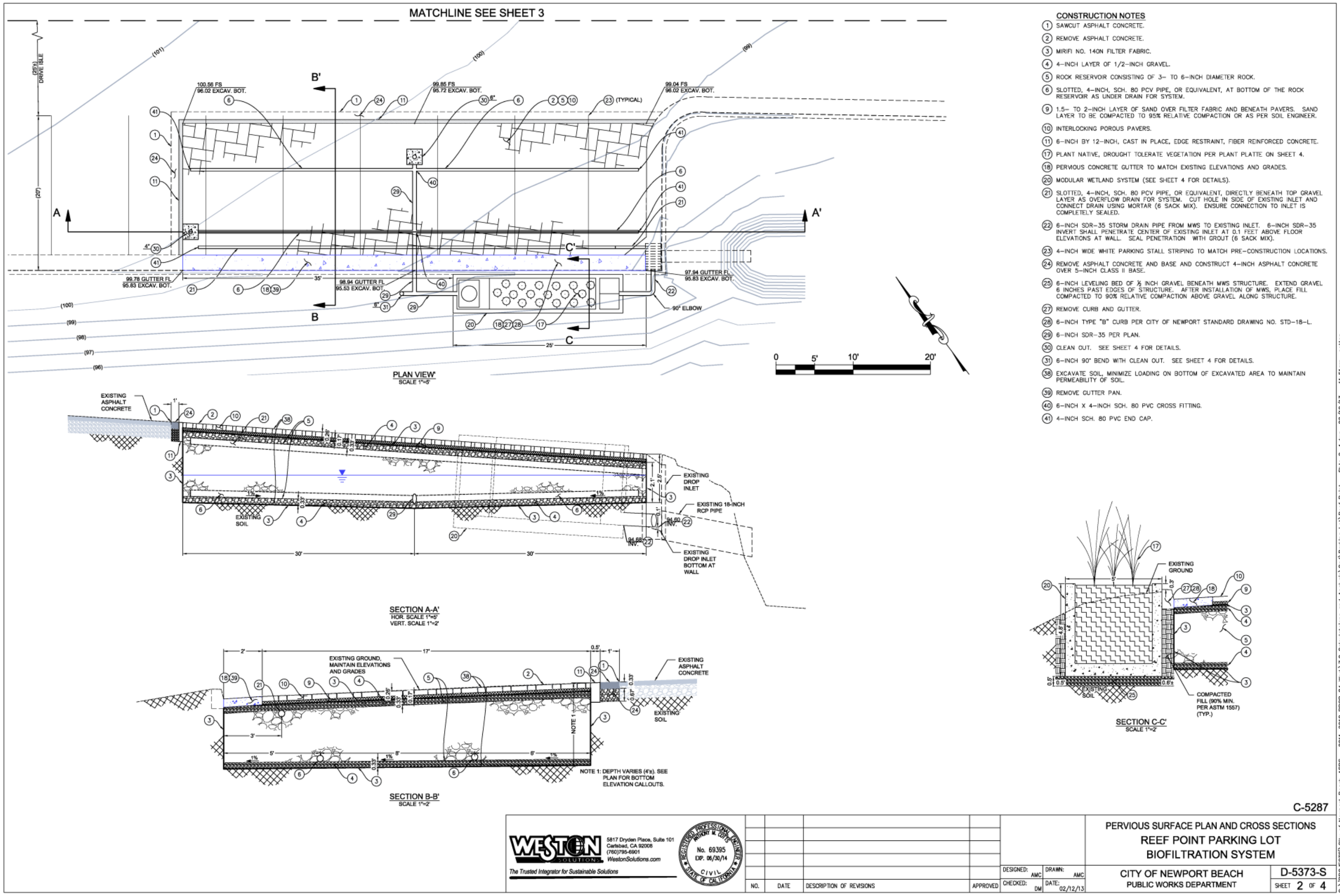
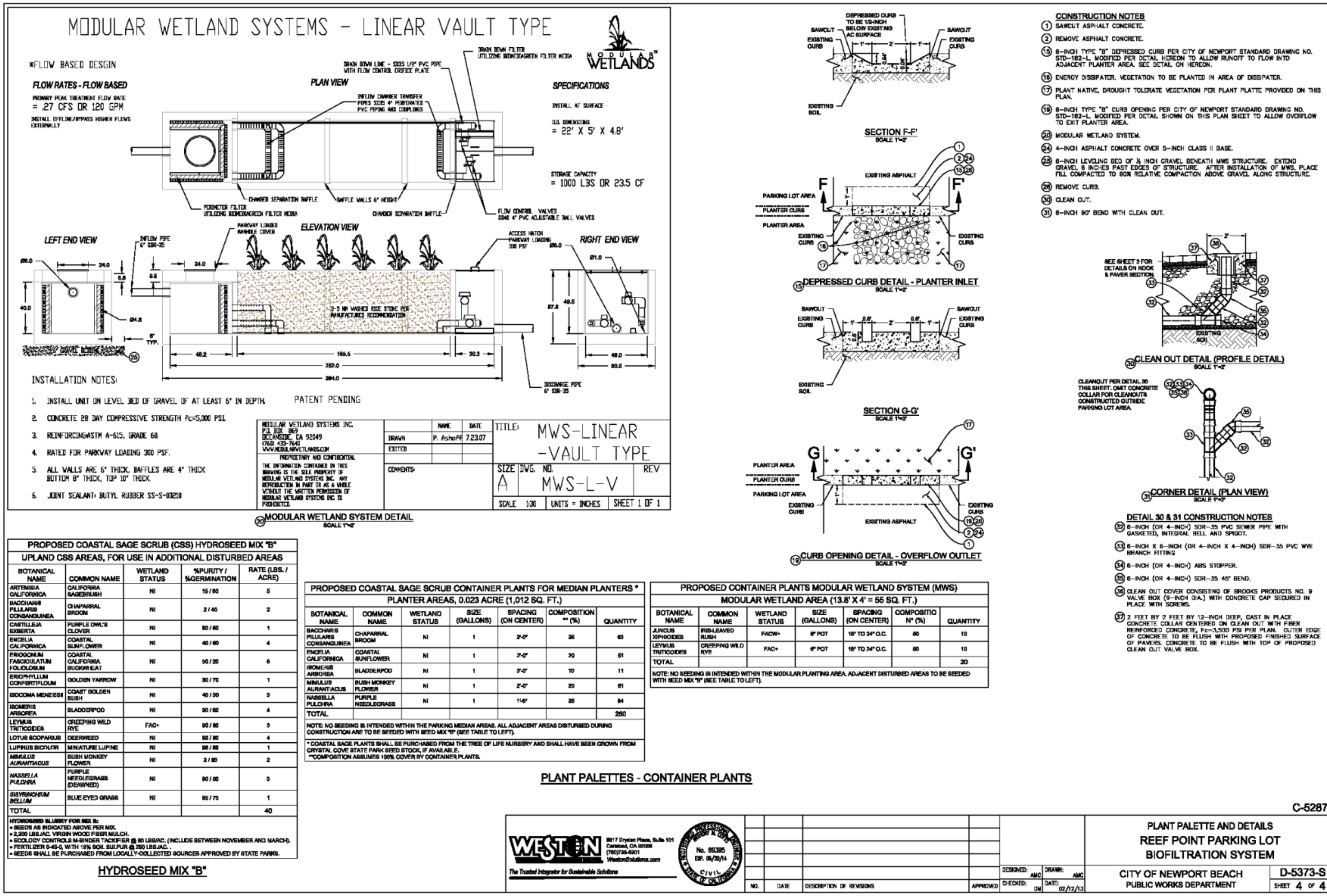


Figure 1-4. Reef Point Biofiltation Treatment Train Design



PROPOSED COASTAL SAGE SCRUB (CSS) HYDROSEED MIX "B"				
UPLAND CSS AREAS, FOR USE IN ADDITIONAL DISTURBED AREAS				
BOTANICAL NAME	COMMON NAME	WETLAND STATUS	%PURITY / %GERMINATION	RATE (LBS. / ACRE)
ARTEMISIA CALIFORNICA	CALIFORNIA SAGEBRUSH	NI	15 / 60	5
BACCHARIS PILULARIS CONSANGUINEA	CHAPARRAL BROOM	NI	2 / 40	2
CASTILLEJA EXSERTA	PURPLE OWL'S CLOVER	NI	50 / 60	1
ENCELIA CALIFORNICA	COASTAL SUNFLOWER	NI	40 / 60	4
ERIOGONUM FASCICULATUM FOLIOLOSUM	COASTAL CALIFORNIA BUCKWHEAT	NI	50 / 20	6
ERIOPHYLLUM CONFERTIFLOUM	GOLDEN YARROW	NI	30 / 70	1
ISOCOMA MENZIESII	COAST GOLDEN BUSH	NI	40 / 30	3
ISOMERIS ARBOREA	BLADDERPOD	NI	90 / 60	4
LEYMUS TRITICOIDES	CREEPING WILD RYE	FAC+	90 / 80	3
LOTUS SCOPARIUS	DEERWEED	NI	85 / 80	4
LUPINUS BICOLOR	MINIATURE LUPINE	NI	98 / 85	1
MIMULUS AURANTIACUS	BUSH MONKEY FLOWER	NI	2 / 80	2
NASSELLA PULCHRA	PURPLE NEEDLEGRASS (DEAWNED)	NI	90 / 80	3
SISYRINCHIUM BELLUM	BLUE-EYED GRASS	NI	85 / 75	1
TOTAL				40

HYDROSEED SLURRY FOR MIX B:
- SEEDS AS INDICATED ABOVE PER MIX.
- 2,200 LBS./AC. VIRGIN WOOD FIBER MULCH.
- ECOLOGY CONTROLS M-BINDER TACKIFIER @ 80 LBS/AC. (INCLUDE BETWEEN NOVEMBER AND MARCH).
- FERTILIZER 0-45-0, WITH 19% SOIL SULFUR @ 250 LBS./AC. .
- SEEDS SHALL BE PURCHASED FROM LOCALLY-COLLECTED SOURCES APPROVED BY STATE PARKS.

PROPOSED COASTAL SAGE SCRUB CONTAINER PLANTS FOR MEDIAN PLANTERS *						
PLANTER AREAS, 0.023 ACRE (1,012 SQ. FT.)						
BOTANICAL NAME	COMMON NAME	WETLAND STATUS	SIZE (GALLONS)	SPACING (ON CENTER)	COMPOSITION ** (%)	QUANTITY
BACCHARIS PILULARIS CONSANGUINEA	CHAPARRAL BROOM	NI	1	2'-0"	25	63
ENCELIA CALIFORNICA	COASTAL SUNFLOWER	NI	1	2'-0"	20	51
ISOMERIS ARBOREA	BLADDERPOD	NI	1	3'-0"	10	11
MIMULUS AURANTIACUS	BUSH MONKEY FLOWER	NI	1	2'-0"	20	61
NASSELLA PULCHRA	PURPLE NEEDLEGRASS	NI	1	1'-6"	25	84
TOTAL						260

NOTE: NO SEEDING IS INTENDED WITHIN THE PARKING MEDIAN AREAS. ALL ADJACENT AREAS DISTURBED DURING CONSTRUCTION ARE TO BE SEEDED WITH SEED MIX "B" (SEE TABLE TO LEFT).

* COASTAL SAGE PLANTS SHALL BE PURCHASED FROM THE TREE OF LIFE NURSERY AND SHALL HAVE BEEN GROWN FROM CRYSTAL COVE STATE PARK SEED STOCK, IF AVAILABLE.
**COMPOSITION ASSUMES 100% COVER BY CONTAINER PLANTS.

PROPOSED CONTAINER PLANTS MODULAR WETLAND SYSTEM (MWS)						
MODULAR WETLAND AREA (13.8' X 4' = 55 SQ. FT.)						
BOTANICAL NAME	COMMON NAME	WETLAND STATUS	SIZE (GALLONS)	SPACING (ON CENTER)	COMPOSITION* (%)	QUANTITY
JUNCUS XIPHIOIDES	IRIS-LEAVED RUSH	FACW+	6" POT	18" TO 24" O.C.	50	10
LEYMUS TRITICOIDES	CREEPING WILD RYE	FAC+	6" POT	18" TO 24" O.C.	50	10
TOTAL						20

NOTE: NO SEEDING IS INTENDED WITHIN THE MODULAR PLANTING AREA. ADJACENT DISTURBED AREAS TO BE SEEDED WITH SEED MIX "B" (SEE TABLE TO LEFT).

Figure 1-5. Reef Point Modular Wetland Systems Design

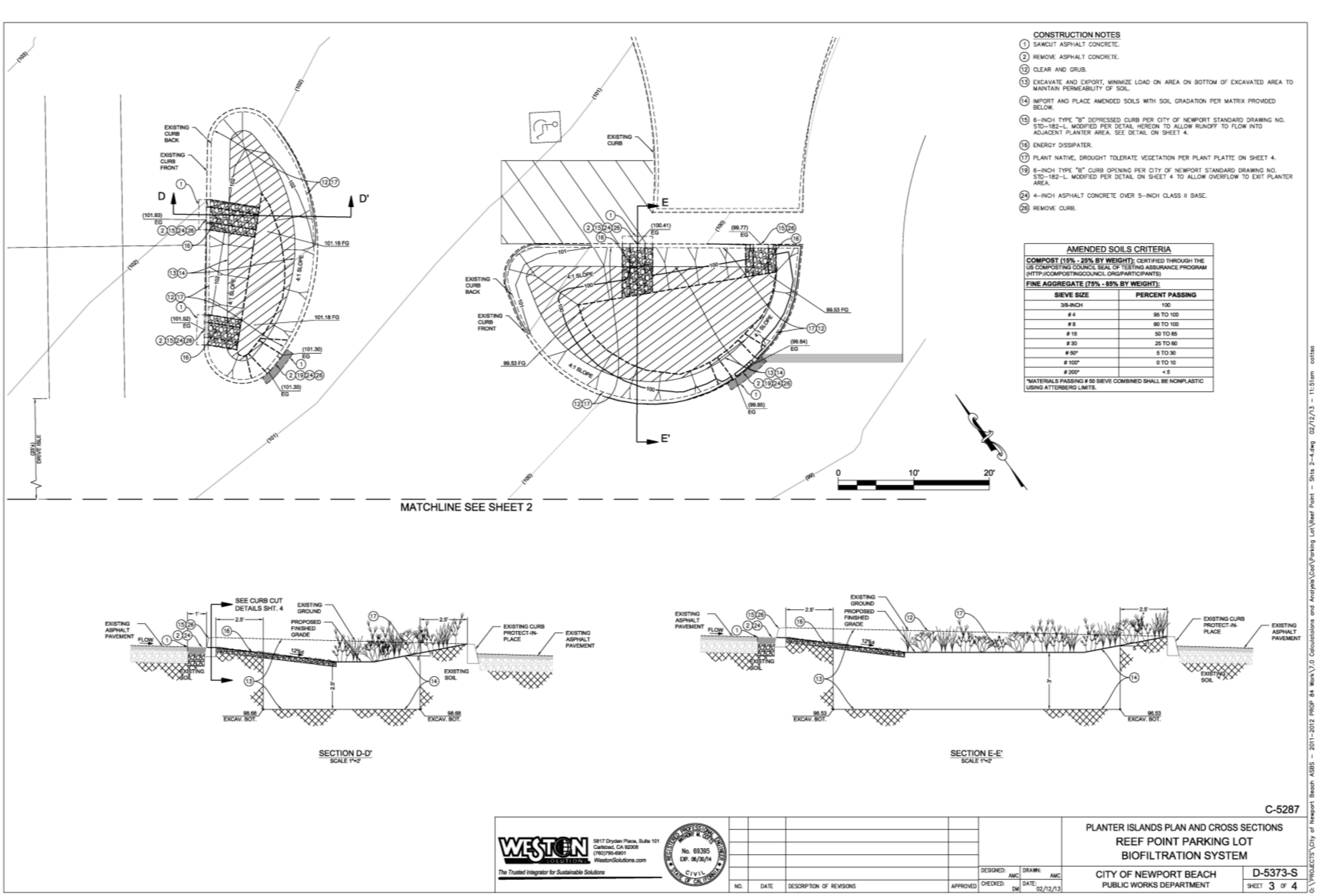


Figure 1-6. Reef Point Parking Lot Bioretention Basin Design

Storm water runoff from the parking lot flows in a southwesterly direction. Flow at the northern end of the parking lot collects in concrete gutters and travels toward the MWS. As the water travels along the gutter, a section of pervious gutter and curb infiltrate the runoff to a rock reservoir that drains to the MWS via perforated PVC piping. Storm water runoff in the central and southern portions of the parking lot flows toward the porous pavers, where the flow infiltrates into the rock reservoir and drains to the MWS. A portion of the parking lot runoff enters the two bioretention planters where it is stored and evapotranspirated. The treatment train system has capacity to handle a 1.25-inch storm.

2.0 MONITORING APPROACH

The general overview for the BMP effectiveness monitoring events for the Reef Point parking lot at Crystal Cove included estimating the total volume of flow captured by the onsite BMPs during the rainfall events, collecting and analyzing samples, and applying the results to calculate the pollutant loads removed.

2.1 Equipment Installation and Flow Monitoring

Models and rain gauge data were used to estimate the sheet flow on the parking lot surface that entered the MWS (Figure 2-1), porous pavement, and bioretention planter BMPs. A Solinst Levelogger and weir were installed into the rear catch basin of the MWS to continuously quantify the flow of water exiting the BMP (Figure 2-2). The rain gauge at the base of Buck Gully was used to accurately measure the quantity and intensity of the rainfall for each storm event. Following each monitored event, the equipment was removed and data was downloaded.

2.2 Sample Collection Locations

Two stations, located above and below the implemented BMP structures, were sampled to assess the BMP's effectiveness in reducing pollutant loads to the ASBS. The sampling station Reef Point In was located along the concrete gutter/curb along the west side of the parking lot just upstream of the point at which it transitions to being a pervious surface, and was representative of untreated runoff flowing from the parking lot. The sampling station Reef Point Out was located in the catch basin at the terminus of the MWS treatment train, and was representative of runoff that had gone through the BMP or, had surpassed the BMP due to saturation conditions.

Table 2-1. Monitoring Locations

Sample Location	Latitude	Longitude
Reef Point In	33.56681° N	-117.83128° W
Reef Point Out	33.56671° N	-117.83114° W

Figure 2-1. Reef Point In Sampling Location

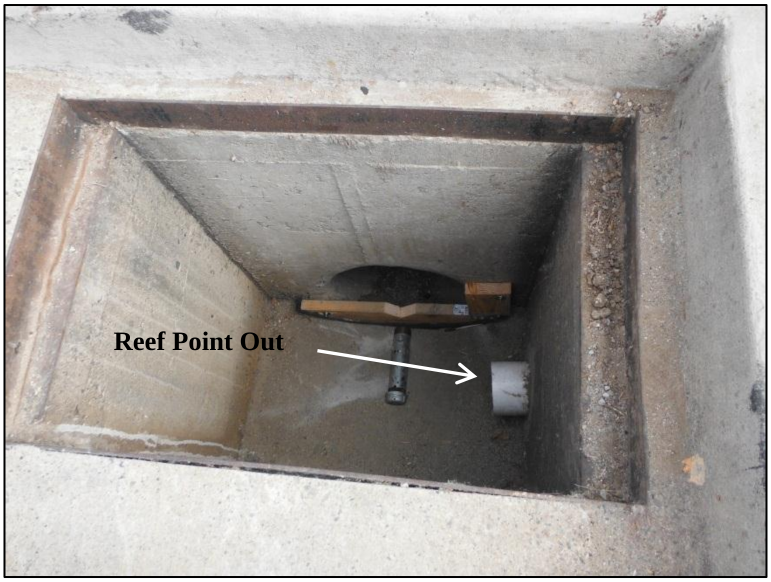


Figure 2-2. Catch Basin Sampling Location: Reef Point Out

2.3 Sample Collection Methods

Two wet weather events were monitored at Reef Point Parking Lot during the 2013-2014 storm season. A wet weather event for this study is defined as an event with 0.1 inches of rainfall and had a 72-hour antecedent dry period. Time-weighted sampling, consisting of a composite of up to four samples collected over the course of the storm event, was performed at each of the sites.

Samples were collected by hand using a collection bottle unless the flow was too low; in which case, a sterile syringe was used to collect sample water. Field staff wore clean, sterile gloves during sample collection. Each field sample was uniquely identified with sample labels in indelible ink. All sample containers were identified with the appropriate identification number, the date and time of sample collection, and preservation method. Chemistry samples were composited for each site using equal volumes of storm water from each sample period (flow throughout the storm was assumed to be similar due to the impracticality of obtaining flow data from parking lot sheet flow). One composite sample from each of the two sample locations, plus one duplicate sample, was sent to Physis Environmental Laboratories, Inc. for analysis for each storm event. All compositing was performed using pre-cleaned mixing chambers. All oil and grease samples from Reef Point were collected at the peak of the storm and processed as grab samples. Samples were kept on ice, under chain of custody, and delivered to the laboratory within the required holding time. The composite samples were analyzed for the list of constituents in Table 2-2. Also provided in Table 2-2 are the detection limits, sample volumes, and type of sample containers. Holding times and type of preservation used for each analyte are provided in the QAPP (Weston, 2011).

Table 2-2. Constituents Monitored for the Effectiveness Assessment of the Reef Point Parking Lot BMP

Constituent	Units	Method	MDL	RL	Volume/ Container
Field Parameters					
pH	pH units	Oakton meter	-	-	Measured in field
Specific Conductance	umhos/cm	Oakton meter	-	-	Measured in field
Temperature	Celsius	Oakton meter	-	-	Measured in field
General Chemistry					
Total hardness as CaCO3	mg/L	SM 2340-B	0.1	0.5	250-ml HDPE
Total suspended solids	mg/L	SM 2540-D	0.5	0.5	1-L HDPE
Oil & Grease	mg/L	EPA 1664A	1	1	1-L Wide Mouth Amber Glass
Total and Dissolved Trace Metals					
Aluminum (Al)	µg/L	EPA 200.8	1.65	8.25	1-L HDPE, double bagged
Antimony (Sb)	µg/L	EPA 200.8	0.03	0.15	1-L HDPE, double bagged
Arsenic (As)	µg/L	EPA 200.8	0.09	0.3	1-L HDPE, double bagged
Barium (Ba)	µg/L	EPA 200.8	0.33	1.65	1-L HDPE, double bagged
Beryllium (Be)	µg/L	EPA 200.8	0.02	0.1	1-L HDPE, double bagged
Cadmium (Cd)	µg/L	EPA 200.8	0.005	0.01	1-L HDPE, double bagged
Chromium (Cr)	µg/L	EPA 200.8	0.01	0.05	1-L HDPE, double bagged
Cobalt (Co)	µg/L	EPA 200.8	0.01	0.05	1-L HDPE, double bagged
Copper (Cu)	µg/L	EPA 200.8	0.005	0.01	1-L HDPE, double bagged

Constituent	Units	Method	MDL	RL	Volume/ Container
Iron (Fe)	µg/L	EPA 200.8	1.13	5.65	1-L HDPE, double bagged
Lead (Pb)	µg/L	EPA 200.8	0.005	0.01	1-L HDPE, double bagged
Manganese (Mn)	µg/L	EPA 200.8	0.005	0.01	1-L HDPE, double bagged
Molybdenum (Mo)	µg/L	EPA 200.8	0.02	0.1	1-L HDPE, double bagged
Nickel (Ni)	µg/L	EPA 200.8	0.01	0.02	1-L HDPE, double bagged
Selenium (Se)	µg/L	EPA 200.8	0.02	0.1	1-L HDPE, double bagged
Silver (Ag)	µg/L	EPA 200.8	0.01	0.02	1-L HDPE, double bagged
Strontium (Sr)	µg/L	EPA 200.8	0.03	0.15	1-L HDPE, double bagged
Thallium (Tl)	µg/L	EPA 200.8	0.01	0.05	1-L HDPE, double bagged
Tin (Sn)	µg/L	EPA 200.8	0.06	0.3	1-L HDPE, double bagged
Titanium (Ti)	µg/L	EPA 200.8	0.08	0.4	1-L HDPE, double bagged
Vanadium (V)	µg/L	EPA 200.8	0.03	0.15	1-L HDPE, double bagged
Zinc (Zn)	µg/L	EPA 200.8	0.02	0.1	1-L HDPE, double bagged
Polynuclear Aromatic Hydrocarbons (PAHs)					
1-Methylnaphthalene	ng/L	EPA 625	1	5	2 1-L amber glass
1-Methylphenanthrene	ng/L	EPA 625	1	5	2 1-L amber glass
2,3,5-Trimethylnaphthalene	ng/L	EPA 625	1	5	2 1-L amber glass
2,6-Dimethylnaphthalene	ng/L	EPA 625	1	5	2 1-L amber glass
2-Methylnaphthalene	ng/L	EPA 625	1	5	2 1-L amber glass
Acenaphthene	ng/L	EPA 625	1	5	2 1-L amber glass
Acenaphthylene	ng/L	EPA 625	1	5	2 1-L amber glass
Anthracene	ng/L	EPA 625	1	5	2 1-L amber glass
Benz[a]anthracene	ng/L	EPA 625	1	5	2 1-L amber glass
Benzo[a]pyrene	ng/L	EPA 625	1	5	2 1-L amber glass
Benzo[b]fluoranthene	ng/L	EPA 625	1	5	2 1-L amber glass
Benzo[e]pyrene	ng/L	EPA 625	1	5	2 1-L amber glass
Benzo[g,h,i]perylene	ng/L	EPA 625	1	5	2 1-L amber glass
Benzo[k]fluoranthene	ng/L	EPA 625	1	5	2 1-L amber glass
Biphenyl	ng/L	EPA 625	1	5	2 1-L amber glass
Chrysene	ng/L	EPA 625	1	5	2 1-L amber glass
Dibenz[a,h]anthracene	ng/L	EPA 625	1	5	2 1-L amber glass
Dibenzothiophene	ng/L	EPA 625	1	5	2 1-L amber glass
Fluoranthene	ng/L	EPA 625	1	5	2 1-L amber glass
Fluorene	ng/L	EPA 625	1	5	2 1-L amber glass
Indeno[1,2,3-c,d]pyrene	ng/L	EPA 625	1	5	2 1-L amber glass
Naphthalene	ng/L	EPA 625	1	5	2 1-L amber glass
Perylene	ng/L	EPA 625	1	5	2 1-L amber glass
Phenanthrene	ng/L	EPA 625	1	5	2 1-L amber glass
Pyrene	ng/L	EPA 625	1	5	2 1-L amber glass

An Oakton PH/CON 10 water quality probe was used to measure pH, temperature, and conductivity for samples collected at each sampling location during the event. Field measurements at each station were taken one time per event at the peak of the storm. Field observations included the time when sheet flow from the asphalt was first observed in the gutter flowing into the BMP, time when flow was first observed exiting the BMP, the total rainfall amount based on a portable rain gauge, and the time of each grab sample used in the composite sample.

2.4 BMP Pollutant Load Reduction Calculations

The flow reaching the bioretention BMPs was calculated using a hydrologic model. For both events monitored, the modeled runoff volumes were significantly less the capacities of the BMP, and thus the systems were assumed to capture the entire runoff volume. This assumption was verified by monitoring staff visual observations.

A mass balance approach was selected to estimate the volume of storm water captured in the parking lot pervious pavement BMP system. For periods where the BMP system capture all runoff this was performed by modeling the runoff flows reaching the BMP (upstream), performing flow calculations of the flow discharging from the outfall (downstream) based on level logger data (equipment installation described in Section 2.1), and comparing the upstream and downstream flows in order to estimate both the total flow captured by BMP system and the flow infiltrated. For period of larger flow monitored, such as the first event monitored that had a short duration but fairly high intensity rainfall, the same approach was used combined with additional calculations that accounted for surface flow over pervious concrete gutter that bypassed the system. Surface flow calculations were based on site observations and photographs of the gutter flows taken during the storm.

2.4.1 Flow Modeling

The EPA Storm Water Management Model (SWMM) program was selected to calculate the surface water flow to each of the three outfalls associated with the Core Discharge Monitoring Program. SWMM is a dynamic rainfall-runoff simulation model that can simulate single events or long-term (continuous) runoff quantity and quality. The runoff component of SWMM operates using a collection of subcatchment areas on which rain falls and runoff is generated. Depth of water over the subcatchment is continuously updated with time by solving a numerical water balance equation over the subcatchment. The routing portion of SWMM transports this runoff through a conveyance system of channels and pipes by selecting uniform flow, kinematic wave, or dynamic wave equations. Water quality parameters can also be input to SWMM to simulate pollutant loadings based on land use within each watershed.

The runoff component of SWMM simulates both the quantity and quality runoff phenomena of a subwatershed. The program accepts precipitation data and makes a step by step accounting of infiltration and evaporative losses, surface detention, and overland flow to calculate a runoff hydrograph for the subwatershed and direct these data to the routing module for surface flow routing.

The following characteristics affect the amount of precipitation that becomes storm water runoff:

- Precipitation distribution and intensity
- Subwatershed properties
  - Area and Topography
  - Land Use

- Soils

2.4.1.1 Precipitation

As part of the monitoring effort a rain gauge and data logger was installed at the nearby Buck Gully/Corona Del Mar Beach (located about 2.5 miles north of the monitoring sites). A HOBO Event data logger was connected to a standard tipping-bucket rain gauge mounted on a 10-ft pole at the base of Buck Gully. The data logger recorded time for each 0.01” of rainfall throughout the monitored events. Field monitoring staff installed portable rain gauges at the parking lot site during each storm. The total rainfall amounts collected by the portable gauges very closely correlated with the total rainfall recorded by the Buck Gully gauge. The field staff recorded when rainfall began and ended during the events. Comparing these times to the logger data indicated about 20 minute lag between rainfall at Buck Gully and the parking lot site. Therefore, the 20 minute value was added to the incremental rainfall data, and the adjusted data were used as input into the SWMM.

2.4.1.2 Drainage Area and Topography

The catchment boundaries (subwatersheds) for the area draining to each monitored outfall were determined utilizing GIS and Computer Aided Design (CAD) software, aerial imagery, and as-built plans. Site reconnaissance of the drainage areas was completed in order to verify the desktop drainage delineation analysis. Other key hydrologic input parameters, such as the watershed widths, roughness, etc., were calculated for each of catchments using through this same process (desktop analysis of available resources followed by field verification). Drainage delineation maps of the modeled areas are provided in Appendix B.

Surface slope and subwatershed shape have profound effects on runoff flow within a subwatershed. Storm water runoff flows in the modeled areas are generated from the parking lot surface and sloped areas between the parking lot and Coast Highway into the parking lot curb and gutter system located along the south side of the parking lot. The overland flow path lengths for storm water runoff within outfall drainage areas were determined utilizing CAD software.

2.4.1.3 Land Use

Land use is an important and variable originator of storm water runoff. As natural vegetation is replaced with impermeable surfaces such as pavement and buildings, the amount of rainfall that runs off the land surface and the rate at which it flows are greatly increased. The areas draining to the monitored site includes only parking lot type land use. The percentages of impervious areas were determined through an analysis of aerial imagery utilizing CAD software. The depression storage values as well as impervious area with no depression storage were estimated based on field observations of precipitation total amounts and initial runoff along with best professional judgment. Table 2-3 below provides a summary of the model parameters used associated with the catchment land use in the model.

Table 2-3. Hydrologic Parameters Used in Model for Residential Land Use

Model Land Use	Manning's Roughness Coefficient		Total Impervious Area	Impervious Area With No D-Store	Depression Storage (in)	
	Impervious	Pervious			Impervious Area	Pervious Area
Parking Lot	0.015	0.100	Varies	5	.03	.15

2.4.1.4 Soils

The soils underlying the land uses control how much rainfall can infiltrate in areas that remain in pervious land cover (Orange County, 1986). Based on Plate C of the Orange County Hydrology Manual, the watershed consists predominately of hydrologic soil type D (Orange County, 1986). The modeling infiltration input parameters used in the SWMM model for this soil type are shown in Table 2-4.

Table 2-4. Model Infiltration Input Parameters

Hydrologic Soil Group	Maximum Infiltration Rate (in/hr)	Minimum Infiltration Rate (in/hr)	Maximum Volume (in)	Drying Time (days)
D	0.5	0.05	0.2	7

2.4.2 Weir Calculations

A V-notch weir structure and level logging equipment were installed in the catch basin located downstream of the pervious pavement BMP system (equipment installation described in Section 2.1). Flow calculations were performed based on the level logger data in order to estimate the flows leaving the site. For levels that did not overtop the install timber (i.e., flow through V-notch weir only), flows were determined using the following Kindsvater-Shen method using a 90 degree V-notch weir and data from the level sensor installed in catch basin. The equation used is as follows:

$$Q = C_d * \frac{8}{15} \tan(\theta / 2) * 2g^{1/2} * h^{5/2}$$

Where:

Q = *flow (cfs)*
C_d = *flow coefficient (0.593)*
θ = *V-notch angle*
G = *gravitational constant (32.2 ft/sec^2)*
H = *fluid height (ft)*
(Lingeburg, 2003)

Flows above the installed V-notch weir (above the timber used to support the V-notch weir) were calculated based on the Horton equation for broad-crested weirs as follows:

$$Q = C_s\, b\, H^{3/2}$$

Where:

Q = *flow (cfs)*
C_s = *spillway coefficient (3.0)*
b = *base width (ft)*
H = *fluid height (ft)*
(Lingeburg, 2003)

The equations above were used to develop a rating curve for each site based on the geometry of the weirs and the incremental water level. The flow was then calculated based on the level data collected from the field and its correlation to the developed rating curve.

2.4.3 Surface Flow Calculations

The pervious pavement BMP system is design to capture sheet flow from parking lot reaching the pavers and flows reaching the system within the pervious concrete gutter, and convey these flows into the underlying rock reservoir. However, if the flow rate of runoff within gutter exceeds the hydraulic conductivity of pervious gutter system a portion of the runoff will reach the existing catch basin inlet bypassing the system. During the first monitored storm event the majority of the rain fell in a short amount of time resulting in high flow velocities across the pervious concrete gutter system and a portion of the runoff bypassed the BMP. Photographs were taken of the flow near peak runoff. Analysis of the photographs indicated that flow at the upstream end of the pervious concrete gutter covered a width of about 1.75 ft while flow at the downstream end covered a width of about 1.5 ft. Calculations of the corresponding open system flows were performed using the Manning's formula to determine the upstream and downstream flows. The difference between these two surface flows was the rate at which flow were being conveyed into the system. Based on this flow rate into the BMP and the wetted area of the pervious concrete gutter, the hydraulic conductivity of the system was estimated to be approximately 100 inches per hours. This rate seems feasible, and potentially conservative, since research of pervious concrete has shown hydraulic conductivity of over 1,000 inches per hours (McCain and Dewoolkar, 2010). These data were used to generate curves of gutter flow width versus upstream gutter flow and flow width versus hydraulic conductivity (in units of cubic feet per second) and shown in Figure 2-3.

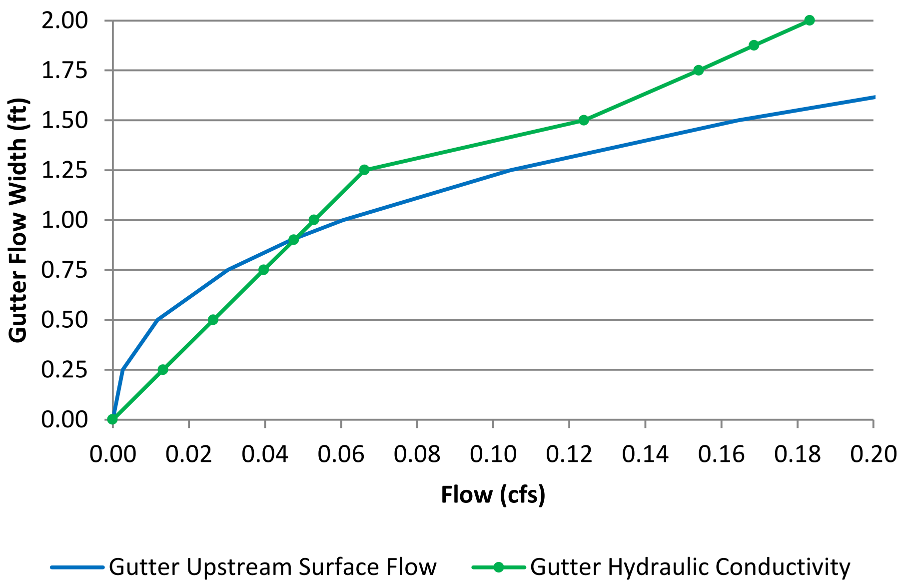


Figure 2-3. Gutter Flow and Hydraulic Conductivity Curves

The curves indicate that below an upstream gutter flow of about 0.05 cubic feet per second (corresponding to an upstream flow width of about 0.9 ft) the system will convey the entire runoff flow into the underlying rock reservoir. Flows in excess of this amount result in a portion of the flow being conveyed into the system and the other bypassing the system. The curves were used to estimate the fraction of the modeled flow reaching the BMP via the curb and gutter conveyed into the BMP for each model time step.

2.4.4 Pollutant Load Calculations

The calculated event outfall discharge volumes were used in combination with analytical chemistry results to estimate loading. In accordance with the QAPP, full chemistry analyses were completed for composite samples collected upstream and downstream of the BMPs. The difference in pollutant concentrations between upstream (influent) and downstream (effluent) samples were applied to the volume of water treated by the pervious pavement system. For the volumes estimated to be infiltrated by the pervious pavement system and the bioretention BMPs, the upstream samples were applied and considered to be full (100%) load removal. The equation used is shown below:

$$Pollutant\ Load = Pollutant\ Concentration\ \left(\frac{mg}{L}\right) \times Volume(ft^3) \times Unit\ Conversion$$

3.0 RESULTS

The first sampling event for this study was conducted on October 9, 2013. During this storm, rain began falling at approximately 15:00 and continued to fall until approximately 19:00. Samples were collected during the initial period of storm runoff as water flowed across the parking lot to the gutter leading to the BMP, during the peak period of runoff, and as runoff began to the recess as rainfall came to an end. A total of four samples were collected and composited into a single sample for the inflow location and four samples were collected and composited for the outflow location. During the sampling a total of approximately 0.33 inches of precipitation was recorded on a portable rain gauge.

The second sampling event was conducted from 10:45pm on November 20, 2013 to 4:00am on November 21, 2013. A total of four samples were collected and composited into a single sample for the inflow location and four samples were collected and composited for the outflow location. The total rainfall for this storm was 0.21 inches.

3.1 Analytical Results

Composite samples were collected at Reef Point-In and at Reef Point-Out. Samples were analyzed for the constituents listed in Table 2-2. Reef Point-In samples were used for load calculations in both the pervious pavement and bioretention BMPs, as separate samples specific to the bioretention BMPs were not collected.

3.2 Field Measurements

Water quality data including pH, temperature, and conductivity were collected at each sampling location during the peak of the wet weather event, as described in Section 2.3. Results are presented in Table 3-1. In general, field measurements of temperature and pH were higher at the outflow sampling location than the inflow sampling location during both storm events, while conductivity decreased during the October 9, 2013 storm and increased during the November 21, 2013 storm event.

Table 3-1. Field Measurement Results

Analyte	Date	Reef Point In	Reef Point Out
Temperature (^{o}C)	10/9/13	19.5	21.1
	11/21/13	17.8	20.4
Conductivity (µS/cm)	10/9/13	1569	869
	11/21/13	356	549
pH (pH units)	10/9/13	6.37	8.25
	11/21/13	7.22	8.17

3.3 Chemistry

Chemical analyses of oil and grease, TSS, hardness, total and dissolved metals, and PAHs are provided in Table 3-2. The complete laboratory analyses, including QA/QC measurements are provided in Appendix C. Results were compared to California Ocean Plan (COP) criteria since reducing impacts to the ASBS were the focus of this study (California Ocean Plan, 2012).

Table 3-2. Results of Chemical Analyses

Parameter	Units	COP	Reef Point IN	Reef Point OUT	Reef Point IN	Reef Point OUT
		Instantaneous Maximum	10/9/2013	10/9/2013	11/21/2013	11/21/2013
Conventionals						
Oil & Grease	mg/L	75	<1	<1	**119.2**	8.1
Total Hardness as $CaCO_3$	mg/L		80.6	400.3	26.2	118
Total Suspended Solids	mg/L	60*	59	17	7	20
Total Metals						
Arsenic(As),Total	µg/L	80	3.22	6.59	2.59	9.58
Cadmium(Cd),Total	µg/L	10	0.927	0.282	0.092	0.197
Chromium(Cr),Total	µg/L		5.17	8.61	0.92	4.9
Copper(Cu),Total	µg/L	30	**30.298**	**30.736**	13.963	18.024
Lead(Pb),Total	µg/L	20	3.001	1.181	0.505	0.8
Nickel(Ni),Total	µg/L	50	27.48	14.37	7.52	5.41
Selenium(Se),Total	µg/L	150	1.08	3.66	0.38	2.68
Silver(Ag),Total	µg/L	7	<0.01	<0.01	<0.01	<0.01
Zinc(Zn),Total	µg/L	200	**290.66**	33.8	67.89	11.09
Dissolved Metals						
Arsenic(As),Dissolved	µg/L		2.06	6.19	2.62	8.51
Cadmium(Cd),Dissolved	µg/L		0.718	0.175	0.088	0.07
Chromium(Cr),Dissolved	µg/L		2.3	7.2	0.53	3.54
Copper(Cu),Dissolved	µg/L		27.511	29.447	13.272	15.962
Lead(Pb),Dissolved	µg/L		0.81	0.209	0.177	0.03
Nickel(Ni),Dissolved	µg/L		24.5	13.63	7.41	4.38
Selenium(Se),Dissolved	µg/L		1.15	3.39	0.45	2.4
Silver(Ag),Dissolved	µg/L		0.03	<0.01	<0.01	<0.01
Zinc(Zn),Dissolved	µg/L		275.02	26.58	66.2	3.1
Polynuclear Aromatic Hydrocarbons						
1-Methylnaphthalene	ng/L		10.2	5	3.3J	2.1J
1-Methylphenanthrene	ng/L		<1	<1	<1	<1
2,3,5-Trimethylnaphthalene	ng/L		<1	<1	<1	<1
2,6-Dimethylnaphthalene	ng/L		<1	<1	<1	<1
2-Methylnaphthalene	ng/L		6	8.7	<1	<1
Acenaphthene	ng/L		<1	<1	<1	<1
Acenaphthylene	ng/L		<1	<1	<1	<1
Anthracene	ng/L		198.4	16.2	16.6	18.4
Benz[a]anthracene	ng/L		<1	<1	<1	<1
Benzo[a]pyrene	ng/L		<1	<1	<1	<1
Benzo[b]fluoranthene	ng/L		<1	<1	<1	<1
Benzo[e]pyrene	ng/L		3.6J	<1	<1	<1

Parameter	Units	COP	Reef Point IN	Reef Point OUT	Reef Point IN	Reef Point OUT
		Instantaneous Maximum	10/9/2013	10/9/2013	11/21/2013	11/21/2013
Benzo[g,h,i]perylene	ng/L		<1	<1	<1	<1
Benzo[k]fluoranthene	ng/L		16.6	<1	<1	<1
Biphenyl	ng/L		26.3	19	12.8	15.3
Chrysene	ng/L		20.6	9.8	6.6	2.3J
Dibenz[a,h]anthracene	ng/L		<1	<1	<1	<1
Dibenzothiophene	ng/L		31.7	18.5	41.7	17.2
Fluoranthene	ng/L		18.7	6.4	<1	<1
Fluorene	ng/L		<1	<1	<1	<1
Indeno[1,2,3-c,d]pyrene	ng/L		<1	<1	<1	<1
Naphthalene	ng/L		15.8	12.6	3.4J	1.9J
Perylene	ng/L		164.8	<1	<1	<1
Phenanthrene	ng/L		19.4	5.1	4.7J	2.5J
Pyrene	ng/L		44.7	10.3	7.6	3J
Total PAHs	ng/L		299.7	41.4	35.5	26.2

October 9, 2013 Storm Event

Conventional Chemistry

Oil and grease concentrations were below the reporting limit for both the Inflow and Outflow samples. The TSS Inflow sample (59mg/l) was slightly below the COP Weekly (7-day average) criteria of 60 mg/L, while the Outflow (17 mg/L) sample was substantially lower.

Total Metals

Copper concentrations were slightly above the COP Instantaneous Maximum (Imax) value of 30 μg/L for both Inflow and Outflow samples, while the Inflow zinc concentration was above the COP Imax value, and the Outflow zinc concentration was below the Imax value. Concentrations of cadmium, lead, nickel, and zinc were lower downstream of the BMP treatment chain the upstream of it. Concentrations of arsenic, chromium, and selenium were higher in at the Outflow location than at the Inflow location. The copper concentration was nearly identical at both the Inflow and Outflow locations (1% change).

Dissolved Metals

Dissolved metal concentrations of cadmium, lead, nickel, silver and zinc were higher at the Inflow site than at the Outflow site, while concentrations of dissolved arsenic, chromium, copper, and selenium were higher at the Outflow site than the Inflow site. Concentrations of dissolved cadmium, lead, nickel, and zinc were lower downstream of the BMP treatment chain than upstream of it, while concentrations of arsenic, chromium, copper and selenium were higher in at the Outflow site than at the Inflow site.

PAHs

Concentrations of 12 individual PAH compounds were detected above reporting limits at the Inflow site, which had a total PAH concentration of 299.7 ng/L. The Outflow site, in which 11 PAH compounds were detected above the reporting limit of 1 ng/L, had a total PAH concentration of 41.4 ng/L. This represents an 86% reduction in total PAH concentration from inflow to outflow (Figure 3-1).

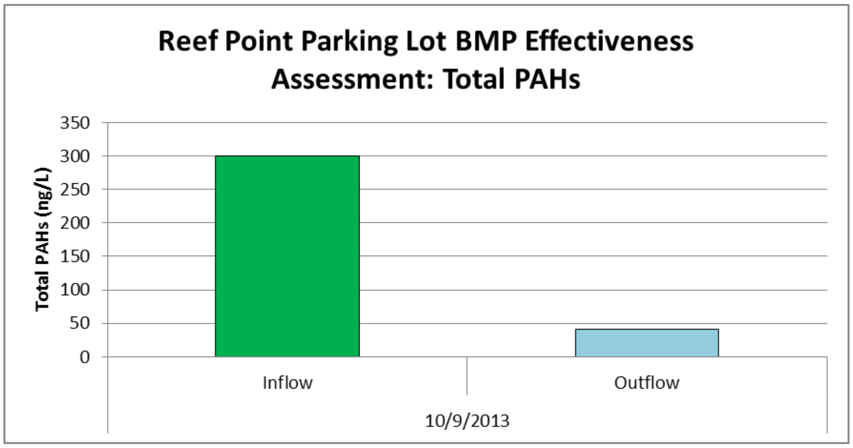


Figure 3-1. Total PAHs at Reef Point during October 9, 2013 Storm Event

November 21, 2013 Storm Event

Conventional Chemistry

The Oil and grease Inflow concentration was approximately 15 times higher than the Outflow concentration, while the TSS Inflow concentration was approximately two times higher than the Outflow concentrations. Both the Inflow and Outflow TSS concentrations were well below the COP Weekly (7-day average) criteria of 60 mg/L.

Total Metals

There were no metals concentrations above COP Imax values during the November 21, 2013 storm event. Concentrations of nickel, and zinc were lower downstream of the BMP treatment chain the upstream of it, while concentrations of arsenic, cadmium, chromium, copper, lead, and selenium were higher at the Outflow location than at the Inflow location. Silver was not detected.

Dissolved Metals

Dissolved metal concentrations of nickel, lead, and zinc were higher at the Inflow site than at the Outflow site, while concentrations of dissolved arsenic, cadmium, chromium, copper, and selenium were higher at the Outflow site than the Inflow site.

PAHs

Concentrations of six individual PAH compounds were detected above reporting limits at the Inflow site, which had a total PAH concentration of 35.5 ng/L. The Outflow site, in which four PAH compounds were detected above the reporting limit, had a total PAH concentration of 26.2 ng/L.

3.4 Flow Data

Flow and rainfall data for the monitored storm events on October 9, 2013 and November 20-21, 2013 are presented in the text that follows. Level loggers were used to measure flow downstream of the pervious pavement BMP system, while modeling was used to calculate flow entering the

BMP system and the water volume captured by the bioretention BMPs. Loads were calculated by multiplying the flow results with the analyte concentrations.

3.4.1 Pervious Pavement BMP System

Monitoring Event 1

Figure 3-2 shows the rainfall distribution, the modeled total runoff flow reaching the pervious pavement BMP, and the flow downstream of the BMP. The graphs show a rapid response to the rainfall followed by slow discharge of captured runoff downstream of BMP. Additional flow calculations are shown in Figure 3-3 including the flow into BMP, attenuated flow reaching the catch basin inlet information, total storm runoff volume, and total BMP capture volume.

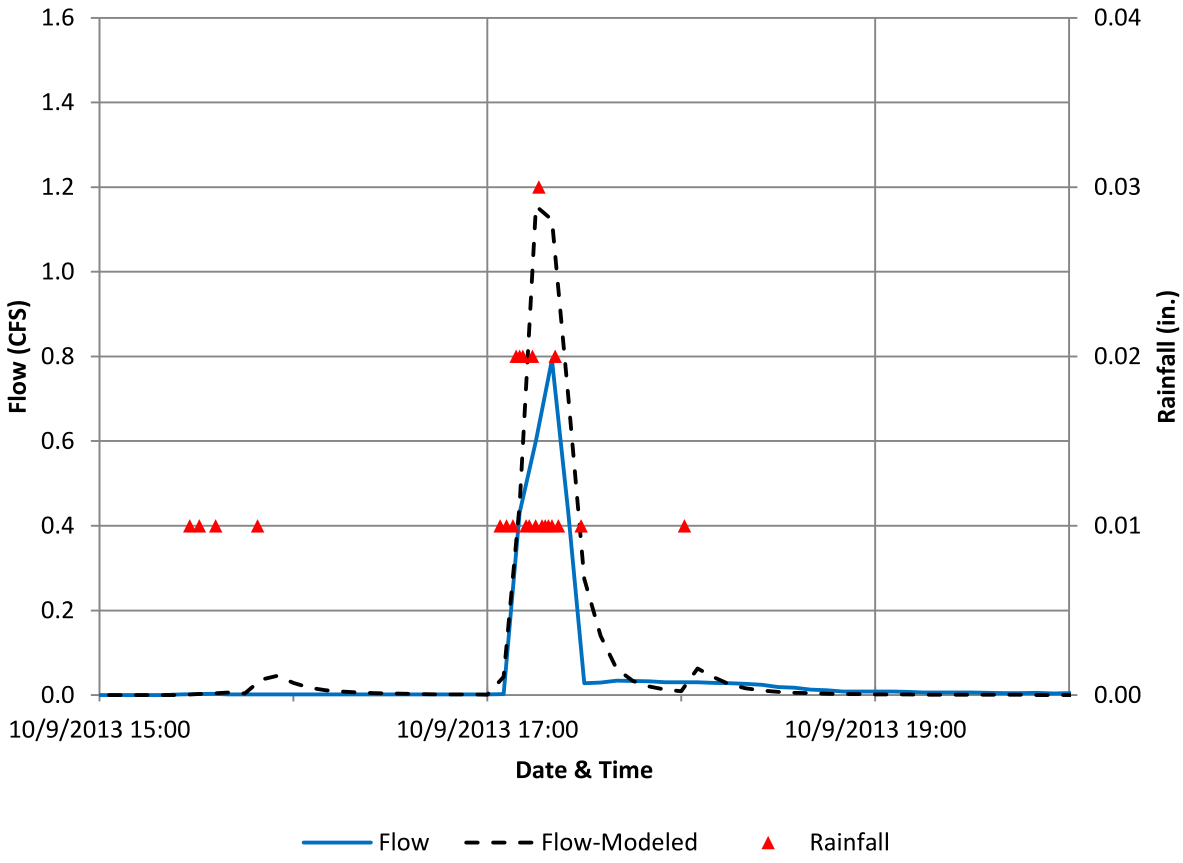


Figure 3-2. Event 1 Rainfall and Flow Graphs, Pavement BMP

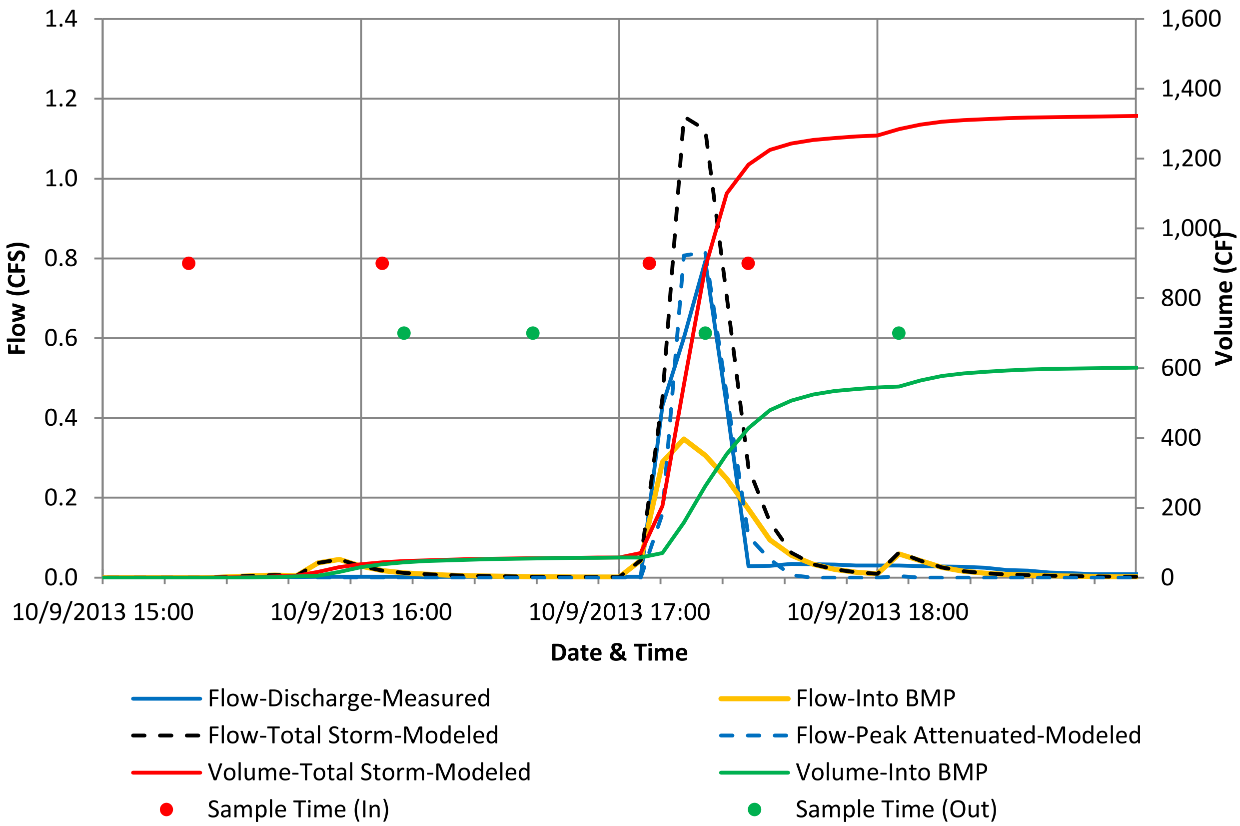


Figure 3-3, Event 1 Flow, Volumes, and Sampling Graphs, Pavement BMP

Table 3-3 provides a summary of the Event 1 flow calculations. The BMP discharge is based on the flow measured downstream of the BMP in times when no runoff flow was bypassing the system. The volume infiltrated is based on the total flow captured by the BMP minus the treated BMP discharge flow.

Table 3-3. Summary of Event 1 Flow Results, Pavement BMP

Parameter	Value
Total Storm Volume	1,377 ft^3
Flow Captured by BMP	657 ft^3
BMP Discharge (Treated)	296 ft^3
BMP Infiltrated	361 ft^3
Volume that Bypassed BMP	720 ft^3

Table 3-4 provides a summary of the Event 1 load calculations for the Total Load entering the parking lot, the load which bypassed the BMP, the load that was infiltrated, the treatment load reduction, and the total load reduction realized by the installed BMP. There was a 42% load reduction for TSS and a 45% load reduction for Total PAHs. The load reduction average for all metals was 23%. Copper and zinc, which had concentrations above COP Imax values, were reduced by 26% and 45%, respectively. Selenium, arsenic and chromium had negative treatment load reductions as a result of their respective concentrations being higher at the BMP discharge location than before they entered the BMP. This scenario, however, seems implausible, and is more likely the result of sample non-heterogeneity or possibly laboratory variability than a true reflection of the functioning of the BMP.

Table 3-4. Summary of Event 1 Load and Load Reductions for Pervious Pavement BMP

Analyte	Total Load (g)	Bypassed Load		Infiltrated Load		Treatment Load Reduction		Total Load Reduction	
		(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
TSS	2,301	1,203	52%	603	26%	352	15%	955	42%
Arsenic(As),Total	0.13	0.07	52%	0.03	26%	-0.03	-22%	0.00	4%
Cadmium(Cd),Total	0.04	0.02	52%	0.01	26%	0.01	15%	0.01	41%
Chromium(Cr),Total	0.20	0.11	52%	0.05	26%	-0.03	-14%	0.02	12%
Copper(Cu),Total	1.18	0.62	52%	0.31	26%	0.00	0%	0.31	26%
Lead(Pb),Total	0.12	0.06	52%	0.03	26%	0.02	13%	0.05	39%
Nickel(Ni),Total	1.07	0.56	52%	0.28	26%	0.11	10%	0.39	36%
Selenium(Se),Total	0.04	0.02	52%	0.01	26%	-0.02	-51%	-0.01	-25%
Silver(Ag),Total	0.00	0.00	52%	0.00	26%	0.00	0%	0.00	26%
Zinc(Zn),Total	11.33	5.93	52%	2.97	26%	2.15	19%	5.12	45%
Total PAHs	0.012	0.006	52%	0.003	26%	0.002	19%	0.005	45%

Monitoring Event 2

For Event 2, Figure 3-4 shows the rainfall distribution, the modeled total runoff flow reaching the pervious pavement BMP, and the flow downstream of the BMP. The graphs show a rapid response to the rainfall followed by slow discharge of captured runoff downstream of BMP. Additional flow calculation are shown on Figure 3-5 including the flow into BMP, attenuated flow reaching the catch basin inlet information, total storm runoff volume, and total BMP capture volume.

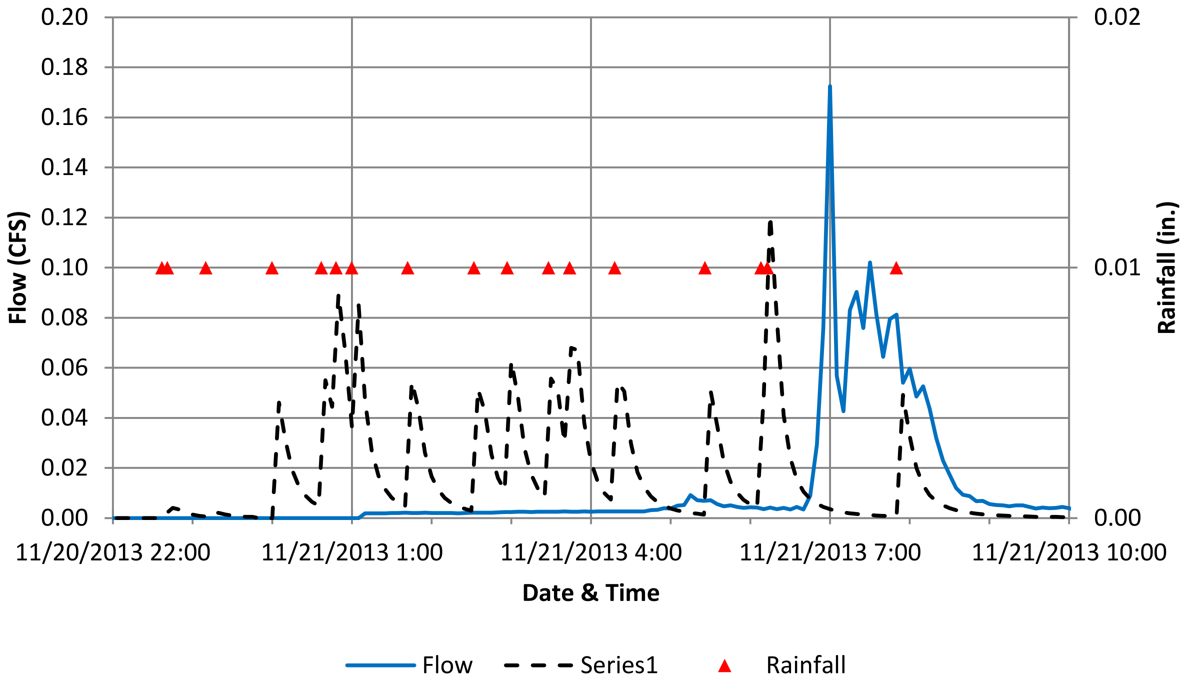


Figure 3-4. Event 2 Rainfall and Flow Graphs, Pervious Pavement BMP

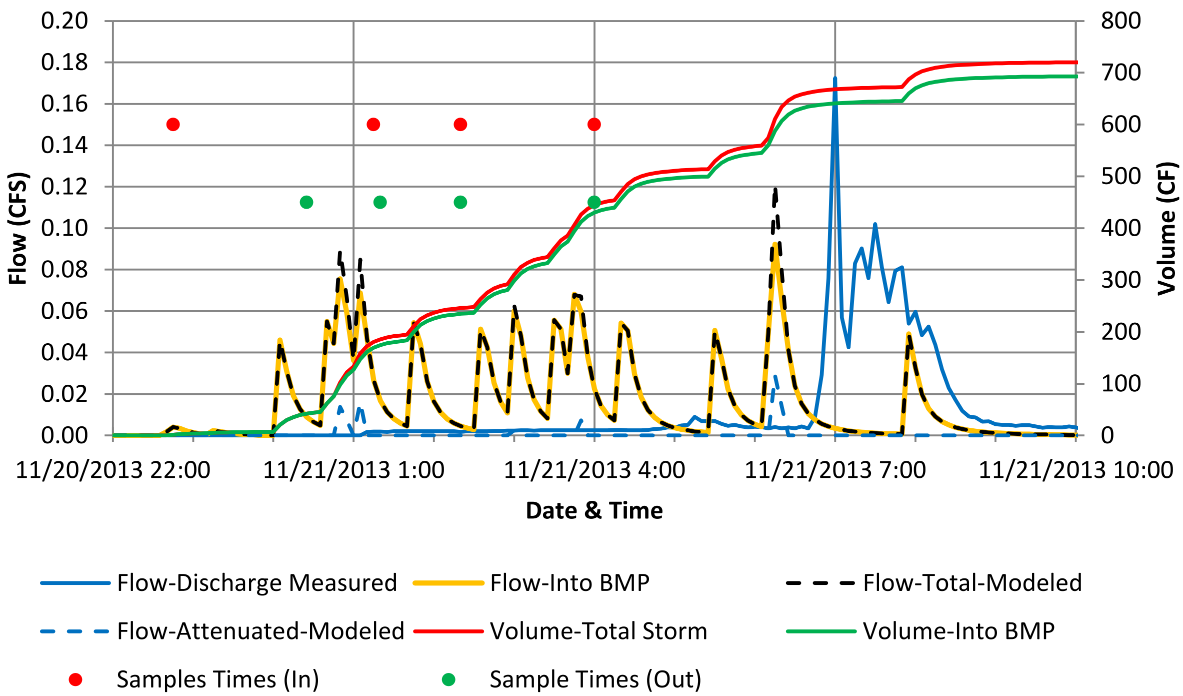


Figure 3-5, Event 2 Flow, Volumes, and Sampling Graphs, Pervious Pavement BMP

Table 3-5 provides a summary of the Event 2 flow calculations. The BMP discharge is based on the flow measured downstream of the BMP as during this storm event runoff flow did not bypass the system. The volume infiltrated is based on the total flow captured by the BMP minus the treated BMP discharge flow.

Table 3-5. Summary of Event 2 Flow Results, Pervious Pavement BMP

Parameter	Value
Total Storm Volume	720 ft^3
Flow Captured by BMP	693 ft^3
BMP Discharge (Treated)	527 ft^3
BMP Infiltrated	166 ft^3
Volume that Bypassed BMP	27 ft^3

Table 3-6 provides a summary of the Event 2 load calculations for the Total Load entering the parking lot, the load which bypassed the BMP, the load that was infiltrated, the treatment load reduction, and the total load reduction realized by the installed BMP. Calculated load reductions varied greatly among the constituents. There was a 113% load increase for TSS, a 44% load reduction for total PAHs, and a 93% load reduction for oil and grease. Cadmium, chromium, lead, and selenium exhibited slight load increases (less than 0.05g), while arsenic had a moderate load increase (0.09g). Cadmium, copper, nickel, and zinc had load reductions. The largest load reductions occurred with zinc (1.27 g) and copper (0.13 g). Selenium, arsenic, lead, and chromium had negative treatment load reductions as a result of their respective concentrations being higher at the BMP discharge location than before they entered the BMP. This scenario, however, seems implausible, and is more likely the result of sample non-heterogeneity or possibly laboratory variability than a true reflection of the functioning of the BMP.

Table 3-6. Summary of Event 2 Load and Load Reductions for Pervious Pavement BMP

Analyte	Total Load (g)	Bypassed Load (g)	Bypassed Load (%)	Infiltrated Load (g)	Infiltrated Load (%)	Treatment Load Reduction (g)	Treatment Load Reduction (%)	Total Load Reduction (g)	Total Load Reduction (%)
TSS	143	5.35	4%	32.9	23%	-194.00	-136%	-161.10	-113%
Arsenic(As),Total	0.05	0.00	2%	0.012	23%	-0.10	-196%	-0.09	-173%
Cadmium(Cd),Total	0.00	0.00	2%	0.000	23%	0.00	-82%	0.00	-59%
Chromium(Cr),Total	0.02	0.00	2%	0.004	23%	-0.06	-315%	-0.05	-292%
Copper(Cu),Total	0.28	0.01	2%	0.066	23%	-0.06	-19%	0.01	4%
Lead(Pb),Total	0.01	0.00	2%	0.002	23%	0.00	-41%	0.00	-18%
Nickel(Ni),Total	0.15	0.00	2%	0.035	23%	0.03	22%	0.07	46%
Selenium(Se),Total	0.01	0.00	2%	0.002	23%	-0.03	-441%	-0.03	-418%
Silver(Ag),Total	0.00	0.00	0%	0.000	0%	0.00	0%	0.00	0%
Zinc(Zn),Total	1.38	0.02	2%	0.319	23%	0.87	63%	1.19	86%
Total PAHs	0.00	0.00	2%	0.000	23%	0.00	21%	0.00	44%
Oil and Grease	2,430	43.9	2%	560	23%	1,705	70%	2,266	93%

3.4.2 Bioretention BMPs

Loads were calculated for the two bioretention BMPs during each of the storm events. Measured inflow concentrations and modeled flows were used to generate the total load estimates. It should be noted that there was substantial variability in chemistry results between the two storm events for some constituents. As a result, some caution should be exercised when examining the estimated event and annual load reductions.

Monitoring Event 1

The total flow and volume captured during the October 9, 2013 storm event is shown in Figure 3-6 and Figure 3-7. During this event, 100% of the volume entering both the east and west bioretention BMPs was infiltrated.

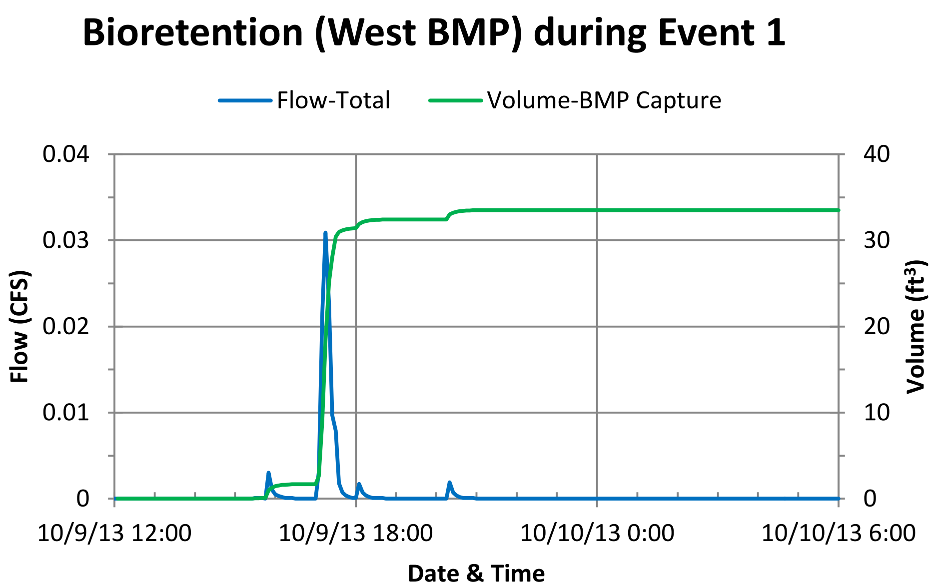


Figure 3-6. Total Flow and Volume of Storm Water Captured in West BMP during October 9, 2013 Storm Event

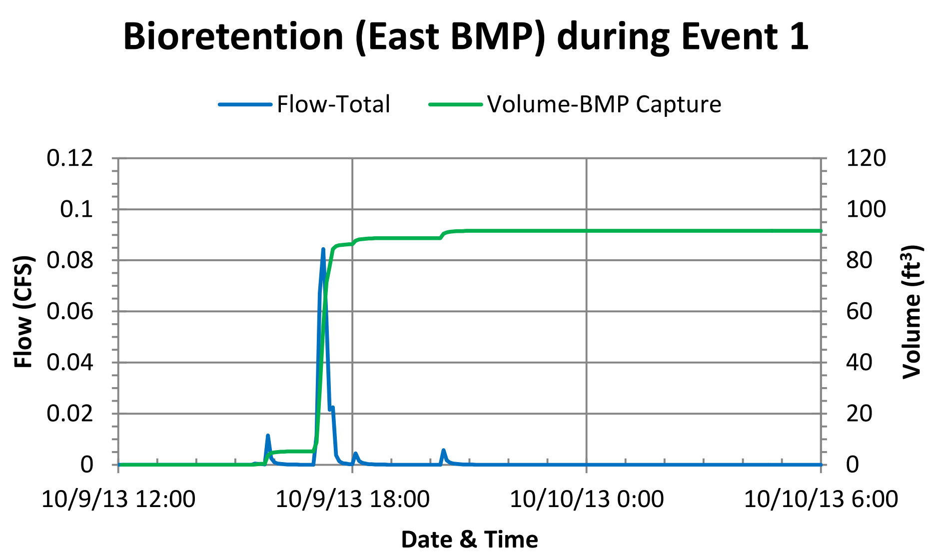


Figure 3-7. Total Flow and Volume of Storm Water Captured in East BMP during October 9, 2013 Storm Event

A summary of the flow entering the east and west bioretention BMPs during the October 9, 2013 storm event is provided in Table 3-7. The total volume captured by both bioretention BMPs was 125.1 ft^3. This volume of water infiltrated into the ground and evaporated into the atmosphere over the next several days (Figure 3-8), representing a load reduction to the ASBS. The total load retained by each BMP for a select list of analytes is shown in Table 3-8.

Table 3-7. Summary of Event 1 Flow Results, Bioretention BMPs

Bioretention BMP (West)		Bioretention BMP (East)	
Parameter	Volume Captured	Parameter	Volume Captured
Total Storm Volume	33.5 ft^3	Total Storm Volume	91.6 ft^3
BMP Capacity	192 ft^3	BMP Capacity	433 ft^3
Amount Captured	33.5 ft^3	Amount Captured	91.6 ft^3

Figure 3-8. West Bioretention BMP during October 9, 2013 Storm Event

Table 3-8. Summary of the Infiltrated Load for East and West Biorention BMPs during Event 1

Analyte	West Infiltrated Load (g)	East Infiltrated Load (g)	% Capture of Water Entering BMP
TSS	56.0	153.0	100
Arsenic(As),Total	0.0031	0.0084	100
Cadmium(Cd),Total	0.0009	0.0024	100
Chromium(Cr),Total	0.0049	0.0134	100
Copper(Cu),Total	0.0287	0.0786	100
Lead(Pb),Total	0.0028	0.0078	100
Nickel(Ni),Total	0.0261	0.0713	100
Selenium(Se),Total	0.0010	0.0028	100
Silver(Ag),Total	0.0000	0.0000	100
Zinc(Zn),Total	0.2757	0.7539	100
Total PAHs	0.0003	0.0008	100

Monitoring Event 2

The total flow and volume captured during the November 20-21, 2013 storm event is shown in Figure 3-6 and Figure 3-7. During this event, 100% of the volume entering both the east and west bioretention BMPs was captured.

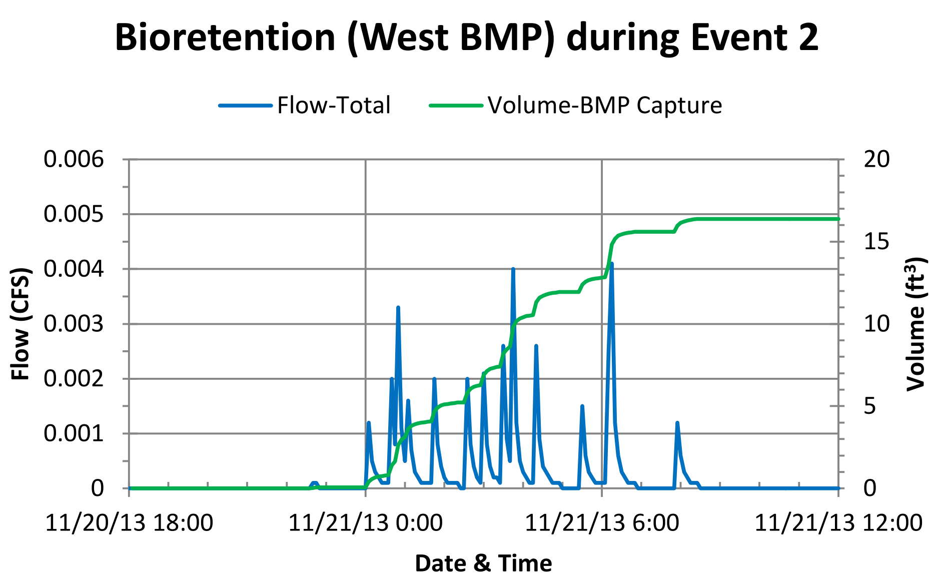


Figure 3-9. Total Flow and Volume of Storm Water Captured in West BMP during November 21, 2013 Storm Event

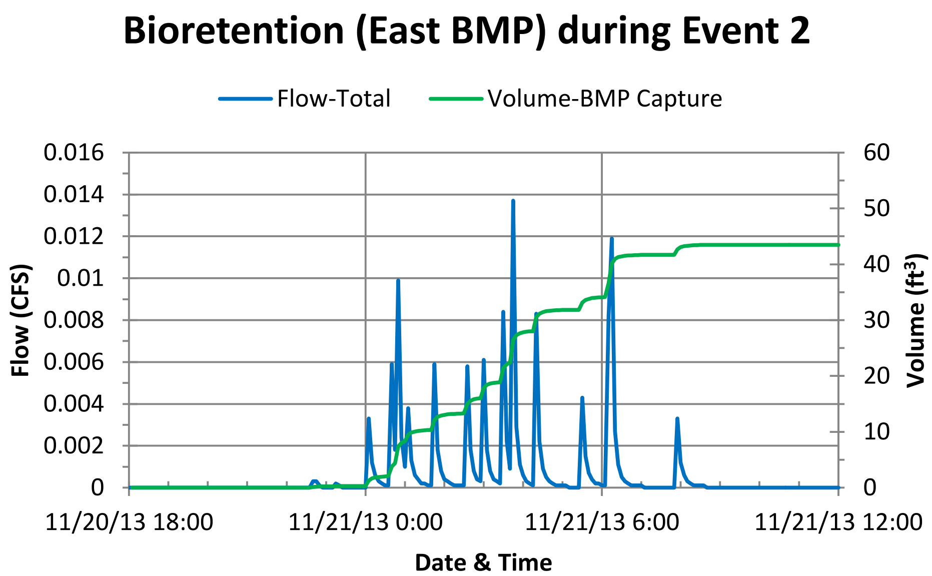


Figure 3-10. Total Flow and Volume of Storm Water Captured in East BMP during November 21, 2013 Storm Event

A summary of the flow entering the east and west bioretention BMPs during the November 20-21, 2013 storm event is provided in Table 3-9. The total volume captured by both bioretention BMPs during this event was 59.9 ft^3, which over the next several days infiltrated into the ground and evaporated into the atmosphere. The total load retained by each BMP for a select list of analytes is shown in Table 3-10.

Table 3-9. Summary of Event 2 Flow Results, Bioretention BMPs

Bioretention BMP 1 (West)		Bioretention BMP 2 (East)	
Parameter	Value	Parameter	Value
Total Storm Volume	16.4 ft^3	Total Storm Volume	43.5 ft^3
BMP Capacity	192 ft^3	BMP Capacity	433 ft^3
Volume Captured	16.4 ft^3	Volume Captured	43.5 ft^3

Table 3-10. Summary of the Infiltrated Loads for the East and West Bioretention BMPs during Event 2

Analyte	West Infiltrated Load (g)	East Infiltrated Load (g)	% Capture of Water Entering BMP
TSS	3.3	0.0086	100
Arsenic(As),Total	1.2	0.0032	100
Cadmium(Cd),Total	0.0	0.0001	100
Chromium(Cr),Total	0.4	0.0011	100
Copper(Cu),Total	6.5	0.0172	100
Lead(Pb),Total	0.2	0.0006	100
Nickel(Ni),Total	3.5	0.0093	100
Selenium(Se),Total	0.2	0.0005	100
Silver(Ag),Total	0.0	0.0000	100
Zinc(Zn),Total	31.5	0.0836	100
Total PAHs	16.5	0.0437	100

3.4.3 Annual Load Reductions

Annual load reductions were calculated using the average load reduction that occurred during the two monitored events, the amount of rainfall which fell during these events, and the average annual rainfall amount for Newport Beach (10.8 inches, www.newportbeachca.gov). Estimates of annual load reductions for the Pervious Pavement BMP are presented in
Results of annual load estimates indicate that 159 kg of TSS, 63.3 g of copper, 92.1 g of nickel, 1.3 kg of zinc, and 453 kg of oil and grease will be removed by the pervious pavement BMP.

Table 3-11, while estimates of the annual load reductions for the bioretention BMPs are presented in Load estimates for the bioretention BMPs indicate that 3.6 kg of TSS, 2.1 g of copper, 1.8 g of nickel, 18.7 g of zinc, and 3.3 kg of oil and grease will be captured by the bioretention BMPs over the course of one year.
Table 3-12.

Results of annual load estimates indicate that 159 kg of TSS, 63.3 g of copper, 92.1 g of nickel, 1.3 kg of zinc, and 453 kg of oil and grease will be removed by the pervious pavement BMP.

Table 3-11. Annual Load Reduction Estimate for Pervious Pavement BMPs

Analyte	Pervious Pavement Total Load Reduction (g)			
	10/9/2013	11/21/2013	Average	Annual
TSS	955.16	-161.10	397	158,813
Arsenic(As),Total	0.00	-0.09	-0.04	-17.3
Cadmium(Cd),Total	0.01	0.00	0.01	2.8
Chromium(Cr),Total	0.02	-0.05	-0.02	-6.1
Copper(Cu),Total	0.31	0.01	0.16	63.3
Lead(Pb),Total	0.05	0.00	0.02	8.8
Nickel(Ni),Total	0.39	0.07	0.23	92.1
Selenium(Se),Total	-0.01	-0.03	-0.02	-8.6
Silver(Ag),Total	0.00	0.00	0.00	0.0
Zinc(Zn),Total	5.12	1.19	3.16	1,264
Total PAHs	0.01	0.00	0.00	1.1
Oil and Grease	0.00	2,266	1,133	453,104

Load estimates for the bioretention BMPs indicate that 3.6 kg of TSS, 2.1 g of copper, 1.8 g of nickel, 18.7 g of zinc, and 3.3 kg of oil and grease will be captured by the bioretention BMPs over the course of one year.

Table 3-12. Annual Load Reduction Estimates for Bioretention BMPs

Analyte	West Infiltrated Annual Load (g)	East Infiltrated Annual Load (g)	Total Annual Load Infiltrated by East and West (g)
TSS	969	2,645	3,614
Arsenic(As),Total	0.07	0.19	0.3
Cadmium(Cd),Total	0.02	0.04	0.1
Chromium(Cr),Total	0.09	0.24	0.3
Copper(Cu),Total	0.58	1.57	2.1
Lead(Pb),Total	0.05	0.14	0.2
Nickel(Ni),Total	0.48	1.32	1.8
Selenium(Se),Total	0.02	0.05	0.1
Silver(Ag),Total	0.00	0.00	0.0
Zinc(Zn),Total	5.03	13.71	18.7
Total PAHs	0.00	0.01	0.0
Oil and Grease	905.8	2402.7	3308.5

4.0 DISCUSSION

Results from the effectiveness assessment of the Reef Point Parking Lot BMPs indicate that in general, it appears to be working as designed, effectively reducing TSS, total metals and total PAH loads in storm water runoff through infiltration, treatment, and bioretention. Over the course of two monitored storm events, total metals loads of copper, zinc, nickel and lead flowing into the modular wetland system treatment (pervious pavement) BMP were reduced by 22%, 50%, 38%, and 35%, respectively, while TSS loads were reduced by 33%, total PAH loads were reduced by 45%, and oil and grease loads were reduced by 93%. These findings are based on a somewhat limited dataset, however, and load reductions would likely vary depending on storm durations and intensities. Increases in loads of arsenic, chromium, and selenium were calculated based on their respective inflow and outflow concentrations. Because it seems unlikely that the treatment system is adding to pollutant loads, the increase in loads of these pollutants (especially arsenic and chromium) may be due to variability of storm water runoff and the low detection levels provided by the laboratory methods. Overall, the pervious pavement BMP is projected to reduce calculated annual loads of TSS, copper, zinc, nickel, and lead by 158 kg, 63.3 g, 1.2 kg, 92.1 g, and 8.8 g, respectively, based on the data collected over the course of both storm events. The pervious pavement BMP captured 48% of the parking lot flow during Event 1 and 96% of the flow during Event 2.

The performance of the parking lot treatment train may be improved by adding flow dissipators along the pervious gutter system. During high rainfall intensity periods, some flow in the curb and gutter system bypass the BMP. This is due to the curb and gutter system having a limited hydraulic capacity (estimated at about 80 inches per hour). Potential future projects may include installing two or three flow dissipators along the pervious concrete gutter. The dissipator would consist of small, prefabricated concrete triangles bolted into the pervious concrete gutter. Runoff hitting the dissipators would be slowed and redirected towards the pervious pavers. The slowing and spreading of flow would increase the surface area so that a greater volume of water (greater portion of total runoff) would be captured during high intensity rainfall periods. The design would need to ensure that the flows are properly redirected towards the pavers and not outside the paved area. Additionally, the design of the concrete triangles should not inhibit parking any more than necessary (e.g., be centered between parking lines). Since pedestrians returning from the beach may inadvertently step on the dissipators, the surface would need to be somewhat smooth without jagged edges.

A 100% load reduction was realized for storm water entering the east and west bioretention BMPs during both of the monitored storm events. Annually, the east and best bioretention BMPs were calculated to reduce loads of TSS by 3.4 kg, copper by 108 g, zinc by 534 g, nickel by 58.9 g, and total PAHs by 270.5 g. It should be noted that the annual load calculations assume storm events that are similar to those that were monitored. If a much larger storm event would occur, runoff into the bioretention BMPs would likely exceed their capacity and subsequently flow to the pervious pavement BMPs.

5.0 REFERENCES

Bight 2013 ASBS Planning Committee. 2012. *Southern California Bight 2013 Regional Monitoring Survey (Bight '13) Areas of Biological Significance (ASBS) Workplan*. October 2012.

McCain and Dewoolkar (McCain, G. and Dewoolkar, M.). 2010. *Porous Concrete Pavements: Mechanics and Hydraulic Properties*. Accessed at: http://www.uvm.edu/~transctr/publications/TRB_2010/10-2228.pdf

Orange County. 1986. *Orange County Hydrology Manual*. October 1986.

Southern California Bight 2008 Regional Monitoring Program: II. Areas of Special Biological Significance. 2011. K Schiff, B. Luk, D. Gregorio, and S. Gruber. Southern California Coastal Water Research Project. Costa Mesa, CA.

State of California, State Water Resources Control Board. 2012. Water Quality Control Plan, Ocean Waters of California: California Ocean Plan. Adopted October 16, 2012.

State Board (State Water Resources Control Board). 2012. *Amending the General Exception to the California Ocean Plan for Selected Discharges into Areas of Special Biological Significance, Including Special Protections for Beneficial Uses*. Resolution No. 2012-001. June 19, 2012.

Weston Solutions. 2011. *Quality Assurance Project Plan and Monitoring Plan: Newport Coast ASBS Protection Implementation Program*. October 2011.