EXECUTIVE SUMMARY

Hybrid Low Impact Development/Best Management Practices for DoD Industrial Site Storm Water Runoff

ESTCP Project ER-201634

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ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per Liter
BMP	Best Management Practice
BSM	Biofiltration Soil Media
CRWQCB	California Regional Water Quality Control Board
DoD	Department of Defense
EMC	Event Mean Concentration
EPA	United States Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
EXWC	Expeditionary Warfare Center
FRC MFC	Fleet Readiness Center Metal Finishing Complex
FS-50	Activated Alumina
ft	feet/foot
gpm	gallon(s) per minute
LID	Low Impact Development
mg/L	Milligrams per Liter
MRL	Maximum Residue Level
NAL	Numeric Action Limit
NAVFAC	Naval Facilities Engineering Command
NBPL	Naval Base Point Loma
NPDES	National Pollution Discharge Elimination System
PVC	Polyvinyl Chloride
TAPE	Testing Assessment Protocol-Ecology
TSS	Total Suspended Solids

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1.0 INTRODUCTION

This technology demonstration addresses elevated concentrations of environmental pollutants commonly found within Department of Defense (DoD) industrial site storm water runoff. The project focus is decreasing toxic metal concentrations (primarily copper and zinc) within storm water runoff emanating from high risk industrial areas. The DoD is under increasing pressure from regulators and local communities to reduce the amount of storm water pollutants discharging into oceans, harbors, bays, lakes, and streams. This technology demonstration provides the DoD with an additional method to decrease the concentration of toxic contaminants within storm water runoff, thereby avoiding Notices of Violation from regulating agencies and improving public perception of DoD environmental stewardship.

The hybrid Low Impact Development/Best Management Practice (LID/BMP) system is an innovative, low maintenance, and gravity driven technology that combines LID with a structural BMP to remove metals, total suspended solids (TSS), and low concentrations of petroleum hydrocarbons from storm water runoff. The high flow LID media and plant matrix reduce the concentration of typical pollutants found in storm water by mimicking the contaminant removal mechanism of a natural swale. It occupies a smaller footprint than a natural swale by exceeding traditional swale percolation rates. The structural BMP further polishes the LID effluent with adsorbent media to remove problematic ionic contaminants like copper and zinc down to ultra-low levels.

2.0 OBJECTIVES

The project objective was to demonstrate and validate a full scale, modular 100 gallons per minute (gpm) Hybrid LID/BMP System that decreases metal concentrations within storm water runoff from high risk industrial areas to ultra-low National Pollution Discharge Elimination System (NPDES) permit limitations. The demonstration was conducted at the Fleet Readiness Center Metal Finishing Complex (FRC MFC) located on Naval Base Point Loma (NBPL) in San Diego, California. Table 1-1 has the site-specific system performance objectives of the demonstration plan derived from the California Regional Water Quality Control Board (CRWQCB), San Diego Region Water Discharge Requirements for the United States Department of the Navy, Naval Base Point Loma Complex of San Diego County, NPDES Permit No. CA0109363.

Table 1. Demonstration Plan Performance Objectives

Performance Objective		Data Requirements	Success Criteria	Results
Quantitative				
Reduce Pollutants in Effluent	Whole Effluent Acute Toxicity Limitation	Hybrid LID/BMP effluent sampling data according to "Methods for Estimating the Acute Toxicity of Effluent and Receiving Waters to Freshwater and Marine Organisms", EPA[1] Method 821-R-02-012	80% survival in 100% effluent from Hybrid LID/BMP outlet	Met

Table 1. Demonstration Plan Performance Objectives (Continued)

Performance Objective		Data Requirements	Success Criteria	Results
	Reduce total copper in storm water runoff	Hybrid LID/BMP influent and effluent sampling data, EPA Method 200.8	Reduce Hybrid LID/BMP effluent concentration of total copper to less than 33.2 µg/L[†,2]	Met
			(or 2.9 µg/L ultra-low secondary success criteria)	Not Met
	Reduce total zinc in storm water runoff	Hybrid LID/BMP influent and effluent sampling data, EPA Method 200.8	Reduce Hybrid LID/BMP effluent concentration of total zinc to less than 260 µg/L[1]	Met
			(or 95 µg/L ultra-low secondary success criteria)	Met
	Reduce oils and grease in storm water runoff	Hybrid LID/BMP influent and effluent sampling data, EPA Method 1664, Revision A (TAPE[3] TPH-dx Method EPA 8015 B)	Reduce Hybrid LID/BMP effluent concentration of oil and grease grab samples to less than 15 mg/L	Met
	Reduce TSS in storm water runoff	Hybrid LID/BMP influent and effluent sampling data, EPA Method 2540.B	Reduce Hybrid LID/BMP effluent concentration of TSS to less than 100 mg/L[†,4]	Met
	Limit export of other storm water pollutants	Storm water influent, LID biofilter effluent, and dual-media filter BMP effluent sampling data. Lab analysis according to various EPA methods.	Limit other potentially regulated storm pollutants that could be exported by treatment components (orthophosphate and total phosphorus)	Met
Limit Capital Cost		Watershed Acreage and actual Capital Cost	Less than $100,000 per acre of drainage	Not Met
Vegetation Health		Observational data and photos during field demonstration	Plants maintain health and do not dieback during dry summer months	Met
Qualitative				
Reduce Preventative Maintenance	Ease of use	Field photographs, field technician feedback, and maintenance log input	Minimal annual maintenance requirement (inspection, sweeping and particulate cleanup)	Met

† Total maximum daily load reduction criteria are included within the NBPL NPDES permit via compliance with Numeric Action Limit (NAL) and acute toxicity requirements.

1 United States Environmental Protection Agency

2 Micrograms per Liter

3 Testing Assessment Protocol-Ecology

4 Milligrams per Liter

3.0 TECHNOLOGY DESCRIPTION

The Hybrid LID/BMP System is comprised of three main components: a pretreatment gabion wall; LID biofilter; and a dual media BMP. These three components treat the storm water runoff as it passes through the system. There are two overflow bypasses, one for the LID biofilter, and one for the BMP media filter. The multi-stage passive system works together to polish the storm water to meet NPDES permit levels.

The pretreatment filter gabion wall is intended to extend the life and improve the performance of the LID biofilter by acting as a roughing filter to remove gross solids, trash, and debris from storm water runoff. The twelve inch tall by six inch wide gabion is constructed of ¾ inch to 2 inch rail ballast (AREMA size No. 4A) enclosed within a ultra-violet resistant, plastic coated wire mesh wrapped within U.S. Fabrics 1540 woven geo-fabric. The gabion is oriented so that it extends across the upstream sides of the LID biofilter to intercept runoff. As the gabion wall fills in with gross solids over time, it creates a small pond upstream of the LID for solids to settle.

Operations and maintenance activities for the gabion include "as needed" sweeping of the asphalt settling area immediately upstream of the LID, sweeping of the upstream face of the woven geo-fabric, and disposal of the swept sediments.

The LID biofilter is the next stage of the Hybrid LID/BMP System and features a proprietary high performance modular biofiltration product called FocalPoint, purchased from California Filtration Specialists. The FocalPoint biofilter is designed to remove copper, zinc, TSS, oils and grease, and other pollutants of concern. The LID footprint for the demonstration is approximately 10 feet (ft) by 20 ft and has a design flow rate of approximately 1 gpm/ft^2 when clean, which equates to a 200 gpm maximum flow rate. However, the design flow rate is expected to diminish over the life cycle of the technology as the biofiltration soil media (BSM) filters TSS and other particulates. The LID biofilter was intentionally oversized to minimize the required preventative maintenance frequency and reduce the BSM replacement frequency. Typical southern Californian native vegetation (Cleveland Sage, Purple Sage) with very low water demands are planted in the BSM. The native plants have appropriate root thickness, density, and length to prevent clogging and short-circuiting of the BSM. The LID biofilter removes typical storm water pollutants at a high hydraulic conductivity of 100 inches per hour. Sand and gravel in the BSM remove particulate pollutants and provide structure for vegetation and some water retention. A small amount of peat in the BSM removes dissolved and organically complexed copper, zinc, and other hydrophobic organics. The peat content also improves the nutrients and water holding capacity of the BSM for healthy plant growth.

The storage tank, irrigation controller, and drip irrigation system are designed to provide sufficient water to meet LID biofilter vegetation needs during dry summer months. The FocalPoint modular underdrain performs as the storage tank and has an impermeable liner to prevent infiltration of water into underlying soils. The storage tank dimensions are approximately 10' wide by 20' long by 9" deep with a total storage volume of approximately 1,100 gallons. A submersible pump located at the bottom of the inspection port within the storage tank supplies water via drip irrigation piping located on the surface of the LID biofilter. The drip irrigation ensures distribution of water across the very porous BSM (underneath the mulch layer). A Rain Bird ESP-SMT smart modular controller provides an adjustable irrigation schedule with a soil moisture sensor override to prevent overwatering during summer months.

The dual-media filter BMP functions as a polishing stage downstream of the LID biofilter to further reduce copper and zinc concentrations below applicable benchmarks. The BMP consists of a two-chamber concrete vault with external dimensions of 16 ft long by 8 ft 3 inches wide and 5 ft 9 inches deep. The first chamber holds the adsorption media (12 ft long and 7 ft 2 ¼ inch wide) filled with 6 inches of 8x30 mesh bone char on top of 9 inches of 28x48 mesh iron coated activate alumina (FS-50). The second chamber is a second clear well chamber (2 ft 7 ½ inch long by 7 ft 2 ¼ inch wide) for hydraulic controls and monitoring infrastructure.

Storm water exiting the LID biofilter flows directly into a 4 inch polyvinyl chloride (PVC) distribution header, which is slightly sloped in the direction of flow and extends the length of the filter media bed. The distribution header sits atop the media bed on top of the geofabric layer with a 2 inch layer of ¾ inch gravel for support and scour prevention. The majority of the remaining pollutants that enter the BMP media bed are in the dissolved fraction or associated with very fine TSS. The bone char and FS-50 layers reduce the concentration of the dissolved contaminants. A ¾ inch washed river stone layer is included below the FS-50 to assist with drainage and prevent media from bleeding into the underdrain.

The dual-media filter BMP is designed for a flow rate of 100 gpm. Flow through the dual-media filter BMP is moderated by a level control weir located within the clear well that maintains an 8 minute contact time between the adsorbent media and storm water runoff. This level control weir can easily be modified to obtain a shorter or longer contact time. Discharge from the weir overflows into the clear well and then continues into the outlet pipe leading to discharge outfall. Any remaining water within the adsorbent media bed and clear well drains through a weep hole over a 72-hour period. Figure 1-1 and Figure 1-2 provide a plan and cross section view of the entire system.

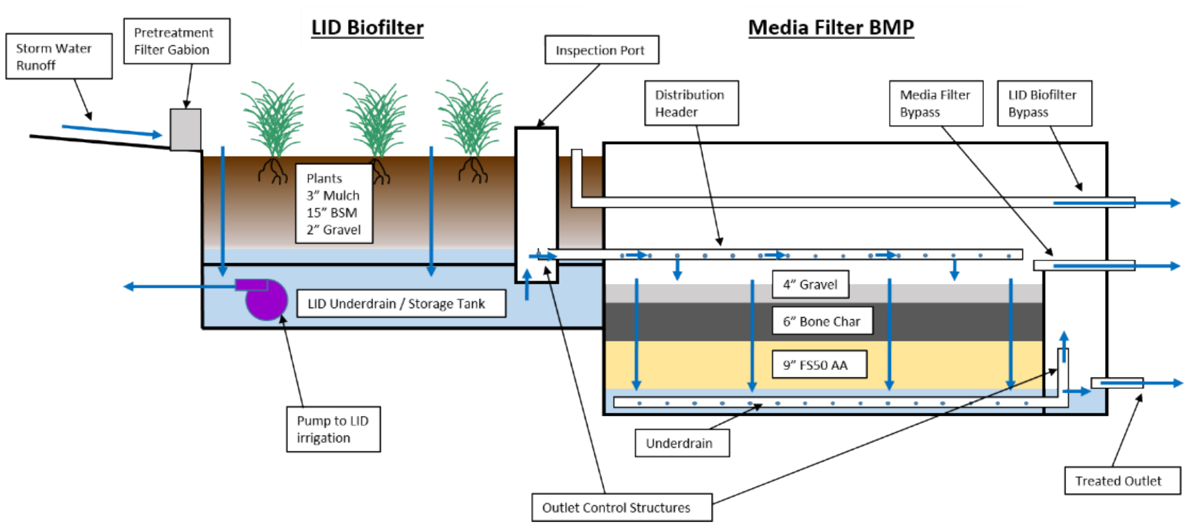

Figure 1. Conceptual Cross Section Diagram for Hybrid LID/BMP System

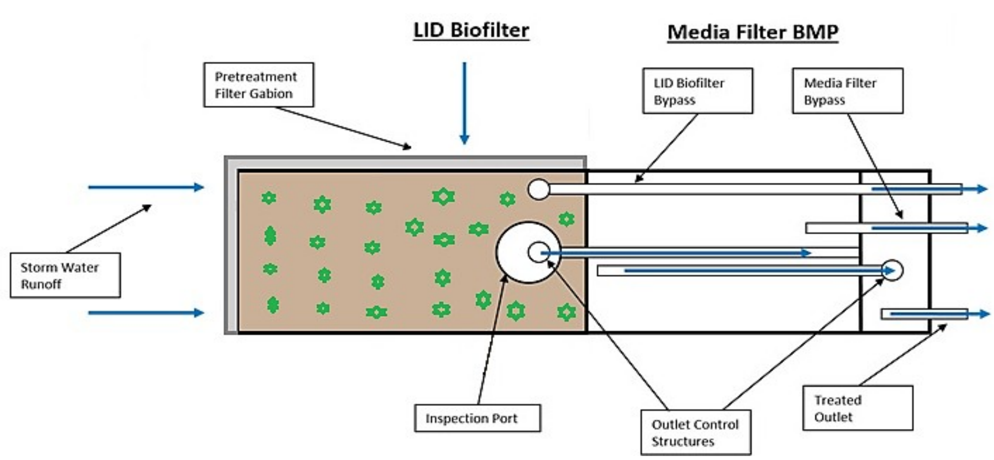

Figure 2. Conceptual Plan View Diagram for Hybrid LID / BMP System

4.0 PERFORMANCE ASSESSMENT

The ability of the technology to remove and/or limit the export of pollutants was evaluated on the basis of pollutant concentrations in composite storm water samples collected at the influent and effluent of the Hybrid LID/BMP System. Additional samples were collected at the inlet and outlet of each component of the LID biofilter stage to better understand the pollutant removal process (and efficiency) for TSS and targeted metals. Effluent concentrations in the LID biofilter and media filter samples were compared to influent concentrations to assess removal or export of pollutants by each system component. Composite water quality samples were collected from 14 qualifying storms during the demonstration period. The Naval Facilities Engineering Command (NAVFAC) Environmental Laboratory located at Naval Base Coronado in San Diego collected the storm water samples, and sample analysis was conducted by an accredited laboratory, ALS Environmental Services Laboratory located in Kelso, Washington. ALS Environmental Services Laboratory was able to meet the lower metals detection limits required for this demonstration project. The data for copper, zinc, and TSS are presented below in the following tables.

Table 2. System Copper Reduction Data

Rain Event Date	Total Copper Influent/Effluent EMC† (µg/L)	Dissolved Copper Influent/Effluent EMC (µg/L)	Total Copper Efficiency Ratio (%)	Dissolved Copper Efficiency Ratio (%)
11/29/18	308/5.79	98.5/1.82	98	98
12/5/18	112.0/5.71	49.3/1.87	95	96
1/5/19	39.3/3.2	31.8/0.95	92	97
1/12/19	84.9/5.97	78.8/6.14	93	92
1/14/19	66.5/4.23	64.5/3.9	94	94
1/31/19	118.0/6.32	75.5/2.07	95	97
2/13/19	82.3/5.02	53.8/2.31	94	96
2/20/19	176/1.49	88.3/0.80	99	99
3/2/19	218/5.29	35.8/2.87	98	92
3/11/19	67.8/4.05	50.4/1.83	94	96
3/20-21/19	217/6.01	63.7/2.9	97	95
4/29/19	379/5.64	298/3.08	99	99
5/10/19	134/4.61	102/2.37	97	98
5/19/19	137/9.32	116/5.59	93	95
Seasonal Efficiency Ratio	153/5.2	86.2/2.8	97	97

† Event Mean Concentration

Table 3. System Zinc Reduction Data

Rain Event Date	Total Zinc Influent/Effluent EMC (µg/L)	Dissolved Zinc Influent/Effluent EMC (µg/L)*	Total Zinc Efficiency Ratio (%)	Dissolved Zinc Efficiency Ratio (%)
11/29/18	769/8.5	433/4.8	99	99
12/5/18	320.0/10.0	223.0/6.1	97	97
1/5/19	156/4.5	140.0/2.5	97	98
1/12/19	246.0/5.3	242.0/9.2	98	96
1/14/19	204.0/13.2	203.0/14.7	94	93
1/31/19	473.0/7.1	404.0/4.2	99	99
2/13/19	241.0/6.2	207.0/5.0	97	98
2/20/19	702/2.5	625/1.9	99	99
3/2/19	424/3.2	94.5/4.4	99	95
3/11/19	240/4.3	204/2.1	98	99
3/20-21/19	379/4.2	291/2.2	99	99
4/29/19	599/7.5	539/5.9	99	99
5/10/19	217/6.1	181/4.7	97	97
5/19/19	265/9.2	239/7.2	97	97
Seasonal Efficiency Ratio	374/6.6	288/5.4	98	98

Table 4. System Total Suspended Solids Reduction Data

Rain Event Date	TSS Influent EMC (mg/L)	TSS Effluent EMC (mg/L)	TSS Efficiency Ratio (%)
11/29/18	280	6.4	98
12/5/18	82.6	5.2	94
1/5/19	7.4	2.4	68
1/12/19	25	2.5	90
1/14/19	26.5	2.2	92
1/31/19	30.7	4.2	86
2/13/19	15.3	3.5	77
2/20/19	58	1.2	98
3/2/19	16.8	1[U]	94
3/11/19	4	1.2	70
3/20-21/19	99.6	2.7	97
4/29/19	33.6	2.2	94
5/10/19	16.5	1[U]	94
5/19/19	9.0	1.2	87
Seasonal Efficiency Ratio	50.4	2.6	95

[U] The analyte was analyzed for but was not detected at or above the maximum residue level (MRL). Substituted MRL value for calculation.

All effluent EMC values for copper were below the NBPL permit limit of 33.2 µg/L. For total copper, one out of fourteen effluent results met the ultra-low NPDES permit limit of 2.9 µg/L, for areas such as Hawaii. The seasonal effluent EMC was 5.2 µg/L and seasonal efficiency ratio was 97%. For dissolved copper, which is thought to be the more toxic fraction, the seasonal effluent EMC was 2.8 µg/L and the average seasonal efficiency ratio was 97%. All effluent EMC values for total zinc were well below the NBPL permit limit of 260 µg/L. The average seasonal efficiency ratio for both total and dissolved zinc was 98%. All effluent EMC values for TSS were well below the NBPL permit limit of 100 mg/L and the ultra-low benchmark of 50 mg/L. The average seasonal efficiency ratio was 95%.

5.0 COST ASSESSMENT

The project goal was to limit system capital costs to $100,000 per acre of drainage. The system capital cost was $157,010 for the one-acre site. The cost exceedance is due to the construction complexity of the site, San Diego's high regional construction cost, and the built-in uncertainties with installing a prototype system on a government installation. When assessing the system's ability to meet the most stringent permit requirements, its small footprint, minimal maintenance requirements, and the total lifecycle cost still makes the system a feasible option. Sites that do not have as many physical restraints as the NBPL site (limited accessibility – i.e., buildings, fences, and underground utilities) are expected to be more affordable. Furthermore, there is some economy of scale with larger watershed areas that reduce overall capital cost.

6.0 IMPLEMENTATION ISSUES

Site layout is a key factor for system implementation. To achieve gravity flow for the entire process, the site must have a 4.5 ft drop in elevation from the asphalt area to the invert of the outfall or discharge point. The BMP media vault is a modular unit, so with larger drainage areas, multiple vaults must be installed in parallel to handle the larger flowrates expected. The LID component is customizable and not based on a set unit size.

This project demonstrated the Hybrid LID/BMP System's ability to achieve high metals and TSS removal consistently over two rain seasons. The average removal percentage for total and dissolved copper was 97%, total and dissolved zinc was 98%, and TSS was 95%. Over the project life, the system received minimal maintenance and only two contractor maintenance cycles were performed to replace the top three inches of mulch on the LID biofilter. Multiple research and development projects continue to use the site as a test bed. The system is still in place at NBPL and actively treating storm water runoff.

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