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Publication Date

2015-04-01

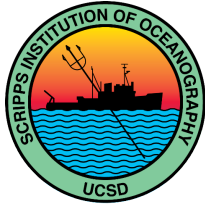


Biofilters in San Diego County: A descriptive analysis of their stormwater management implications, the water regime's role and the way forward



By
Paloma Aguirre

KEY WORDS: Biofilters, Stormwater Management, LIDs, BMPs, San Diego County, Urban Development, Southern California Stormwater Management



Capstone Research Project Final Report

Submitted in partial fulfillment of the requirement for the

Masters in Advance Studies

Marine Biodiversity and Conservation

Scripps Institution of Oceanography

Class of 2015

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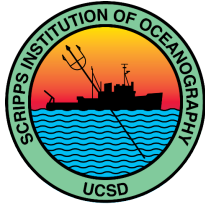


INTRODUCTION

As San Diego County continues to grow, so do the challenges to address stormwater runoff. Stormwater runoff can have significant impacts to coastal and marine ecosystems. Furthermore the need to reduce water consumption and reuse gray water has never been as important as in our current situation. Southern California is experiencing drought conditions unlike anything ever before seen. According to the third national climate assessment (2014), microclimate weather models predict increased temperatures, drought conditions and less frequent but more intense storm events. Drought conditions can lead to water repellent soils, which could increase the volume and speed of stormwater runoff, increasing pollution in our local waterways and coastline.

Low Impact Development (LID) is a land use-planning technique, which aims to create sustainable development while minimizing potential impacts to the environment. It is technique used by urban planners, landscape architects and stormwater managers (EPA, 2015).

Biofilters are considered a type of LID and are commonly referred to as a Best Management Practice or BMP. BMPs attempt to restore hydrology to a pre-development state by capturing pollutants through a number of different techniques including: detention, retention, redirection, repurpose, infiltration, and evapotranspiration techniques. Biofilters are a combination of a media filter, underground retention basin, and a small community of plants on top and other cover such as mulch or rocks. These elements are intended to prevent pollution elements such as solid waste, pathogens, sediments, chemicals and metals from entering waterways and



minimizing impacts to bodies of water intended for beneficial uses (Trowsdale and Simcock, 2011)

Urban runoff in San Diego County is a major stressor to coastal waters (Ahn et al, 2005) causing detrimental effects on coastal and marine ecosystems. Polluted runoff can increase eutrophication due to high levels of nutrients such as phosphorous and nitrate (Correll, 1998) Heavy metals left on surface roads due to tire threading or waste tire leaching, can accumulate on roadways and be carried to the ocean with first flush rain events. Heavy metals have been found to cause ecological and biological impacts. According to recent peer reviewed authors, waste-tire leaching has detrimental effects on amphibians found in ponded water, commercially significant fish-larvae found in estuarine systems, and macro-algae in the marine environment (Turner and Rice, 2010) (Camponelli et al, 2009) (Selbe et al, 2015). This is due to elevated Zn and other heavy metals that leach from waste-tires dissolving at a faster rate in water, preventing many of these organisms from conducting key biological processes such as photosynthesis and proper development. The increasing threat of global warming and the weather change patterns forecasted by leading researchers for Southern California will compound all of these effects.

Excessive sedimentation can also have negative effects to coastal ecosystems. It can blanket estuarine systems and prevent infaunal organisms from receiving sufficient oxygen (Lee et al, 2006). Anthropogenic disturbances upstream throughout coastal watersheds can pose significant bacteriological and viral impacts to recreational waters (Mallin et al, 2000). Additionally, polluted runoff impacts tourism-dependent coastal communities by decreasing recreational use of



the county's beaches due to health risks (DEH, 2015) and discourages would-be-visitors from traveling to the beach to recreate (Lew and Larson, 2005).

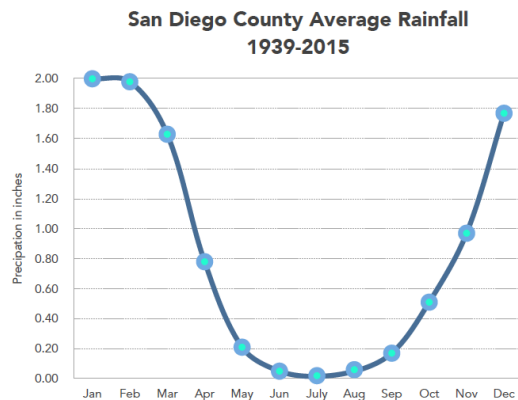
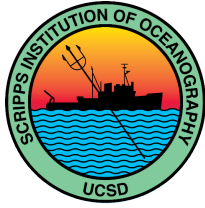


Figure # 1 Average Annual Rainfall for San Diego County

imported water from the Colorado River. Water reuse is an alternative, which could prove to be effective in providing water for irrigation of biofilters. Biofilters/bioretenion basins could help harvest stormwater runoff. Captured water percolates and replenishes aquifers. Recycled water can be used to irrigate biofilters found in public areas managed by the City. With southern California experiencing the most severe drought on record, Governor Jerry Brown issued emergency drought actions, during which the State Water Board adopted the 2015 Water Conservation Regulation in order to safeguard the State's water supply after a prolonged four-year drought (SWRB, 2015). As projected weather change patterns forecast less frequent, but more intense storm events for California, the issue of water erosion due to water repellent soils can complicate the actions of addressing storm water runoff effectively. Authors utilize the term Antecedent Dry Days or (ADD) to account for long periods in between each rainfall event. These ADDs can contribute to increased erosion, stormwater flow velocity and decreased natural

Stormwater harvesting is a practice that would greatly benefit San Diego County, yet it has not been entirely explored. Recent severe drought conditions to this region have prompted water resource managers and decision-makers to explore alternative sources of water other than the



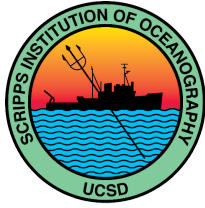
infiltration all due to dry and water repellent soils because of current drought conditions (Ritsema et al, 1998). San Diego has on average most of its rainfall during the months of November, December and January (see Figure # 1) and most dry months lasting from May through October. These periods of dry weather can be exacerbated by forecasted intense drought conditions for southern California. Given that biofilters require a set of components including plants with well established roots to contribute to nutrient uptake in order to fully function as intended, appropriate management of biofilters is now more important than ever to ensure their proper function.

GOALS AND OBJECTIVES

The goal of this study is to conduct an in-depth policy and management analysis of biofilters in San Diego County. This assessment will examine their implications in stormwater management, the water regime's role and recommendations on what specific type of biofilter is the most suited for southern California's projected global warming-related changes in weather patterns.

This study addressed the following questions:

1. Who are the key players in relation to biofilter regulation, design, management and maintenance in San Diego County?
2. What implications does the new 2014 MS4 permit have on their operation and maintenance?
3. What operation and maintenance procedures are required to maintain biofilter ability to remove pollutants from stormwater runoff?



4. What are the current management strategies used by San Diego County's water regime to ensure biofilters are performing appropriate functions?
5. What types of biofilter design are best for San Diego County for San Diego's seasonal changes and projected global warming-related changes in microclimate weather patterns?
6. What management model would work best for San Diego County's water regime in order to improve coordination and communication among all key stakeholders?

WHAT IS A BIOFILTER?

Biofilters are Low Impact Development (LID) techniques, which through physical, physico-chemical and biological processes (Bratieres et al, 2008) filter (retain or remove) pollutants preventing them from entering waterways and aquatic ecosystems. LID techniques include green infrastructure development, devices and design. In the stormwater management regime, a device that helps remove stormwater pollutants are referred to as a Best Management Practice or BMP.

A biofilter is a BMP designed to capture and reduce flow of stormwater runoff through infiltration, evapotranspiration, and discharge via an underground drain outlet structure. Stormwater is treated through a combination of biogeochemical processes, microbial, vegetative and organic uptake and filtration through a mixed or single media filter. Biofilters have the following elements: a) media filter, b) basin retention and c) an ecological community consisting



of physical elements, plants, animals and a microbial infauna community (Figure#2). Research has suggested that biofilters with these elements are conducive to establishing deep seed roots.

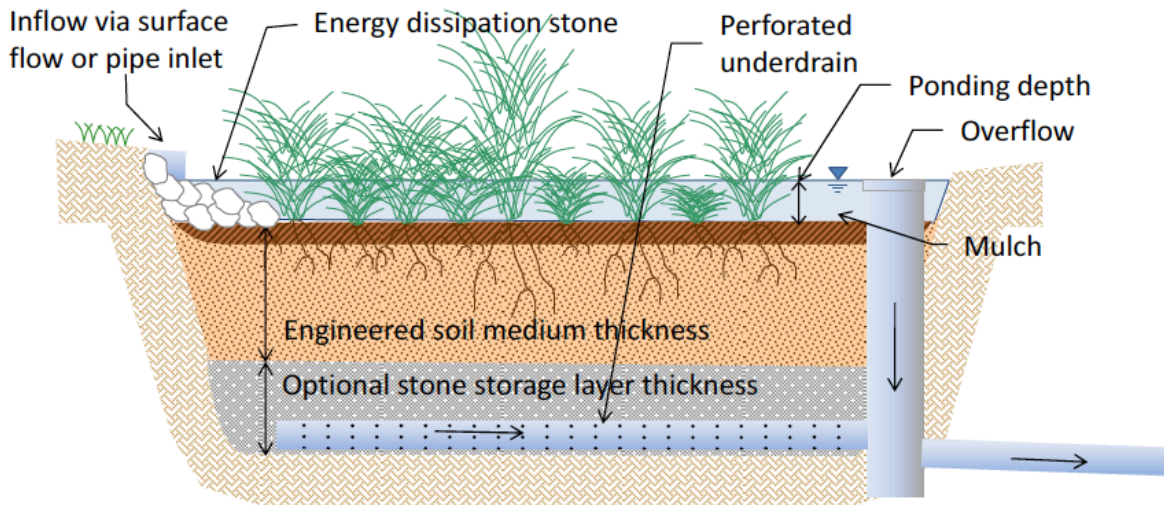


Figure 2. Biofilter elements. Image source: Model Best Management Practices Manual Handbook, 2015.

Deep seeded roots have been demonstrated to have the strongest ability to remove pollutants (Read et al, 2009).

The term biofilter is used interchangeably with other types of BMPs (bioswales, rain gardens, rock gardens), which can prove to be problematic because it can increase the potential for miscommunication and confusion (Fletcher, et al 2014).

Here I describe the different definitions found in the literature:

Bioretention systems

Bioretention systems filter polluted stormwater through biologically active plants and soils thereby removing contaminants from the water (Payne et al, 2014). A bioretention system, also



known as a rain garden, biofilter, or biofiltration system, is a terrestrial-based water quantity and quality control practice that can be designed to mimic pre-development flow patterns or hydrological regimes. It contains a vegetated soil filter, with a planting layer overlying a porous medium and, often, an under-drain for effluent collection (Davis et al, 2009)

Bioretention Swale or Basin

Some peer reviewed article authors use the term bioretention, bioretention swale and bioretention basin interchangeably. According to authorities in Australia a Bioretention Swale is a LID, which can *harvest* stormwater, while filtering it through an engineered soil media and convey it downstream for discharge into a waterway or body of water.

Infiltration and Vegetated Infiltration basin

Infiltration basins are utilized to capture stormwater runoff and re-inject it into underground aquifers through natural percolation. They are generally utilized in areas prone to drought or water shortages in order to help reverse declining groundwater availability and to prevent seawater from entering the system.

According to Fletcher et al, (2014) utilization of correct terminology within the urban stormwater management sector is essential. He states that many terms are developed regionally based on specific local and cultural perspectives. In 2004, Ellis et al published the *Urban Drainage Multilingual Glossary* to improve the essential communication needed among all the different professionals within stormwater management and governance sector.



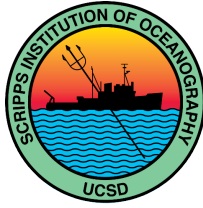
For the purpose of this study I will consider biofilters to be what the San Diego County Water Regime considers a combination of bioretention/biofilter BMP.

Biofilters provide a number of ecosystem benefits. They aid in flood prevention, improve stormwater quality and can provide habitat for wildlife (Kazemi et al, 2009, 2011). Additionally, biofilters can enhance the aesthetic value of a community, promote environmental stewardship and educate the public on stormwater pollution prevention.

Biofilters can also increase the quality of life of a city by adding aesthetic value to it. Biofilters can be placed in public places such as parks, schools, roadways etc. They can be established within local municipalities jurisdiction along with interpretive signs. Interpretive signs have been used by the County of San Diego’s Park and Recreation Department as well as the CA Department of Fish and Wildlife to help educate the public on the region’s natural resources and to raise awareness of anthropogenic impacts that can be detrimental to local ecosystems (Figures # 3 and 4)



Figure #3 Otay Valley Regional Park Interpretive Sign, furnished by San Diego County Park and Recreation, 2013.



Global sustainability models have shown that engaging a community, regardless of socio-economic demographics, can develop a sense of pride and ownership of green infrastructure developed with LID techniques (Barbosa and Villagra, 2015).

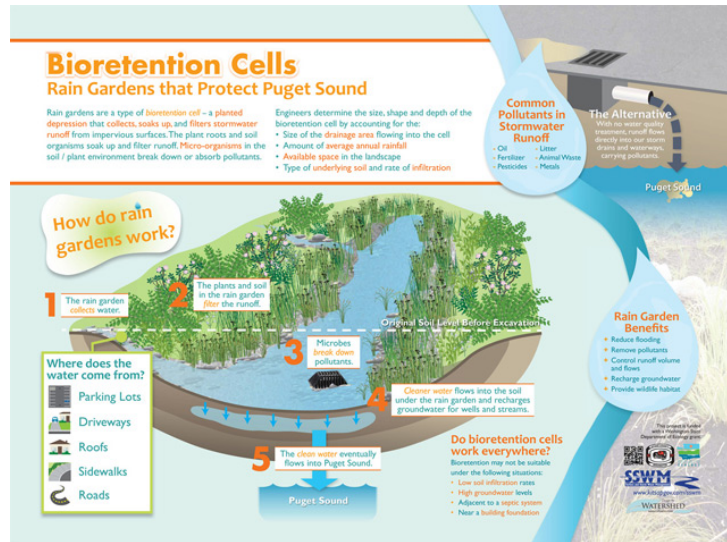


Figure #4 Example of a Bioretention Interpretive Sign from Puget Sound, the Watershed Company, Kitsap County (2012) retrieved from www.watershedco.com/landscape-architecture/kitsap.php

This is of relevance to biofilters

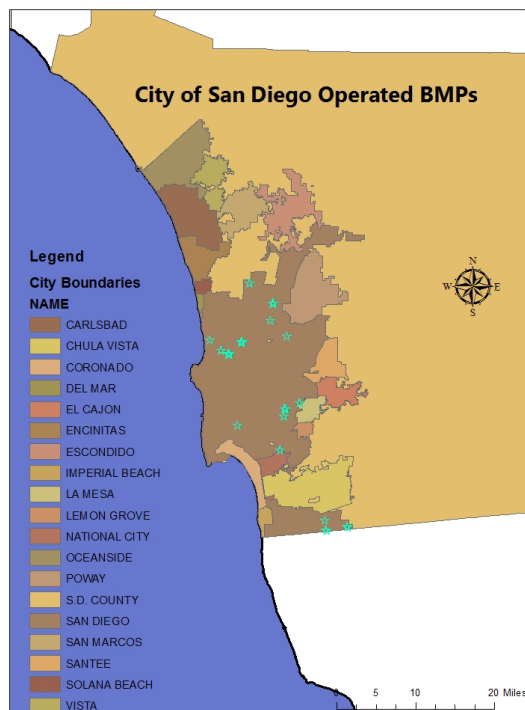
because many municipalities place biofilters in public areas adjacent to private homes. It is important for community residents to understand the importance of these structures, much in the way the general public has learned about storm drains and how these carry pollutants directly to the ocean without any treatment; the public should be able to understand the function biofilters serve and the ecological benefits they bring in addition to addressing pollutants. These benefits include providing habitat for local fauna and micro-organisms.

Case studies have shown that by engaging communities in close proximity to public green spaces developed with Low Impact Development (LIDs), and encouraging community participation in their design, implementation and stewardship of these spaces improves and they have a longer life-span (TRNERR, 2012)



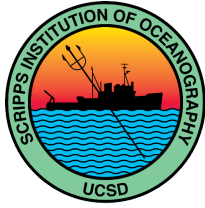
Although biofilters have been increasingly used by stormwater managers, and their effectiveness has been demonstrated, there is still a need for further research on location-specific needs, the ideal designs to maximize their effectiveness within the San Diego County’s micro-climate and the most efficient operation and maintenance practices for stormwater managers in San Diego County.

SAN DIEGO COUNTY BIOFILTERS



San Diego County is home to 18 cities and 11 watersheds that drain within its jurisdictional boundary. According to the most recent census (2010), San Diego County is home to a population of 3,095,313 people and has a projected population growth rate that will yield a population of approximately 4.4 million by the year 2050 (SANDAG, 2015). Urban development will continue to pose increasing anthropogenic stress on urban streams and local waterways which discharge mainly

into estuarine and coastal waters. Authors define impacted bodies of water within an urban setting as “urban stream syndrome” (Pyke et al, 2011). Additionally, San Diego County is home to a number of estuaries which provide essential ecosystem services such as carbon sequestration and habitat for threatened and endangered bird species, and serve as nurseries for key

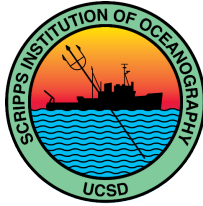


commercially significant fish species. Therefore adequately managing biofilters to decrease stormwater pollution and potentially harmful impacts to them is important.

To effectively and efficiently manage stormwater runoff in San Diego County, all stormwater regime stakeholders need to work collaboratively. For the purpose of this project we need to first understand all of the key players who have a direct or indirect role within San Diego County's stormwater regime as it relates to biofilters and describe their roles within it to better understand what works and what can be improved. I divided these key stakeholders and sectors into four main categories:

1. Governance
2. Stormwater Managers
3. Innovation
4. Design

Each shall have a description of their roles and responsibilities, their operating mechanisms, methods and, an assessment of what is working well and what could be improved as it relates to effective management of biofilters in San Diego.



1. GOVERNANCE

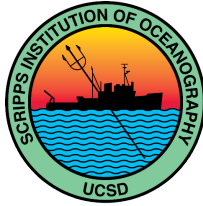
The Regulatory and Jurisdictional Framework for San Diego County as it relates to biofilters

An increasing number of authors state that the integrative term of governance is redefining what has been long considered simple one-way directional government regulation with respect to resource management. According to author Pahl-Wostl, the term “governance embraces the full complexity of regulatory processes and their interaction” He adds that the “notion of *resource governance* takes into account the different actors and networks that help formulate and implement [its] policy” (2009). In San Diego County, stormwater governance can be considered a resource governance and there are so many processes, actors and interactions as they relate to biofilter regulation. I shall describe the key regulators and policies, which apply to them as follows:

1.1 THE STORMWATER REGULATORS

1.1.1 State Water Resources Control Board

In 1967 the state of California created the State Water Resources Control Board (Water Board) The Water Board is tasked with ensuring the state waters achieve the reasonably highest water quality for beneficial uses. They regulate both water allocations and water quality for recreational uses. In California, there are nine Regional Water Quality Control Boards (Regional Board) who are charged with developing and enforcing water quality objectives and implementation plans that protect the waters of the state.



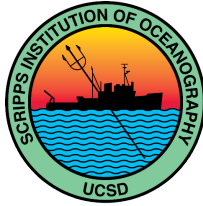
1.1.2 San Diego Regional Water Quality Control Board, Region 9

The San Diego Regional Water Quality Control Board (Regional Board) is responsible for developing and enforcing water quality objectives and creating and implement plans for region 9, which includes San Diego, Riverside, and Imperial counties.

The Regional Board is charged with monitoring water quality, issuing waste discharge permits and enforcement actions to permit violators. Permits are issued within the legal parameters of the federally mandate Clean Water Act (CWA) 33 U.S.C. §1251 et seq. (1972). The CWA was created in order to ensure basic structure for wastewater treatment and ensure the highest possible water quality standards for surface waters in order to maintain their beneficial uses.

In 2013, the Board announced the update to the NPDES Municipal Separate Storm Sewer System MS4 Permit for the San Diego Region. As part of these new regulations, the Board mandated a watershed-based approach to improving water quality. The mandate stated that each San Diego County jurisdictions within each would select a representative from the building industry, an environmental non-profit representative and representatives from local municipalities geographically located within each watershed. These groups are the Water Quality Improvement Plan (WQIP) panel. Each WQIP panel works toward determining the pollutant of highest concern within their watershed. The panel then in turn would develop a strategy to address this or these pollutants and present their plans before the board midway through 2015.

These plans will be presented in June 2015.



1.2 PERTINENT BIOFILTER REGULATIONS

1.2.1 National Pollutant Discharge Elimination System (NPDES) for Multiple Separate Storm Sewer Systems (MS4)

The National Pollutant Discharge Elimination System permit for Multiple Separate Storm Sewer Systems (MS4) is the legal instrument issued by the San Diego Regional Water Quality Control Board to municipalities to comply with the Clean Water Act.

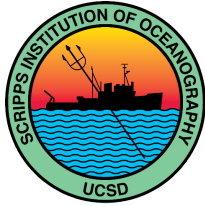
The Board issued the first NPDES MS4 permit in 1990 and has gone through several iterations since because the clean water act has a five year cycle for NPDES permits.. The Board adopted its most recent update for the Multiple Separate Storm Sewer System (MS4) order R9-2013-0001.

The MS4 permit draft was shared with all 18 cities within San Diego and the other non-municipal Copermittees, allowing almost two years for the municipalities to create their management plans and ensure compliance by June 2015 when the permit takes effect.

Additionally the new MS4 permit requires all 18 municipalities, the County of San Diego, the City of San Diego, the Airport Authority and the Port Authority to update their Jurisdictional Urban Runoff Management Programs (Regional Board, 2013)

1.3 WHO IS RESPONSIBLE FOR MANAGING BIOFILTERS?

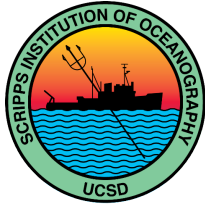
ABOUT COPERMITTEES AND MUNICIPALITIES



Copermittees may be a combination of County and City depending on jurisdiction and geographical location as well as other non-municipal co-permittees. Each Copermittee may have an internal department, which can have partial or full involvement in MS4 work and actions. For example: The City of San Diego has a Department of Public Works and a Department of Transportation and Stormwater. Each department may have a role in meeting compliance from BMP design, planning, installation, operation and maintenance. These departments in turn can and do hire external consulting firms to conduct any of these activities when departmental staff is insufficient. These firms conduct tasks as determined by each department staff, who then in turn report to the regional board on an annual basis (and each other if Copermittees) in order to ensure MS4 permit compliance

1.3.1 Who are the Copermittees and Municipalities?

A Copermittee and/or Municipality is the responsible entity which has obtained an MS4 permit issued by the San Diego Regional Water Quality Control Board and is responsible for implementing it and meeting compliance. They can be a combination of county, city or primary or secondary permittees depending on what is best suited for the entity. In San Diego County, Copermittees choose to co-manage and implement the MS4 permit depending on jurisdictional and/or geographical location. Listed in figure #4 are all of San Diego County's Copermittees and in figure #5 is an example of the hierarchical structure of implementation of the MS4 permit.



COPERMITTEES AND MUNICIPALITIES IN SAN DIEGO COUNTY

City of Carlsbad	City of Encinitas	City of National City	City of Santee
City of Chula Vista	City of Escondido	City of Oceanside	City of Solana Beach
City of Coronado	City of Imperial Beach	City of Poway	City of Vista
City of Del Mar	City of La Mesa	City of San Diego	County of San Diego
City of El Cajon	City of Lemon Grove	City of San Marcos	San Diego County Regional Airport Authority
San Diego Unified Port District			

Figure # 5: List of Copermittees and Municipalities responsible for biofilters and regulated under the MS4 permit

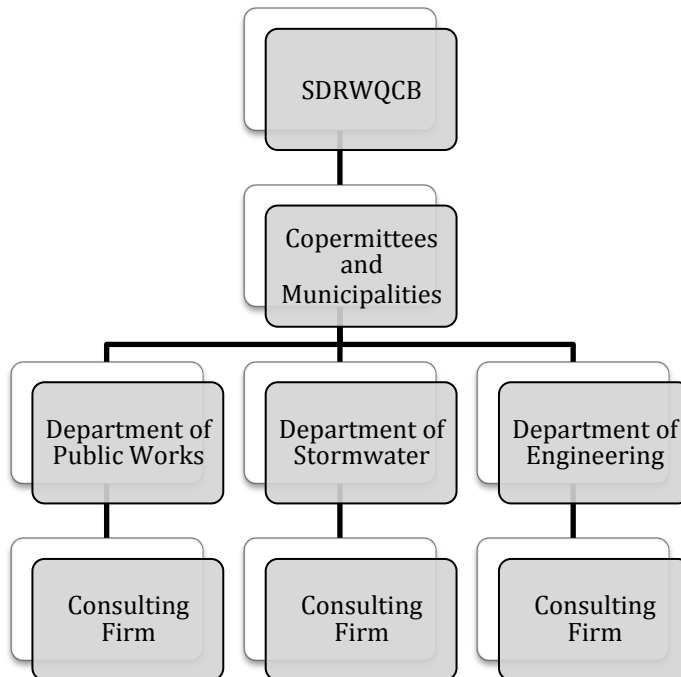
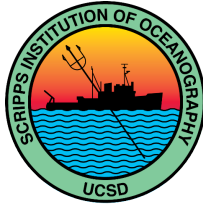


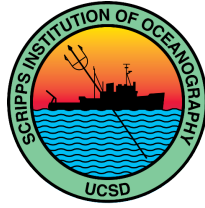
Figure #6 Examples of the number of different departments, which may interact with MS4 actions for stormwater management and compliance. This is only an example to reflect the hierarchical flow of responsibility. Each city may have different names for each department and may or may not be Copermittee or stand-alone permittee.

1.4 PROGRAMS THAT RELATE TO BIOFILTERS

1.4.1 Jurisdictional Urban Runoff Management Program

This extensive document drafted by City of San Diego is a management plan that has served in the past as a detailed series of actions needed to ensure compliance with the MS4 permit.

Recently the Regional Board requested the plan be updated to include the Water Quality Improvement Plan's stressor of highest priority identified by stakeholders from each of the general Water Management Areas (WMA). Each WMA is lead by a designated Copermittee with jurisdiction within that area. Some WMAs share jurisdictional boundaries creating shared



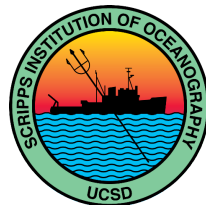
management and coordination responsibilities within each designated group. This program is relevant to biofilters in that it sets the municipalities' regulations as required by the Regional Board and has specific guidelines for operation and maintenance of biofilters.

1.4.2 Model Best Management Practices Design Manual (formerly Stormwater Urban Mitigation Plan)

The Model BMP Design Manual (BMP manual) is a new directive from the most recent update to the MS4 permit for San Diego County. This manual is the newest iteration to what was formally known as the STANDARD Urban STORMWATER Mitigation Plan (SUSMP) which itself was based on the 2007 version of the MS4 permit. The BMP manual was released as a public draft in January 2015 and will be adopted along with the implementation of the new 2015 MS4 permit

The BMP manual is a set of guidelines to be adapted and used based on locally specific needs. The intent is to give permit applicants guidelines on how to design their stormwater management plans whether they are public or private developers. It is also meant to provide procedures for selecting, installing and maintaining BMPs including biofilters.

To better understand each agency, program and entity's roles and responsibilities within the context of regulation and enforcement of biofilters I created a table summarizing each (Table #1).

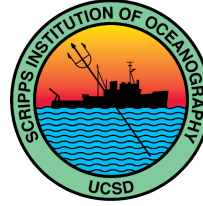


NAME	ROLE	STRUCTURE	RESPONSIBILITY	JURISDICTIONAL and/or GEOGRAPHICAL REACH	ENFORCEMENT CAPACITY
San Diego Regional Water Quality Control Board (SDRWQCB)	To ensure compliance of the Clean Water Act. To draft and enforce, policies and regulations to ensure water quality objectives are met within Region 9 (San Diego, Riverside and Imperial Counties)	Six full-time professionals representing different areas of water quality, supply and engineering make up the board and are responsible for adopting plans, programs and regulations. An executive officer is responsible for overseeing the entire Region 9 and its three main departments: groundwater, healthy waters, and surface water protection.	Responsible for developing plans to designate water quality objectives and beneficial uses of water bodies in San Diego County.	San Diego, Imperial, and Riverside Counties	Has the capacity to issue non-compliance fines and has a specific and consistent methodology to issue them. More information can be found in the State Water Resources Board Water Quality Enforcement Policy: http://www.swrcb.ca.gov/water_issues/programs/enforcement/docs/enf_policy_final111709.pdf
California Stormwater Quality Association (CASQA)	A non for profit association with the goal of making advancements in stormwater management by educating, collaborating, conducting research and serving as a guide within the regulatory realm.	Formerly the California Stormwater Quality Task Force, an inter-governmental advisory group to the State Water Resources Board. Established as a 501 (c)3 in 2002. A chair, vice-chair, treasurer and executive program coordinator structure its board. An Executive Director oversees the daily activities.	As a non-profit, its responsibility is toward its mission. Yet, because of their history with the State Water Board, they are held in high regard and are often used as a resource for latest research and guideline publications by professionals in the field.	California-wide stormwater permittees.	NONE
Copermittees and Municipalities	To lead efforts to improve water quality discharge into waterways, water bodies and ocean. To develop management plans to address stormwater. To oversee all	Multiple. Cities: Eighteen within San Diego County. Each can have different departments depending on their size and budget. County: Divided into	To ensure compliance of the MS4 as a single standing permittee or Copermittee before the SDRWQCB. As such is responsible for creating management plans and implementing them,	All of San Diego County	All Copermittees and Municipalities have individual city, county, port and airport enforcement codes. Each have a set of enforcement actions.



	actions toward addressing stormwater runoff and sustainable development.	<p>five districts governed by five elected board supervisors for each district. Multiple departments with MS4 involvement.</p> <p>Port: Governed by a chair, vice-chair, secretary and representatives from each of the four cities with jurisdiction with the port.</p> <p>Airport: Independent agency governed by an appointed board of nine members who represent all areas of San Diego County</p>	whether with own staff or sub-contracting out to consulting/environmental firms. Provide annual reports to their governing bodies and to the Regional Board.		
Consulting Firms	To aid in the needs of Copermittees and Municipalities in a multitude of roles ranging from research, LID design, engineering, drafting stormwater management plans, operation and maintenance and drafting annual reports.	Structure can be multiple types but all within a for-profit configuration.	To ensure contractual agreements with hiring agency/entity. Indirect responsibility to comply with MS4. Yet, main responsibility lies on the hiring municipality and/or Copermittee.	Local, State and National.	NONE

Table #1: Description of roles and responsibilities of stakeholders within the jurisdictional and regulating framework of San Diego County.



2. STORMWATER MANAGEMENT

Management, Compliance, Operation and Maintenance of Biofilters

2.1 Model BMP Design Manual San Diego Region (January 2015 public draft) For Permanent Site Design, Storm Water Treatment and Hydromodification Management

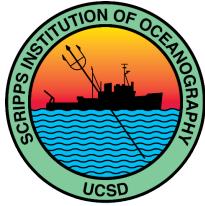
Since BMPs are required to meet specific standards for design, implementation, and long term maintenance plans in order to ensure the effectiveness, I will review the provisions that relate to biofilter management and maintenance that are found in this manual.

In order for biofilters to effectively function they must undergo regular periodic inspection and maintenance by their owner. If this action does not take place, biofilters run the risk of deteriorating and losing their ability to decrease/eliminate pollutants.

As outlined in the BMP manual, the MS4 permit applicant must create a Stormwater Quality Management Plan or (SQMP) when applying to its corresponding jurisdiction. The SQMP must include specifications outlined in both the BMP manual and the MS4 as they relate to the biofilters (if this is the structure they have selected to install) in order to comply with stormwater requirements.

In addition to many other specifications relating to stormwater management, the SQMP will include proof of the mechanism the applicant will use for long-term biofilter maintenance.

2.2 BIOFILTER MAINTENANCE REQUIREMENTS



Maintenance Actions and Frequency

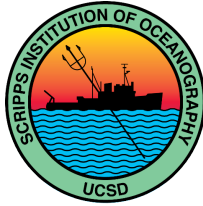
The BMP manual strongly suggests maintenance for biofilters, specifically cleaning out anything that may cause it to clog and retain water. However, there are very brief guidelines for the opposite of conditions: drought. Plants, which play a key role on the surface by providing shade, roots which contribute to nutrient uptake and other ecological benefits are not quite understood therefore not as intensely scrutinized.

The optimum maintenance frequency the manual recommends is on an as-needed basis.

If the maintenance threshold is exceeded by the time inspection is conducted during the first year following its installation, then maintenance actions need to be taken immediately by the owner prior to the next wet weather event. During the first year the city will inspect regularly the BMP monthly from September to May. If the owner has met all requirements for maintenance then the inspection shall be conducted annually. The inspection is conducted by self-reporting and if needed in person by either staff from the Copermittee or by a hired consulting firm. For a sample inspection sheet provided by consulting firm Dmax see Appendix 1. Dmax is under contract with the City of San Diego Stormwater Department.

Landscape Design

Regarding landscape design and types of plants suggested for biofilters in San Diego County, the BMP manual recommends the use of drought-resistant and native species that will need minimal irrigation and the least amount of fertilizers, because fertilizers have the capacity to contribute to runoff pollution. Shrubs, salvias, succulents and vines are some species which are drought tolerant non-invasive easy to maintain and long performing. It also recommends that after the



establishment period of two to three years (during which they would require irrigation) the species selected should not require irrigation, only after long dry periods. The manual also suggests the selection of plants be made by an experienced landscape architect familiar with LID techniques.

Typical Maintenance Indicators of BMPs	Maintenance Actions
Accumulation of sediment, litter or debris	Remove and properly dispose of accumulated materials without damage to the vegetation
Poor vegetation establishment	Re-seed, re-plant or re-establish vegetation per original plans
Overgrown vegetation	Mow or trim as appropriate, but not less than the design height of the vegetation per original plans when applicable (e.g. a vegetated swale may require a minimum vegetation height)
Erosion due to concentrated irrigation flow	Repair/re-seed/re-plant eroded areas and adjust the irrigation system
Erosion due to concentrated storm water runoff flow	Repair/re-seed/replant eroded areas, and make appropriate corrective measures such as adding erosion control blankets.
Standing water in vegetated swales	Make appropriate corrective measures such as adjusting irrigation system removing obstruction of debris or invasive vegetation, loosening or replacing top soil to allow for better infiltration, or minor re-grading for proper drainage. If the issue is not corrected by restoring the BMO to the original plan and grade, the City shall be contacted prior to any additional repairs or reconstruction.
Standing water in bioretention, biofiltration with partial retention, or biofiltration with partial retention or biofiltration areas or flow through planter boxes for longer than 96 hours following a storm event	Make appropriate corrective measures such as adjusting irrigation system, removing obstruction of debris or invasive vegetation, clearing underdrains (where applicable) or repairing/replacing clogged or compacted soils.
Obstructed inlet or outlet structure	Clear obstructions
Damage to structural components such as weirs, inlet or outlet structures	Repair or replace as applicable
*These BMPS typically include a surface ponding layer as part of their function which may take 96 hours to drain following a storm event	

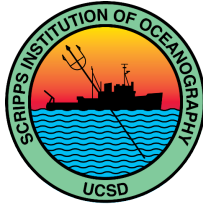


Table #2 Recreated from Model BMP Design Manual San Diego Region, public draft, January 2015.

According to the BMP manual, a specific-stand-alone operation and maintenance plan must be developed by the owner, in addition to the one required to be included in the SWMP.

Requirements include photos of the BMP, structural specifications, and who will conduct the long-term maintenance (whether a private or public agency).

California Stormwater Quality Association Stormwater Best Management Practice Handbook

The California Stormwater Quality Association Stormwater Best Management Practice Handbook (CASQA) is another set of guidelines that the Regional Board and Stormwater managers recommend new permittees refer to. It has recommendations on how to design, install and maintain biofilters. The challenge with this particular handbook is that under its biofilter section, they used references from Santa Cruz and Ventura Counties. These counties have average annual rainfalls of 28 and 14.5 inches respectively (WRCC, 2015).

Discussion

The BMP and CASQA manuals are great resources for future and current permit applicants and stormwater managers. However, permittees could benefit from having specific guidelines for current and future microclimate patterns for San Diego County. Listing drought resistant species and having more frequent and rigorous maintenance requirements for biofilters could successfully continue to be used and dissection could be prevented.

Recommendations:



Divide the CASQA BMP handbook into the major California regions based on weather patterns.

Utilize research data that explores ecologically based studies for biofilters and their maintenance.

Create a more targeted set of recommendations for biofilter maintenance in lieu of relaying that decision to the City engineer and/or plan developer.

DESIGN

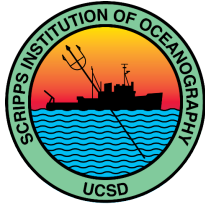
The Role of Planners and Designers of Biofilters

LID Engineers and Designers

Engineers and LID designers have as their main priority the structural functionality of biofilters. They consider the hydrological flow implications of the type of structure, their design and their influent/effluent capabilities, largely from an engineering perspective.

Urban Planners

Urban planners play a pivotal role in integrating sustainable LIDs and long-term urban features with human-integrated ecosystems. They are visionaries and are progressive thinkers, particularly as it relates to sustainable development. Urban Planners seek to enhance the quality of life of humans in balance with their environment considering all aspects of development: social, economic, health and well-being (Pezzoli et al, 2014). They contribute the big picture of overall design for a higher quality of life. This entails planning development that is ultimately sustainable, enhances the quality of life, and is conducive to stewardship. Therefore planners can play a key role in biofilters and their effectiveness in stormwater management. Urban planners influence biofilter design. (Figure # 8).



Landscape Architects

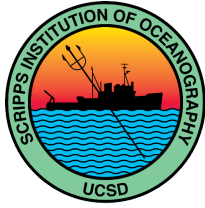
Landscape Architects play one of the most important roles in regard to the types of plants selected for biofilters. They are the ‘go to’ resource for many stormwater managers and designers for plant-type selection. Landscape Architects can not only enhance the aesthetic value of a community but also, significantly contribute to its urban biodiversity because of the types of plants and sustainable choices they make when creating their designs.

There are a number of associations that operate at the local and national level in San Diego County that seek to engage the public and professionals in wise, sustainable planning and design for Low Impact Development. These include the American Public Works Association, American Planning Association, American Society of Landscape Architects, Building Industry Association, and National Association of Environmental Professionals, and American Society of Civil Engineers.

Additionally, there are working groups that focus on co-management and/or research such as the Southern California Coastal Water Research Project, the San Diego Integrated Regional Water Management, the Water Quality Improvement Panels by each of San Diego County’s Watersheds, and several regional and local NGOs working toward improving water quality in the region. Yet, there are no specific task forces or working groups that fully integrate all of the key players previously discussed.

INNOVATION

The Role of Researchers in Understanding Biofilter Effectiveness

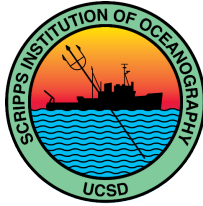


Researchers work to provide information that can help optimize biofilter effectiveness and functionality. They study what biofilter features best remove pollutants, nutrients, heavy metals and pathogens. They also discover what ecosystem benefits result from varying biofilter composition and how biofilter construction can alter sedimentation and other types of physical processes that may affect pollution dispersion. However, despite the existence of peer-reviewed publications, research results do not always find their way to the stormwater management regime.

Scientists have experimentally examined the functionality of biofilters in terms of hydrology and contaminant removal (Blecken et al, 2009). They have manipulated the types of filter media, saturated zones (Blecken et al, 2009), plant species and density (Reed et al, 2009) and are starting to examine the role of soil invertebrates in biofilter function (Levin and Mehring 2015). Much of the relevant research has been done in Australia where drought has led to advanced biofilter research among academics.

Despite the fact that there is a plethora of recent data and experimental studies being conducted on biofilters, their full potential for pollutant removal as a micro-ecosystem is not entirely understood. Not enough data on the biological elements of biofilters exists. In order to improve the ability of biofilters to filter stormwater, more research needs to be done in this realm.

Additionally, there is insufficient regionalization of results. There are no experimental data on southern California native species used for biofilters as well as a lack of studies on entire plant communities in stormwater biofilters specifically as they relate to southern California seasonal weather patterns and projected changes due to global warming.



Recommendations:

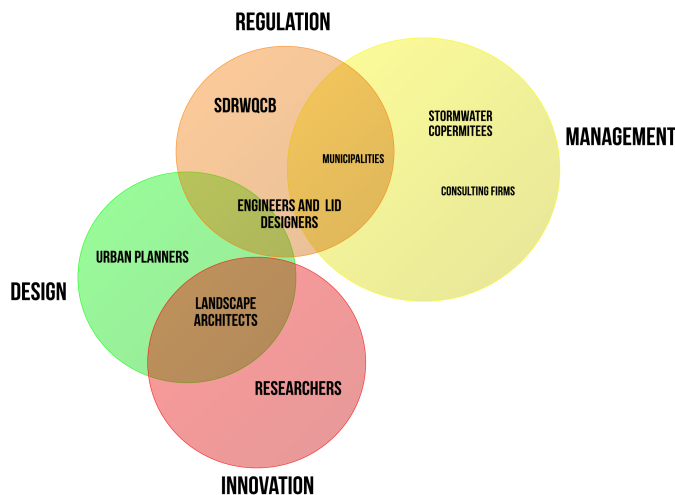
- (1) Conduct research on native, drought-resistant plants and their ability to remove pollutants as part of biofilters in San Diego County.
- (2) Conduct research on the different types of soils and the infaunal organisms that may be best suited for contaminant removal in San Diego County biofilters.
- (3) Determine what ecosystem benefits or services biofilters contribute and quantify their value. These may include nutrient, metal, organic and sediment removal, flood control, carbon sequestration, aesthetics, pollination services and more.
- (4) Apply ecological theory to the study of biofilters (as in Levin and Mehring 2015). Key ideas that might be useful in biofilter design include island biogeography, ecosystem function-biodiversity relationships, and spatial ecology (metapopulations, metacommunities and landscape ecology).
- (5) Research should be conducted to explore how to integrate the socio-ecological-economic aspects of biofilters in order to maximize ecosystem benefits. This could be explored through the theory of Coupled Human and Natural Systems (CHANS). CHANS are integrated systems in which people interact with natural components, studying the human-nature interactions. Although the complexities this type of study entails have been explored they remain misunderstood (Liu, et al 2007). Currently, the National Science Foundation is seeking to support this very types of CHANS initiatives. As stated in their 2015 request for proposals the projects they seek to fund must have the following four components: projects to be supported by CNH must include analyses of four different



components: (1) the dynamics of a natural system; (2) the dynamics of a human system; (3) the processes through which the natural system affects the human system; and (4) the processes through which the human system affects the natural system.

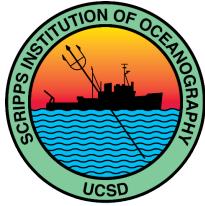
End of Section Discussion

Figure # 8 Venn diagram of key stakeholders and how their roles may or may not overlap, circles, which do not touch, depict the sectors that have mostly no interaction or two-way flow of information.



Urban planners, landscape architects, researchers and stormwater managers must work in collaboration to maximize biofilter success rate. They do not always overlap or interact as far as their activities and interactions. Although some of these fields make an effort to work collaboratively or at least to exchange information, they rarely work together simultaneously

(see Figure #8) The result is a lack of sufficient data to conclusively quantify the effectiveness of the biofilter. Rather decisions are being made based on the assumption that they work. For example, removing trash and debris from the surface does not ensure biofilter optimal functionality. Since inspections are conducted in an annual basis and often are self-reported, little room is left to estimate if a biofilter is functioning in its full capacity. Inspecting biofilters on an annual-basis does not negate other failures within the system. If in fact they are inspected (and



not just self reported), the entire ecological community in the biofilter is not being inspected therefore leaving room for mismanagement. If the plants are not being cared for in the manner that is needed in order for them to perform their services, then the biofilter loses a percentage of the filtering and pollutant removal capabilities.

Recommendations:

To advance the effective use of biofilters regionally I recommend the creation of a working group formed of ALL of the previously described stakeholders, as each contributes crucial design and maintenance elements to biofilters. This is particularly urgent for San Diego County, and the status of its water regime. San Diego County would benefit significantly from having a *Biofilter Task Force*. The Biofilter Task Force could be self-funded. This would insure that the ideas that would stem from this collaboration do not stagnate as inactive ideas.

Rather they would promote a synergistic, innovative collaboration of relevant fields that contribute to the LID sector and supply a continuous stream of ideas, therefore protecting our natural resources.



CASE STUDY – A Scripps Biofilter

Ecology embankment biofilter filter monitoring at Scripps Institution of Oceanography as managed by UCSD's Department of Environment, Health and Safety Department



Figure # 9 Media filter at Scripps Institution of Oceanography, UCSD, San Diego. Photo Courtesy of Kim O'Connell

The Department of Environmental Health and Safety (EHS) at the University of California San Diego (UCSD) is the department responsible for stormwater management, developing plans, treatment controls and meeting MS4 compliance on campus. EHS is under a Phase II section F “non-traditional” stormwater permit and is required to meet new standards required by the Regional Board by July 2015.



In 2013, EHS installed a treatment control device on the westernmost side of Scripps Institution of Oceanography at UCSD to filter stormwater runoff. The media filter under the soil consists of an ecology mix: an aggregate blend that removes pollutants through physical, chemical and biological processes.

EHS explains these processes as follows:

Physical Filtration - The gravel filters out sediments.

Chemical Precipitation - Carbonate from dolomite increases alkalinity of runoff leading to the formation of metal carbonates and hydroxides. Calcium from dolomite and gypsum, and magnesium from gypsum combine with phosphate to form relatively insoluble metal-phosphate particles that are filtered out in the gravel.

Sorption by Cation Exchange - Gypsum and dolomite adsorb metals.

Biological Uptake – Perlite improves moisture retention, which allows the formation of a biofilm in the ecology mix. The biofilm removes metals, phosphorous, and metabolizes petroleum hydrocarbons.

The topsoils of the ecology embankment were planted with local native vegetation to reduce sediment runoff and hold stormwater runoff (Figure #10).



Figure #10 Media Ecology Embankment, photo by Kim O'Connell

Media Filter Monitoring

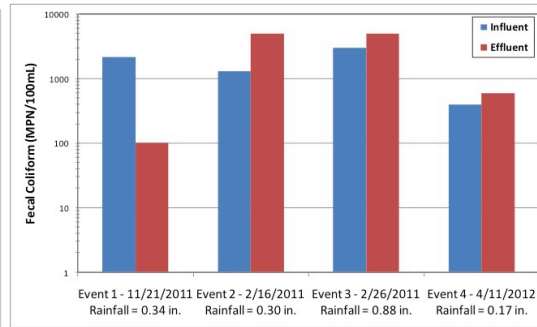
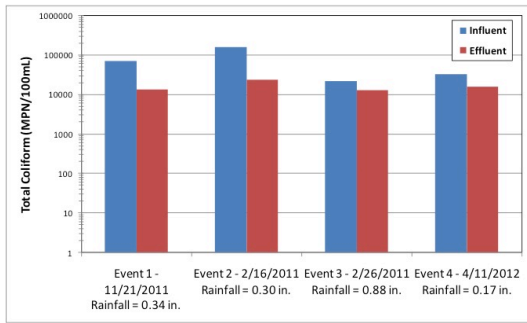
In 2011-12, EHS conducted monitoring during 4 rainfall events for metals, total suspended solids, and fecal indicator bacteria (FIB) by sampling influent and effluent water.

The biofilter appears to have removed suspended solids, *Enterococcus*, and Zinc very effectively but on 2 of 4 events fecal coliform was increased in the biofilter effluent (Fig. 11-15 A-E).

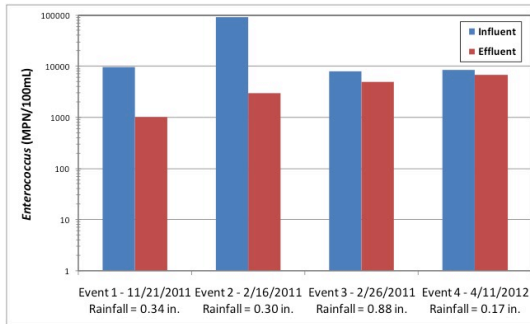
Figure #11-15

A. TOTAL COLIFORM

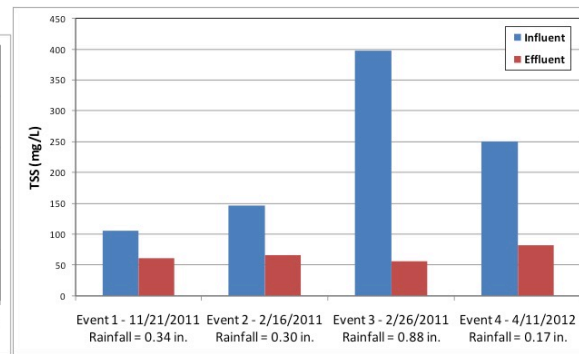
B. FECAL COLIFORM



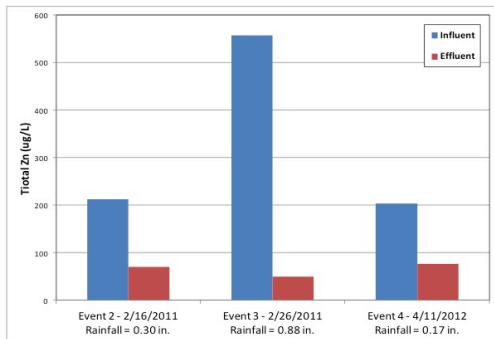
C. ENTEROCOCCUS



D. TOTAL SUSPENDED SOLIDS



E. TOTAL ZINC



Figures # 11-15 All monitoring data, images and definitions courtesy of Kim O'Connell, UCSD EHS Stormwater Manager

Discussion



It is unknown if the topsoil vegetation had any effect or role in removing any of the measured constituents. The vegetation is now largely absent due to dissection from drought conditions. Quantification of infaunal organisms in the soil is being carried out by K. Galloway and L. Levin.



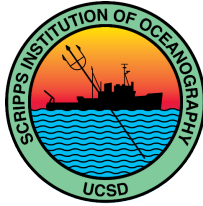
Figure # 11 photo by Paloma Aguirre, May 29, 2015

Media filter shows no vegetation on topsoil.

FINAL RECOMMENDATIONS

In conclusion, biofilters are an effective BMP to address and filter stormwater runoff. As San Diego continues to move toward low impact and sustainable development we must progress in an integrated, and ecologically focused manner. This study is one of the first biofilter policy and management analyses conducted for San Diego County. In light of the new biofilter build, design and maintenance guidelines and regulations, I make the following recommendations for each sector:

REGULATION



The State Water Resources Board should update their use of recycled water for irrigation easier, particularly as it relates to irrigation public spaces with biofilters. This would help minimize the impact from the current drought we are experiencing and ensure biofilters continue to maintain their stormwater filtration effectiveness while preventing their tops soils from turning water repellent and contributing to erosion and flooding during the next wet weather event.

With the new regional board directive to create watershed-based improvement plans, green infrastructure may come to the forefront and give way to new initiatives to address stormwater. This could encourage increased use of aggregate data collection for monitoring, tracking, sustaining and funding off-site compliance which could in turn produce more green spaces.

GOVERNANCE

Create a San Diego biofilter task force with representatives from the scientific research community, urban planning, landscape architects, stormwater management and the Regional Board to create strategies and implement them as needed. Identify funding from each of these sectors to ensure this task force is actively engaged and not just creating “shelved” strategies. Similar task force models have shown to be successful in stormwater BMP management, such as the Bay Area Stormwater Agencies Association. Their mission is to promote regional consistency and to facilitate efficient use of public resources. A hosted public forum would be ideal to begin this first assessment moderated by leading researchers in the field.

DESIGN



Create biofilters with drought resistant and native species that will require minimal irrigation while maintaining their effectiveness. The selection of these species should be based on the most recent data available from the scientific research community studying ideal species for San Diego's current seasonal conditions and projected global warming related weather change patterns for southern California.

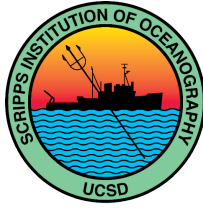
INNOVATION

Within the scientific research sector, research on native, drought-resistant plants and their ability to remove pollutants as part of biofilters in San Diego County should be conducted.

Determine what ecosystem benefits or services biofilters contribute and quantify their value. These may include nutrient, metal, organic and sediment removal, flood control, carbon sequestration, aesthetics, pollination services and more.

Conduct research on the different types of soils and the infaunal organisms that may be best suited for contaminant removal in San Diego County biofilters.

Finally, apply ecological theory to the study of biofilters (as in Levin and Mehring 2015). Key ideas that might be useful in biofilter design include island biogeography, ecosystem function-biodiversity relationships, and spatial ecology (metapopulations, metacommunities and landscape ecology).



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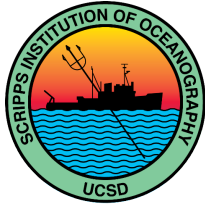
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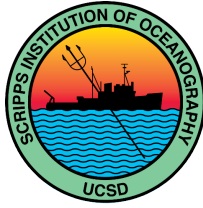


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ACKNOWLEDGEMENTS

I would like to acknowledge and thank my advisor and chair Dr. Lisa Levin, my committee member Dr. Keith Pezzoli and committee member and mentor Dr. Serge Dedina, for sharing with me their invaluable knowledge, their encouragement, and support. The expertise you brought from each of your fields greatly contributed to the success of this research study.

Thank you for doing the work you do toward making our world a better one.

Special thanks to the following people who contributed to this project:

Kim O'Connell

Environmental Health and Safety Department, UCSD

James Nabong and James Hook

City of San Diego Transportation & Storm Water Department

Laurie Welsh, P.E.

San Diego Regional Water Quality Control Board

Tad Nakatani

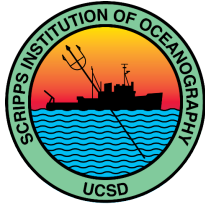
Dmax Engineering, Inc.

Dr. Ashmita Sengupta

Southern California Coastal Research Project

Chris Helmer

Environmental Program Manager, City of Imperial Beach



Jen K. Mcwhorter CDIP

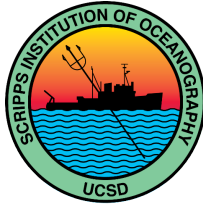
Scripps Institution of Oceanography at UCSD

Andrew Merhing, Carlos Neira, Jen Gonzalez, Kirk Sato, Katie Galloway (Kimley-Horn & Associates), Lily McCormick, Natasha Gallo,

and the rest of the Lisa Levin Lab

Juli Beth Hinds

Birchline Planning, LLC



APPENDICES



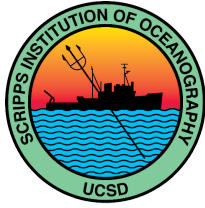
City of San Diego
Treatment Control BMP Inspection Program
Inspected by D-Max Engineering, Inc.

I. Project Items
Project/Site Name:
Project/Site Street Address:
Project/Site City, State, ZIP:
Project/Site Land Use:
Maintenance Responsibility:
Does the maintenance agreement include BMP information?
Referenced Drawings:
Does the site drainage match available drawings?

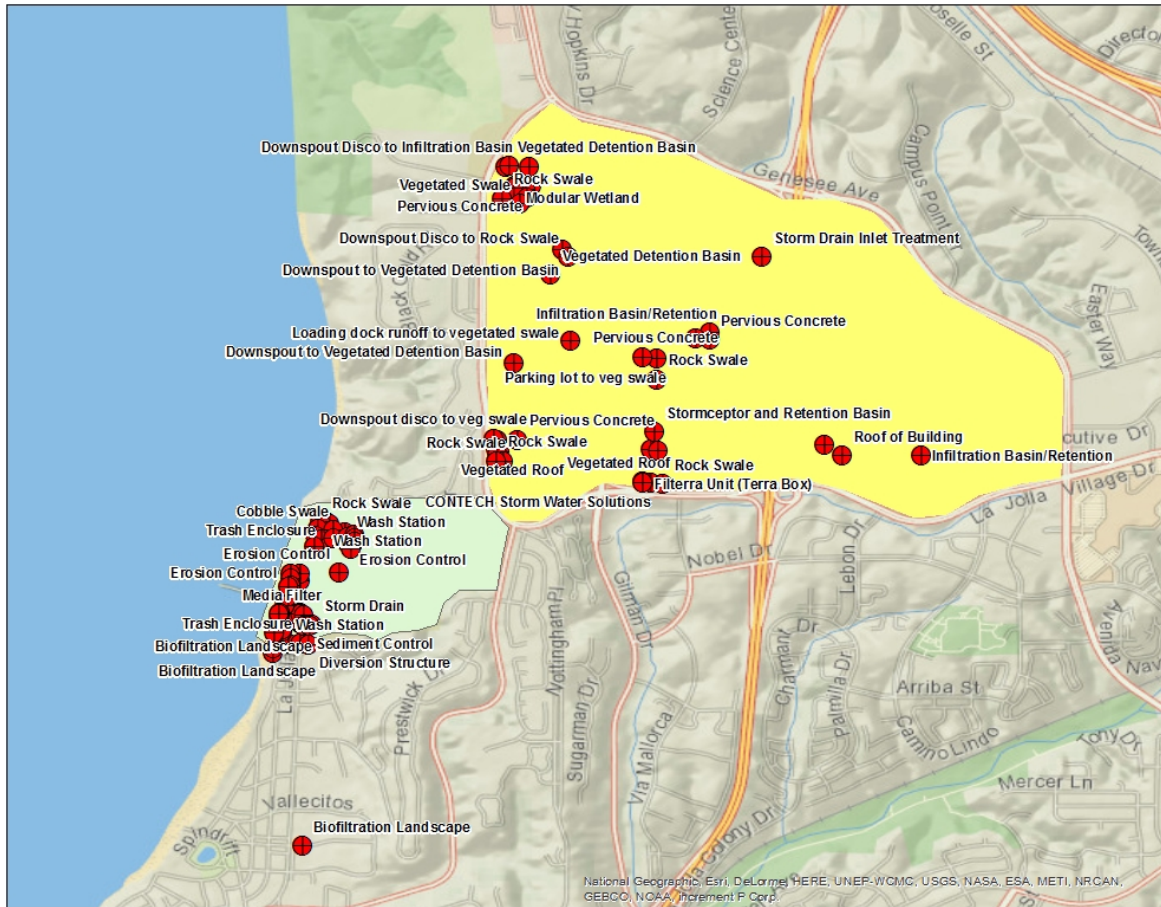
II. Project/Site Contact for Maintenance Items
Update contact info below, OR:
Name: Title:
Firm:
Street Address:
City, State, ZIP: Phone: ext.
Fax: Email:

III. Inspection Items (Items that apply to all BMPs at a site)
Inspector Name:
Inspector Firm: D-MAX Engineering, Inc.
Inspection Date: Inspection Time: AM/PM
Inspection Type:
Time since last measurable precipitation:
Site Personnel Present: Title:

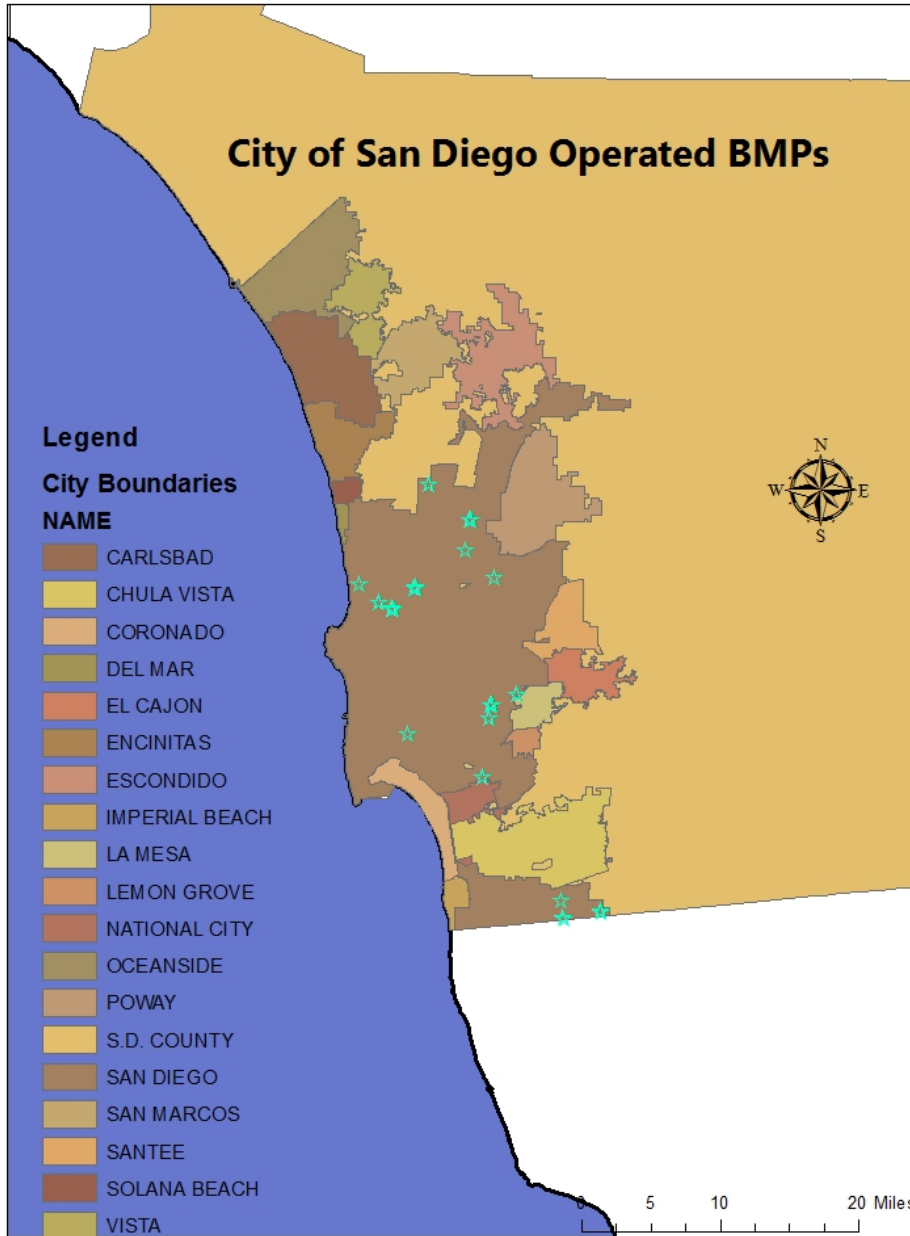
IV. Project/Inspection Item Notes
Notes:



Best Management Practice type and location at University of California San Diego



Map by Paloma Aguirre and Jennifer McWhorter, with BMP inventory data provided by Kim O'Connell from the Environmental Health and Safety Department, University of California San Diego.



BMP inventory data provided by James Hook, City of San Diego Transportation & Storm Water Department, Storm Water Division.