City of Anaheim
Storm Drain Funding
Feasibility Study

Submitted to:

Submitted By:

February 2020

Table of Contents

Figure Index

Table Index

Appendix Index

1. Executive Summary

The purpose of this Storm Drain Funding Feasibility Study (Study) is to analyze the feasibility of utilizing various funding mechanisms to fund the City's Storm Water Program. This Study identifies funding requirements for maintenance, capital improvements, and compliance with regulations; reviews certain funding mechanisms; and develops a framework for user fees. The City understands and recognizes the need for compliance with storm drain permits, new regulations requiring trash capture devices or infrastructure, meeting service requirements for flood mitigation, and the value of runoff capture for flood mitigation and augmentation of groundwater supplies, where feasible and beneficial to the parcels.

The majority of the City's storm drain infrastructure was designed and built during the 1950s and 1960s. The storm drains were built in accordance with engineering standards to protect property and infrastructure from the risk of flooding by conveying and disposing of runoff to major channels and rivers with eventual discharge to the Pacific Ocean. While serving their purpose of conveying storm water, these storm drains also convey trash, debris, and other pollutants. Since their original construction, the significant change from pervious to impervious land use throughout the City has also resulted in greater flows and several storm drains can no longer manage these flows or projected flows expected to be generated by the land uses permitted by the City's General Plan. For new systems, the City ensures that a new development's storm drain system is engineered to comply with storm drain regulations and capacity requirements.

In addition, the City has found through its Master Plans of Storm Drainage (MPSDs) that a majority of its existing storm drains are deteriorating, structurally failing, are hydraulically deficient, have exceeded their service life of 50 years, or currently require upgrades and modifications to comply with State regulations, including unfunded state mandated regulations aimed at preventing trash, debris, and pollutants from entering natural waterways.

Currently, the City performs storm drain maintenance and repairs or rehabilitation as needed when there's a threat of imminent failure or in response to an emergency situation. Because the City does not have a dedicated source of funds for the storm drain system, a majority of the service calls are reactive in nature and only provide temporary relief. Minimal preventive maintenance is performed and capital improvements have not been constructed as recommended by the MPSDs. From a financial perspective, when compared to the costs of allowing an asset to fail, preventive maintenance measures have been shown to maintain or increase an asset's performance during its service life or result in overall reduced total costs for maintaining the asset.

Throughout the United States public agencies have implemented funding mechanisms to address maintenance and repair of their aging storm drain infrastructure and to comply with similar regulations. Annually, Western Kentucky State University surveys storm drain fees from over 1,700 agencies, across 40 states, as shown in Table ES.1 below:

Table ES.1 Western Kentucky University Stormwater Utility Survey (2019)

Agencies	Agencies Surveyed	Monthly Fee Ranges Reported
California	56	$0.48 - $23.71
United States	1,716	$0.21 - $38.10

Nationwide, the average single-family residential (SFR) charge from the 2019 survey is $5.85 per month.

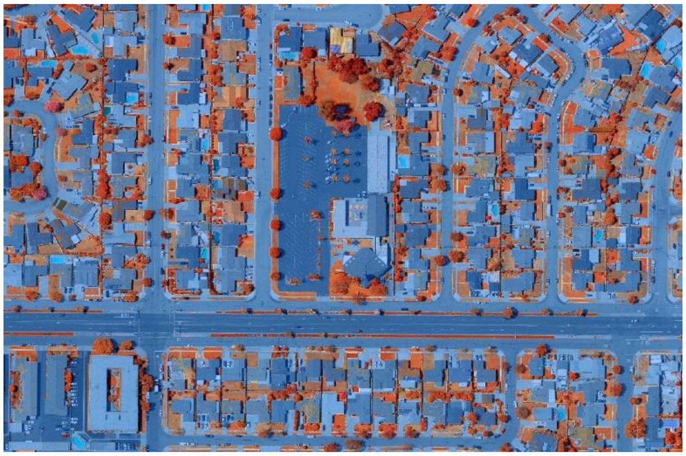
In California, following the adoption of Proposition (Prop) 218 by the voters in 1996, agencies have both failed and succeeded at passing new fees or taxes to pay for storm drain maintenance and improvements. Under Prop 218 water, sewer, and refuse collection fees services are exempt from the voter approval process and follow a separate noticing and public hearing process. In 2002, an attempt to include storm sewers as a sewer service was struck down by an appeals court. In response to the appeals court decision and to provide agencies with an additional option for implementing a storm water fee, the California legislature passed Senate Bill (SB) 231 in 2017. Under SB231 the definition of "sewer" was explicitly clarified to include storm water. However, since the passage of SB231, no agency has utilized SB231 to establish a storm water or storm drain type of rate or fee. For this Study, a variety of funding options were considered.

For transparency and compliance with Prop 218, the development of the framework for the storm drain fees is based on the allocation of costs for maintenance and capital improvements determined from the volumetric contributions of storm flow based on local land use and its impervious area percentage. Land use designations consisted of Single-Family Residential, Multi-Family Residential, Commercial/Industrial, Municipal, Schools, and Parks/Open Space. Impervious surfaces are defined as natural exposed rock and manmade structures and surfaces that prohibit the percolation of surface water into the underlying ground. Impervious areas intensify surface runoff and increase the potential for higher flow rates, flow volumes, flow velocities, erosion, and the transport of trash, debris, and pollutants.

The Study's approach included using the City's geospatial data, cross-referenced with the Orange County Assessor's Parcel database and with corresponding land use impervious percentages listed in the Orange County Hydrology Manual to identify the parcel's land use and impervious percentage values. The impervious values were further verified using Geographical Information System (GIS), aerial imagery, and remote sensing software as shown in Figure ES.1 to obtain more accurate land use category impervious area percentages.

To obtain the storm drain funding requirements, projected capital improvements and maintenance costs were determined. Capital improvements from previously adopted MPSDs identify existing storm drain infrastructure capital improvements that primarily consist of storm drains with hydraulic deficiencies.

Figure ES.1 Aerial Image with Remote Sensing



Impervious Area

Pervious Area

Maintenance funding requirements were primarily determined based on the City's experience with its wastewater collection system, known storm drain permitting requirements and costs, and upcoming regulations for storm drains. Based on this, the following four major cost categories were determined for use in the fee model:

1. Operations and Maintenance (O&M) of Storm Drains
2. Capital Improvements (Priority CIPs), funding of priority storm drain projects in the MPSDs
3. Current Regulatory Compliance Costs
4. Implementation of New Regulations (i.e. Trash Amendments and Best Management Practices)

Four scenarios were evaluated that either determined fee levels that could generate desired funding levels or identified funding levels that could be achieved with assumed first-year rates. These scenarios are summarized in Table ES.2. All scenarios cover the costs of O&M, Regulatory Compliance, and Trash Amendments (Items 1, 3, and 4 above). Scenario 1 looks at CIP funding level 1 (Section 3.4.4.2.2) spread evenly over 30 years and determines the required first-year single-family rate upon which a rate structure is developed. Scenario 2 is the same as Scenario 1 except that it looks at funding level 2 (Section 3.4.4.2.2). Scenario 3 assumes a first-year single-family rate of $5.85 per month (national average) and determines the approximate funding level that can be achieved with that rate structure using a pay-as-you-go program. Scenario 4 is the same as Scenario 3 except that it uses bond financing in addition to as pay-as-you-go funds. Given the uncertainties in longer-term projections, all scenarios were limited to 5-year projections.

Table ES.2 Summary of Preliminary Storm Drain Funding Model Scenarios

Model Scenario	Funding Goal	Monthly Starting Single-Family Residence Fee*	Finance Type	Aggregate Funding at 5 Years
1	$177,500,000	$5.45	Pay-As-You-Go	$31,400,000
2	$363,000,000	$8.79	Pay-As-You-Go	$64,200,000
3	Starting Rate @$5.85**	$5.85	Pay-As-You-Go	$35,400,000
4	Starting Rate @$5.85**	$5.85	Bond	$82,400,000

*Single-Family Residence Fee is High Density Residential. See report for other land use designations.
**National Average per WKUSU Survey 2019.

The scenarios follow a cost of services methodology that is based on a parcel's relative contribution of storm water to the City's storm drain system. The parcel's contribution was based its land use type and from engineering principles established from the County of Orange, available parcel database, geospatial data, and digital aerial images with remote sensing software. The results of the Study show that the City's near-term funding requirements for maintenance, regulatory, and select priority capital improvements can be met with, for example, a Single-Family Residential (SFR) monthly amount of $5.45 (escalated by 3% per year), below the National average of $5.85. Should the City not implement the Storm Drain Fee, there is the potential for significant physical and property damage resulting from flooding events and reduction of emergency services due to flooding. In addition, the City may face the potential for significant regulatory fines and also penalties resulting from upcoming regulations.

Based on these findings, GHD's and DTA's recommendations are for the City to further pursue implementing a storm drain fee that follows Prop 218 with SB231 that would be further supported by the development of a detailed cost of services study that would including the following:

- Development and refinement of a long-term CIP (i.e., 20 or 30-year with a list of projects, updated cost, and year needed);
- Further refinement of the City's parcel database (i.e., reconciliation of City GIS data and County Assessor's parcel data);
- Weigh the feasibility and appropriate level of bond financing vs. Pay-As-You-Go options or other financing mechanisms, in coordination with implementation of long-term CIP;
- Establish a storm drain fee structure based on the individual parcel contribution;
- Determine Storm Drain Fee collecton method or mechanism; and
- Legal counsel oversight and involvement throughout, development of public relations program and the engagement of public outreach citywide.

Implementation of a storm drain fee would fund measures and projects to address the current storm drain infrastructure needs, address deficient capacity in the storm drain system, implement flood mitigation projects, and begin compliance with future regulations in an effort to avoid potential fines from regulatory agencies. In addition, the establishment of a program with dedicated funding will demonstrate the City's commitment and effort at improving its level of service and reducing its contribution of trash, debris, and pollutants to natural waterways and the Pacific Ocean.

GHD and DTA recommend a storm drain fee in accordance with Prop 218 and SB 231. However, in the event decision makers choose not to follow this method, the Pre-SB231 ballot measure process can also be followed, whereby simple majority of property owners, or at least a two-thirds voter approval by registered voters, is required.

2. Acronyms

AB: Assembly Bill.

ADU: Accessory Dwelling Unit.

BMP: Best Management Practice.

City: The City of Anaheim.

CIP: Capital Improvement Project.

CPI: Consumer Price Index

DU: Dwelling Unit.

EPA: United States Environmental Protection Agency.

ERU: Equivalent Runoff Unit.

GIS: Geographic Information System.

LID: Low Impact Development.

MPSD: Master Plan of Storm Drainage.

MS4: Municipal Separate Storm Sewer System.

N/A: Not Applicable.

O&M: Operations and Maintenance.

SFR: Single-Family Residential

SB: Senate Bill.

3. Development of Feasibility Study

3.1 Introduction

GHD and DTA (the “Consulting Team”) was selected by the City of Anaheim through a competitive selection process to study and evaluate potential financial means and methods to address currently unfunded State mandated requirements on the improvement, operation and maintenance of the City’s storm water system, also referred to in this Study as storm drain. SB 231, which was adopted in 2017, provides local agencies with a mechanism to fund storm drainage operations by including “storm water” in the definition of “sewer” for the purposes of Proposition (“Prop”) 218. The Storm Drain Funding Feasibility Study (“Feasibility Study”) is intended to analyze feasibility of various funding options and begin to develop the framework that is based on engineering means and methods to financially establish resources that can be used by the City to operate and maintain the storm drain system, and comply with current and anticipated future regulations for storm water and storm drains. This Feasibility Study will analyze land use data and utilize hydrologic methods to determine storm drain flow contributions and annual storm drain funding needs under different scenarios.

This Feasibility Study includes the following sections:

- Financial Mechanisms;
- Technical Approach; and
- Preliminary Recommendation.

Combined engineering and financial models are utilized to balance budgets derived from proposed funding resources with the expenditures required to construct, operate, and maintain needed facilities for the regulated objectives of the Citywide storm drain programs. Models can be based on different funding assumptions, such as Pay-As-You-Go funding, bonded indebtedness, or combinations of both, where Pay-As-You-Go is the use of a Storm Drain Fee to pay directly for capital facilities without debt financing.

This Feasibility Study developed financial models to analyze various planning levels and budgets. The preliminary results of alternative model scenarios can be used by the City to evaluate the implementation of a Storm Drain Fee. Specifically, the model results can:

- Determine land use classes and the corresponding runoff contributions;
- Relate funding resources to the level of funding that the Storm Drain Fee can support;
- Compare the pros and cons of Pay-As-You-Go financing vs. bond financing; and
- Determine the sensitivity of model results to factors such as escalation, inflation rates, land use assumptions, project costs and project timing.

3.2 City Storm Drain System

The City's storm drain system is comprised of underground and above ground infrastructure that serves to convey and dispose of runoff. The California State Water Resources Control Board ("State Water Board") regulates the storm drain system through the issuance of MS4 permits. The MS4 permits include various requirements, such as the implementation of Best Management Practices ("BMPs") and treatment of runoff.

The City's existing storm drains are designed to convey and dispose of runoff in accordance with the Orange County Hydrology Manual. The Orange County Hydrology Manual primarily addresses flow rate generation and the hydraulic components of the storm drain and is not an all-encompassing manual that discusses water quality or maintenance requirements stipulated by the State Water Board. A majority of the City's storm drains were built in the 1950s and 1960s and have been in service for more than the 50 year design life. In addition, these storm drains are deteriorating or near the end of their service life, do not meet the City's current capacity requirement, and/or are not maintained routinely due to lack of funding stream. Most commonly, the storm drains are operated with very limited funding, which results in minimal preventive maintenance, condition/structural assessments, repairs, or rehabilitation. Currently, storm drain maintenance and repairs or rehabilitation are performed as needed or in response to an emergency scenario or reactive situations. However, when compared to the costs of allowing an asset to fail, preventive maintenance measures have been shown to maintain or increase an asset's performance during its service life or resulting in overall reduced total costs for maintaining the asset (Source: EPA's Fundamentals of Asset Management, www.epa.gov)

As indicated above, the City's existing storm drain system are antiquated and are inadequate to handle existing and future capacities expected to be generated by the land uses permitted by the City's General Plan. Changes in land uses and revised storm drain design parameters make it desirable to develop long-and short-range plans for the City's storm drain system. The most comprehensive and reliable method for study of storm drain needs require a regional approach rather than the more fragmented study areas previously utilized to determine future requirements.

The future needs of the City for expansion and capital improvements of its storm drain system require periodic updating and amendment to account for growth and shifting population patterns. Over the past 10-15 years, the City has completed a MPSD for each of the City's watershed areas to keep the City's drainage infrastructure in compliance with the City's Drainage Design Manual's requirements to mitigate flood risks, and to identify storm drains deficient in capacity and those in disrepair and in need of replacement and/or rehabilitation. These MPSDs are the basis for the development of the City's storm drain CIP list. The City has formally adopted the MPSDs, which prioritize projects for the establishment of a CIP. However, the identified CIPs have not been implemented or constructed due to the lack of funds. More information, including a listing of these CIPs, is discussed under the Technical Approach section.

3.3 Financial Mechanisms

This section discusses potential local financial resources and financing mechanisms that can provide funding for capital costs and the ongoing maintenance of the storm drain system, including needed services and improvements related to capacity and compliance with current and future storm drain legislation.

Federal, State, and other funding can be very useful in funding one-time projects or coping with shortfalls, but consistent availability of such funding cannot be assured and is often beyond the control of local public agencies. In addition, Federal and State programs often involve financing that requires a local match and/or local funding stream to repay them and primarily fund capital improvements (rather than O&M). It is assumed when the City makes an effort to apply for any available grants and loans that, to the extent the City is able to receive such funding, the need to undertake the local mechanisms cited below may be diminished. Due to the variability and unpredictable nature of Federal and State grants, consistent local funding sources are being recommended because they are under the control of the City and more predictable for continuous and on-going short-term needs and long-term proactive planning.

The City is currently evaluating the feasibility of using a water quality credit trading system to better allocate funds within City departments based on project benefit/allocation models. The City will and should continue pursuing the feasibility of this effort. However, as this analysis is still under development, water quality credits are not included as a funding source in this Study because it is not meant for capacity construction. In addition, general obligation bonds are not being considered as a potential financing mechanism as part of this Feasibility Study. Instead, the focus of this Feasibility Study is to identify a new dedicated and consistent local funding source for capital facilities and O&M.

3.3.1 Legislation Overview

3.3.1.1 Proposition 218

The adoption of Prop 218 by the voters in California in 1996, was pivotal in infrastructure financing. Prop 218, or the "Right to Vote on Taxes Act," was a successful effort by the Howard Jarvis Taxpayers Association ("HJTA") to ensure that local governments could not levy any taxes, assessments or user fees on property owners without the express consent of the voters in the community where such charges would be levied. Specifically, all general taxes need to be approved by at least one-half of the electorate, all special taxes need to be approved by at least two-thirds of the electorate, and all special assessments and property-related fees must be approved by at least one-half of the impacted property owners submitting mailed ballots prior to the public hearing at which such special assessments or fees are to be approved by a local legislative body (or, at the option of the legislative body, by at least two-thirds of the registered voters). Any fee that is property-related, or that arises as a consequence of property ownership, falls under the scrutiny of Prop 218. The only exceptions to these voter approval requirements are fees for sewer, water, and refuse collection. Such fees can be enacted or increased by ordinance. However, based on the California Supreme Court's decision in *Bighorn-Desert View Water Agency v. Verjil* (2006), the fees are subject to Prop 218 noticing and public hearing requirements.

In 2002, *HJTA v. City of Salinas* clarified and refined Prop 218's voter exemption for sewer, water, and refuse collection fees. In this case, the court considered a challenge to fees imposed by City of Salinas to fund storm water drainage and flood control program developed to address water quality challenges created by storm water runoff. The trial court found in favor of the City of Salinas, but the Sixth Appellate District of the State Court of Appeals overturned the trial court's finding by a 3-0 vote. The basis for the Appeal Court's decision was an emphasis on Prop 218's fundamental premise that “the provisions of this act shall be liberally construed to effectuate its purposes of limiting local government revenue and enhancing taxpayer consent.” As a result, the Appeals Court determined that a fee based on land use was not a charge directly based on use (such as the metered use of water for a water fee), and that it was in fact a fee based on ownership of property because a property owner could not escape the fee by declining to accept the service. The Appeals Court went on to declare that storm water and flood control activities are separate from sewer and water services, and therefore are not eligible for the voter exemption permitted under Prop 218 for sewer and water fees.

3.3.1.2 SB 231

Recognizing that the Appeals Court declared storm water and flood control activities are separate from sewer and water services, SB 231 was authored by Senator Robert Hertzberg and signed into law by then-Governor Jerry Brown in October 2017. SB 231 expands the definition of “sewer” under Prop 218 to include systems for collection, treatment, or disposal of storm water runoff.

Pursuant to SB 231, sewer is now defined, for purposes of Prop 218, to include “systems, all real estate, fixtures, and personal property owned, controlled, operated, or managed in connection with or to facilitate sewage collection, treatment, or disposition for sanitary or drainage purposes, including lateral and connecting sewers, interceptors, trunk and outfall lines, sanitary sewage treatment or disposal plants or works, drains, conduits, outlets for surface or storm waters, and any and all other works, property, or structures necessary or convenient for the collection or disposal of sewage, industrial waste, or surface or storm waters.”

SB 231 states that storm waters are carried off in storm drains, and careful management is necessary to ensure adequate state water supplies, especially during drought, and to reduce pollution.

Under SB 231, storm water is now considered a component of “sewer,” and therefore receives the same exemption from the voter approval requirements established under Prop 218 (as previously discussed in Section 3.3.1.1) that apply to sewer, water, and refuse collection fees.

In response to the *HJTA v. City of Salinas* decision, SB 231 explicitly states that storm water is included in the definition of sewer for purposes of Prop 218.

3.3.1.3 ADU Legislation

According to the California State Legislature, Accessory Dwelling Units (“ADUs”) provide additional rental housing and are an essential component in addressing housing needs in California. In 2017, several changes to State ADU laws went into effect (SB 1069, AB 2299, and AB 2406). These changes are intended to reduce barriers, streamline approval, and expand capacity to accommodate the development of ADUs. As a result of this legislation, it is likely that new ADUs will be constructed in the City. However, adding ADUs to residential lots may result in an increase in storm water runoff from such property. If a property owner designs and constructs an ADU on an area that was originally permeable, then it will result in an increase in runoff from the property. However, under SB 1069, ADUs cannot be considered new residential uses for the purpose of calculating utility connection fees or capacity charges. No such restriction currently applies to fees for ongoing utility services. The City’s current 2018 policy on ADUs allows the City to consider the impact of ADUs on runoff when implementing a fee or charge. ADUs may decrease permeable area and the result may be in increase of fees.

3.3.2 Overview of Local Financing Mechanisms

This section discusses potential local funding sources and financing mechanisms that can provide funding for capital costs and the ongoing needed maintenance of the storm drain system, including services and improvements related to capacity and compliance with current and future storm drain legislation.

3.3.2.1 Storm Drain Fee

3.3.2.1.1 Pre-SB 231

Prior to the adoption of SB 231, the most comprehensive approach for funding the capital costs of storm drain facilities and associated Operations and Maintenance ("O&M") would be the use of a Storm Drain Fee without the voting exemption granted by SB 231. A Storm Drain Fee is considered a property-related fee under Prop 218 and requires a simple majority of property owners, or at least a two-thirds voter approval by registered voters subject to the Storm Drain Fee.

3.3.2.1.2 Post-SB 231

As mentioned in the previous section, pursuant to SB 231, storm water is now considered a component of "sewer" for purposes of Prop 218. Although Prop 218 does not require voter approval for sewer, water, and refuse collection fees, it does require certain noticing and public hearing requirements to be adhered to, including the following:

a. The local government must provide written notice by mail to each property owner subject to the new fee or charge and must contain the following information:

    i. The amount of fees or charges proposed;

    ii. The basis upon which the fees or charges were calculated;

    iii. A statement regarding the reason for the imposition of the new, or increases to the existing, fees or charges; and

    iv. The date, time, and location of the public hearing at which the local government will consider the new fees or charges or proposed increases to the existing fees or charges.

b. Local government must hold a public hearing and determine whether there is a majority protest against the fee or charge no less than 45 days after the written notice is mailed. The submittal of written protests prior to the public hearing by a majority of the property owners affected by the fee or charge is sufficient to prevent the imposition of that fee or charge.

In addition, as parcel-related fees, these fees must still be calculated according to Prop 218 guidelines. Prop 218 requires that:

a. Revenues derived from the fee or charge shall not exceed the funds required to provide the property-related service.

b. Revenues derived from the fee or charge shall not be used for any purpose other than that for which the fee or charge was imposed.

c. The amount of fee or charge imposed upon any parcel or person as an incident of property ownership shall not exceed the proportional cost of the service attributable to that parcel.

d. No fee or charge may be imposed for a service unless that service is actually used by, or immediately available to, the owner of the property in question. Fees or charges based on potential or future use of a service are not permitted.

e. No fee or charge may be imposed for general governmental services including but not limited to police, fire, ambulance, or library services where the service is available to the public at large in substantially the same manner as it is to property owners.

A local agency can utilize a Storm Drain Fee to pay directly for storm drain facilities and O&M ("Pay-As-You-Go") or use a Storm Drain Fee as a funding source to support the issuance of bonds.

3.3.2.2 Parcel Tax

Special taxes are levied by local governments for special purposes. A tax levied for a special purpose is a special tax if tax proceeds are deposited in the local government's general fund and special tax may not be ad valorem real property taxes. Two of the most common types of special tax include the following:

1. Parcel Tax; and
2. Mello-Roos tax (discussed further in the next section).

In California, parcel taxes are decided by registered voters and require at least a two-thirds voter approval.

3.3.2.3 Mello-Roos Community Facilities District ("CFD")

A CFD can be used to pay for storm drain infrastructure related to new development. Although a two-thirds vote of the "qualified electors" is required to establish a CFD, the boundaries of a potential CFD could be set so that fewer than twelve registered voters initially reside within the CFD. In this case, the qualified electors would be the property owners (not the registered voters), and if a property owner were conditioned to form or annex to a CFD to develop their property, they would need to agree to include their property in the CFD. While this type of financing would not generate funds to pay for existing development costs, it could cover a substantial portion of the cost of such capital improvements and services related to future development and redevelopment for the property owners it would serve.

The Mello-Roos Community Facilities Act was enacted by the California State Legislature in 1982 (Section 53311 et. seq. of the Government Code) to provide an alternate means of financing public infrastructure and services subsequent to the passage of Prop 13 in 1978. The Act complies with Prop 13, which permits cities, counties and special districts to create defined areas within their jurisdiction and, by a two-thirds vote within the defined area, impose special taxes to pay for the public improvements and services needed to serve that area.

A CFD can provide for the purchase, construction, expansion, or rehabilitation of any real or other tangible public property with an estimated useful life of at least 5 years. It may also finance the costs of planning, design, engineering, and consultants involved in the construction of improvements or formation of the CFD. The facilities or real property financed by the CFD do not have to be physically located within the CFD.

Furthermore, a CFD may also pay for certain types of public services such as flood and storm protection services. However, a CFD could finance these services only to the extent that they are in addition to those provided within the area of the CFD before the CFD was created and could not supplant services already available within that area.

3.3.2.4 Assessment District

There are a number of types of Assessment Districts ("ADs") that could be utilized to fund storm drain facilities and O&M costs. Under the Municipal Improvement Act of 1913 and the Improvement Bond Act of 1915, any city or county can establish an AD to fund certain storm drain and water quality improvements, as well as the O&M of those specific improvements. Furthermore, under the Benefit Assessment Act of 1982, these same public agencies can establish ADs to finance the O&M of drainage and flood control services, as well as drainage and flood control facilities that need not be related to the services being financed.

However, unlike the financing mechanisms discussed previously, ADs are subject to specific benefit requirements as a result of both their enabling legislation and Prop 218. Under their enabling legislation, public works improvements and services are eligible for AD financing to the extent that properties within the AD receive a special, measurable, local, and direct benefit from such improvements and services. Traditionally, improvements to be financed using an AD include but are not limited to local streets and roads, water, sewer, storm drains, utility lines, and landscaping. Improvements of general benefit to a community are not eligible for AD financing.

3.3.2.5 Development Impact Fees

A development impact fee is established pursuant to California Government Code, Section 66000, known as the "Mitigation Fee Act" and can be utilized to fund various public improvements, including storm drain and sewer facilities, that are needed to serve new development. A development impact fee is a one-time charge imposed by a local agency on new development to recover, or partially recover, the estimated reasonable cost of providing public facilities needed to mitigate the impacts of such new development.

The payment of the impact fee occurs prior to the beginning of construction of a dwelling unit or non-residential building (or prior to the expansion of existing buildings of these types). Fees are often levied at final map recordation, issuance of a certificate of occupancy, or more commonly, at building permit issuance.

In addition, there are strict nexus, or benefit, requirements when establishing an impact fee. Also, a fee cannot include costs attributable to existing deficiencies, but can fund costs used to maintain the existing level of service or meet an adopted level of service that is consistent with the general plan.

3.3.3 Survey of California Cities with a Storm Drain-Related Tax or Fee

As of the date of this Feasibility Study, no local agency in California has utilized SB 231 to establish a Storm Drain Fee. However, a number of cities, including the City of Berkeley and the County of Los Angeles have recently been successful in adopting a fee and parcel tax, respectively, to fund storm water program costs. In 2018, the City of Berkeley adopted a Clean Stormwater Fee ranging from $34.31 to $51.87 per year that is based on property size, land use type, and amount of impervious surface. Considered a property-related fee, it required a simple majority vote of property owners and received 61% of the vote. In November 2018, voters in Los Angeles County approved Measure W, which authorized the Los Angeles County Flood Control District to enact a parcel tax – a property tax of $0.025 per square foot of "impermeable space." Measure W earned 69.45% of the vote.

In addition, the City of Los Altos failed in its effort to adopt a storm water fee. The City proposed a storm water fee based on land use type and lot size in October 2018. Considered a property-related fee, it required a simple majority vote of affected property owners, but only received a 44% approval vote.

Prior Southern California successes also include the City of San Clemente's Clean Ocean Fee and the City of Santa Monica's Storm Water User Fee and Clean Beaches and Ocean Parcel Tax. The Clean Ocean Fee (San Clemente) was adopted in 2002 and has been renewed twice since (in 2007 and 2013) and is currently in effect through June 30, 2020. Considered a property-related fee, it required a simple majority vote of property owners and received 57% of the vote (75% and 53% of the vote in subsequent renewals). The Storm Water User Fee (Santa Monica) was adopted in 1995 (prior to Prop 218) and is based on property size and land use type. The Clean Beaches and Ocean Parcel Tax (Santa Monica) was adopted in 2006 with 67% of the vote and exclusively funds implementation of the Santa Monica's Watershed Management Plan. At the time of the fee and parcel tax adoption, both cities stressed the importance of community outreach and educating, informing, and outlining a clear plan of action.

On a nationwide scale, other public agencies have been successful in their attempts to establish a storm water utility. The annual Western Kentucky University Stormwater Utility ("WKUSU") Survey, recently completed in June 2019, identified roughly 1,716 storm water utilities located across 40 states and the District of Columbia with an average monthly single-family residential charge of $5.85. The storm water utilities identified in the study, such as the Cities of Sacramento ($11.31); Mesa, Arizona ($7.32); Aurora, Colorado ($10.46); and Plano, Texas ($3.10), are similar in size and population with the City of Anaheim.

An overall summary of select findings of the utility survey by Western Kentucky University is shown in Table 3.1 below.

Table 3.1 Summary of Western Kentucky University Stormwater Utility Survey 2019

Agencies	Number of Agencies Surveyed	Monthly Fee Range	Year Established Range	Population Range
Agencies with similar population with Anaheim	30	$1.08 - $16.82	1974 - 2016	226,918 to 543,566
California*	56	$0.48 - $23.71	1979 - 2012	4,161 to 3,792,621
United States*	1,716	$0.21 - $38.10	1974 - 2018	Less than 100 to 3,792,621

*Note: Monthly fees not available for all agencies.

3.3.4 Financing Mechanism Recommendation

While each financing mechanism discussed above has its own merits, the Consulting Team identified preliminary recommendations and reasoning for each in Table 3.2 below.

Table 3.2 Potential Financing Mechanisms

Financing Mechanism	Recommendation
Prop 218 (Post-SB 231 Storm Drain Fee)	Yes, comparable to the funding of wastewater and water under Prop 218 guidelines. See Section 4.2 for future actions needed.
Prop 218 (Pre-SB 231 Storm Drain Fee)	Alternative in the event decision makers choose not to implement Post-SB 231 and instead follow a mail-in ballot measure process. Mail-in ballot process, requires simple majority of property owners, or at least a two-thirds voter approval by registered voters.
Parcel Tax	No, requires 2/3 vote of qualified electors.
Mello-Roos Community Facilities District	Under consideration for new development and redevelopment.
Assessment District	No, greater legal scrutiny related to general vs. special benefit methodology and strict special benefit requirements.
Development Impact Fees	Under consideration for new development and redevelopment.

From the financing mechanisms available, the Consulting team recommends that the City pursue the implementation of a Storm Drain Fee in compliance with Prop 218 comparable to its other utilities. This proposed Storm Drain Fee will provide a funding source for both capital improvements and ongoing maintenance of storm drain facilities within the City. Section 3.4, "Technical Approach," below describes a technical approach that meets the requirements of Prop 218 and can be used to calculate and implement a Storm Drain Fee under specific Citywide conditions, including detailed CIPs, estimated costs, and proposed O&M of the storm drain system. In addition, while not analyzed further in this Study, the Consulting Team recommends that the City continue to explore the use of CFDs and development impact fees to mitigate the burden of new development on the City's storm drain infrastructure.

3.4 Technical Approach

3.4.1 Methodology

To establish a Storm Drain Fee, the City will need to meet the requirements of Prop 218 as set forth in Section 3.2.2.1.2, which will require (among other things) that there is a proportional relationship between the fee charged to a parcel and cost of service being provided.

In general, the cost of a Citywide storm drain system is related to its capacity to capture, retain, treat, infiltrate, and/or release storm flow from within City boundaries. For the purposes of this Feasibility Study, it is assumed that the storm flow discharge rate of a local land use is directly related to its relative volumetric contributions of storm flow to the City collection and retention systems. Thus, relative runoff will be the metric used to allocate capital improvement costs of storm drain systems to the contributing land uses. Land use assumptions, such as the numbers of residential units, non-residential acreage, and impervious surface area, are discussed in detail in Sections 3.4.2 and 3.4.3. The relative runoff from each land use can be compared to the runoff from a typical single-family unit to determine the Equivalent Runoff Unit ("ERU") values for the various land uses as discussed in more detail in Section 3.4.6, "Funding Alternatives." Total program costs can then be allocated to the various land uses in proportion to runoff and thus a fee structure can be defined.

Total capital improvement and O&M costs can then be divided by the total ERUs to determine the cost per ERU. This unit cost can then be applied to the various land uses to determine the respective cost allocations.

3.4.2 Parcel-Based User List

Defining accurate parcel data is required to establish a parcel-based Storm Drain Fee. When combined and analyzed together, the City's Geospatial Data and the County of Orange's Tax Assessor Parcel Data provide a reliable source for establishing a parcel data user list. County data consists of property deeds, recorded maps, and other recorded legal information for each Assessor's parcel as provided by the County of Orange Assessor's office. The consolidated land use designations include Single-Family Residential, Multi-Family Residential, Commercial/Industrial, Municipal, Schools, and Parks/Open Space. For purposes of this Feasibility Study, the land uses were consolidated, as follows:

- Single-Family Residential (High, Medium, and Low Density);
    - Low, Medium, and High density single family residential land uses were developed based on number of dwelling units per acre, taken from the Orange County Hydrology Manual
- Multi-Family Residential;
    - Multi-Family Residential includes condominiums and apartments. These two land-use types share the same impervious area percentage.
- Commercial/Industrial;
- Open space and parks;
- Schools; and
- Municipal (police, fire, County, and other Governmental properties).

3.4.3 Land Use Classifications and Impervious Area Ratios

Watershed development and planning requires current and projected impervious surface percentages to calculate various hydrologic values. The City's Geospatial Data provided by the City of Anaheim Planning Department on May 2019, was cross referenced with the corresponding land use impervious percentages listed in the 1986 Orange County Hydrology Manual and its 1996 Addendum to arrive at a common definition for land use and impervious percentage. Impervious surfaces are defined as natural exposed rock and manmade structures that include but are not limited to roadways, driveways, roofs, sidewalks, parking lots, paved areas, and other surfaces that prohibit the percolation of surface water into the underlying ground. Impervious areas intensify surface runoff, increasing the potential for higher flow rates, flow volumes, flow velocities, erosion, and sediment transport. The Orange County Hydrology Manual Section C.5 associates land uses with impervious surface percentages. The percentages from the Orange County Hydrology Manual listed in Table 3.3 below were used as a guideline for determining values for the City.

Table 3.3 Orange County Hydrology Manual Land Use Impervious Percentages

Land Use	Range-Percent	Recommended Value for Average Conditions-Percent
Natural or Agriculture	0	0
Public Park	10-15	15
School	30-50	40
Single-Family Residential:		
2.5-Acre Lots	5-15	10
1-Acre Lots	10-25	20
2 Dwellings/Acre	20-40	30
3-4 Dwellings/Acre	30-50	40
5-7 Dwellings/Acre	35-55	50
8-10 Dwellings/Acre	50-70	60
More Than 10 Dwellings/Acre	65-90	80
Multi-Family Residential:		
Condominiums	45-70	65
Apartments	65-90	80
Mobile Home Parks	60-85	75
Commercial, Downtown Business, or Industrial	80-100	90

1. Land use should be based on ultimate development of the watershed. Long-Range MPSDs for the County and incorporated cities should be reviewed to insure reasonable land use assumptions.

2. Recommended values are based on average conditions that may not apply to a particular study area. The percentage impervious may vary greatly even on comparable sized lots due to difference in dwelling size, improvements, etc. Landscape practices should also be considered as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. A field investigation of study area shall always be made, and a review of aerial photos, where available, may assist in estimating the percentage of impervious cover in developed areas.

The Orange County Hydrology Manual values listed above were used as a guideline together with the Consulting Team's review of the City's public land use information and MPSDs to determine average impervious ratios for the consolidated land uses described in Section 3.4.2, "Parcel Based User List," above. These land use classes and values are shown in Table 3.4 below.

Table 3.4 Land Use Impervious Percentages

Land Use (LU)	Recommended Value for Typical LU Conditions-Percent
Parks or Open Space	10
Municipal Facilities, Police, Fire	90
Public Schools	40
Single-Family Residential:	
(High Density) 4-8 Dwelling Units ("DUs")/Acre	50
(Medium Density) 1-3 DUs/Acre	35
(Low Density) less than1 DU/Acre	20
Multi-Family Residential (Includes more than 8+ DUs/Acre) *	75
Commercial, Industrial	90

* Multi-Family Residential includes condominiums and apartments, both LU types share the same impervious area percentage

3.4.3.1 Field Verification of the Baseline Impervious Area Data

The baseline impervious area percentages in Table 3.4 above were derived from land use information documented in the Orange County Hydrology Manual and based on values that were established more than 30 years ago. Advances in technology have afforded new approaches to collect impervious area data from the physical environment, which includes remote sensing and the use of Geographic Information Systems ("GIS") software. The Consulting Team further refined the impervious data to be used in the Feasibility Study by delineating the City's impervious area in GIS, performing a desktop quality control check of the results, and then field verifying approximately 30% to 50% of the land uses in the entire City, as detailed in Appendix B. The resulting verified and final land use impervious area percentages is shown in Table 3.5 below and will be used in this Feasibility Study.

Table 3.5 Final Verified Land Use Impervious Area Percentages

Land Use (LU)	Recommended Value for Typical LU Conditions-Percent
Parks or Open Space	15
Municipal Facilities, Police, Fire	75
Public Schools	50
Single-Family Residential:	
(High Density) 4-8 Dwelling Units ("DUs")/Acre	50
(Medium Density) 1-3 DUs/Acre	35
(Low Density) less than1 DU/Acre	30
Multi-Family Residential (Includes more than 8+ DUs/Acre)	60

Table 3.5 Final Verified Land Use Impervious Area Percentages

Land Use (LU)	Recommended Value for Typical LU Conditions-Percent
Commercial, Industrial	80

3.4.4 Storm Drain Funding Requirements

The funding requirements to be satisfied by a Storm Drain Fee include the (i) current level of O&M costs, (ii) new capital improvement costs, (iii) costs related to NPDES Storm Water Regulatory Compliance Administration and for Maintenance of City Right-of-Way BMPs, and (iv) costs related to Trash Amendments.

3.4.4.1 Current O&M

The City provided a detailed report of FY 2018-2019 budgeted O&M for storm drain activities, which totaled $1,407,181. The majority of these costs include labor, equipment and vehicle costs, professional services, and infrastructure maintenance costs. In certain cases some of the City's CIP's being implemented are in fact reducing maintenance routines (thereby costs). The City's "Green Infrastructure" alley program is an alternative to traditional CIP improvements and is alleviating certain "hot spots", "recall" areas, or frequency.

For the purposes of analyzing the projected storm drain O&M funding requirements, the budgeted costs for FY 2018-2019 are used for the first year of O&M costs, while costs for subsequent years are inflated based on historical Consumer Price Index ("CPI") adjustments.

3.4.4.2 CIP

The City's storm drain system is quite diverse with facilities located throughout the City as shown on Figure 3.1. The current MPSDs were previously prepared and approved by the City between 2005 and 2017. The intent of these MPSDs is to provide comprehensive long-term planning for the implementation of storm drains and the costs associated with these improvements. Recommended capital improvements identified in the MPSD provide detailed cost data and priority levels necessary to establish a CIP list and project infrastructure funding needs.

Individual project costs from each MPSD were combined into one database to analyze total project costs. To account for construction cost inflation, the original cost estimates presented in the MPSD reports were multiplied by an inflation adjustment factor based on the report approval year. These inflation adjustment factors are summarized in Table 3.6.[1]

Table 3.6 2019 U.S. Dollars Adjustment Factors

MPSD Approval Year	2019 Adjustment Factor
2005	1.32
2007	1.28
2008	1.24
2010	1.20

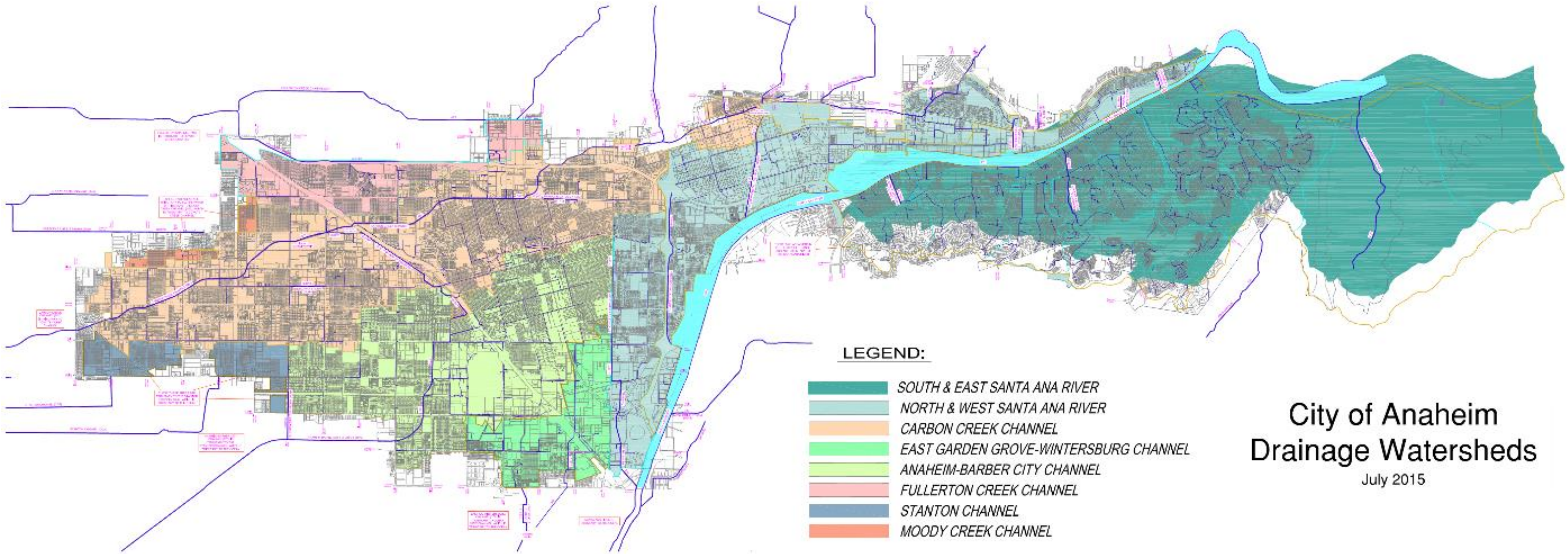
[1] Annual inflation adjustment values were referenced from Engineering News-Record Construction Cost Index 20-City Average.

Table 3.6 2019 U.S. Dollars Adjustment Factors

MPSD Approval Year	2019 Adjustment Factor
2013	1.14
2017	1.03

The MPSD studies focused on the capacity criteria outlined in the City's Storm Drainage Manual for Public and Private Storm Drainage Facilities, dated August 2005, and the age of the facility, to prioritize potential flood risks and structural failures throughout the City. Current Trash Amendment and Low Impact Development ("LID") requirements stipulated by regulatory documents were not accounted for during the development and approval of the aforementioned MPSDs. The Trash Amendment funding requirements will be covered in detail in Section 3.4.4.4.

Figure 3.1 City Drainage Watersheds



In addition to summarized project costs, project prioritization was discussed in multiple MPSDs. The prioritization was intended to establish an order of importance for funding allocation and construction sequencing. For the purposes of this Feasibility Study, the priority level and anticipated costs are supporting factors to establishing a Storm Drain Fee, as well as providing information and guidance for future regional storm drain planning or other future storm drain initiative studies.

The prioritization helped determine which of the proposed storm drain projects were of the greatest importance so that the City can make informed funding decisions and choose which projects should be constructed first as funding becomes available. It is anticipated that projects identified as capacity deficient in the MPSDs, and prioritized accordingly, will consider multiple design alternatives to mitigate/address capacity issues that include but are not limited to pipe rehabilitation, pipe replacement, pipe upsizing, diversion of runoff, the installation of runoff capture and disposal systems, and compliance with regulatory requirements.

Building on the definitions of prioritization outlined in the MPSDs, the overall total implementation project costs from the approved MPSDs totaled $866.4M (2019 U.S. dollars) as shown in the Table 3.7 below.

Table 3.7 Storm Drain CIP MPSD Summary (2019 U.S. Dollars)

Watershed MPSD	Priority 1 MPSD Projects	Total for All MPSD Projects
Grand Total	**$362,987,179**	**$866,422,349**

3.4.4.2.1 Project Priority

For this Feasibility Study, it is important for the City to fund the $363M Priority 1 projects with the new Storm Drain Fee to address the most immediate capacity needs beginning with areas without existing infrastructure in place ("New Required Storm Drain Facilities") followed by aging infrastructure as shown in Table 3.8 below. To prioritize the projects as outlined in the MPSDs on the basis of aging infrastructure, the Consulting Team conducted preliminary as-built research to identify the storm drain systems' years in service. These projects were ranked by age 1-19 years, 20-29 years, 30-39 years, 40-49 years, and greater than 50 years.

Table 3.8 Storm Drain Priority 1 CIP Implementation Cost by Age Summary (2019 U.S. Dollars)

New or Years in Service	Total Cost (2019 Dollars)
New Required Storm Drain Facilities*	**$153,998,186**
Greater or equal to 50 years	**$23,456,065**
40-49 years	**$141,975,369**
30-39 years	**$40,018,877**
20-29 years	**$3,538,682**
0-19 years	**$0**
Grand Total for Priority 1	**$362,987,179**

Notes:
*Per MPSDs, varies per location, extension of existing storm drain system

3.4.4.2.2 Funding Level Alternatives

For the purposes of this Feasibility Study, the following funding levels were evaluated:

1. Facility age greater than or equal to 50 years ($23.5M) plus new construction ($154M) for a total of $177.5M; and
2. Total Priority 1 funding of $363M.

3.4.4.3 NPDES Compliance

3.4.4.3.1 NPDES Storm Water Regulatory Compliance Administration

The City implements an NPDES Storm Water Regulatory Compliance Program to comply with the State issued MS4 permit. The ground level implementation of the multiple specific programs is performed by various City Departments. Historically, in addition to implementing several programs that fall within Public Works' purview, the Department has accepted responsibility for the oversight of these compliance programs. This oversight includes, assistance to Departments with program development and refinement, as well as coordination with the State, County and other Cities on related issues.

The annual costs for this oversight is currently budgeted at $1.6 million per year and is shown as such in Year 1 of the model (see Table 3.9 below). Inflation adjustments to account for annual wage and price inflation are based on the Engineering-New Record Construction Cost Index. However, these regulations continue to become increasingly complex and more stringent, therefore an added 5% per year increase is included to account for this escalation. This is consistent and even conservative when looking backward 15 years.

Table 3.9 NPDES Storm Water Regulatory Compliance Administration (2019 U.S. Dollars)

	Year 1 Cost (2019 Dollars)
Labor/personnel	$ 227,206
Contracted Services	$ 800,000
Permit Fees	$ 600,000
Total	$ 1,627,206

One of the ground level implementation programs which is not part of the oversight program is the O&M (inspecting, monitoring, cleaning, repairing, and rehabilitating) of City Right of Way BMP's. These costs are discussed in Section 3.4.4.2.3 below.

3.4.4.3.2 O&M for City Right-of-Way BMPs

The City requires personnel, materials, and equipment to operate and maintain the service life of BMPs within City right-of-way. These BMPs are recent additions to the Citywide storm drain system, and are required for the implementation and compliance of NPDES requirements. The annual costs for the O&M of BMPs within City right-of-way is currently budgeted at $60,000 per year and is shown as such in Year 1 of the model (see Table 3.10 below). The City's separate BMP Credit system budget study (which is currently being assessed) further discusses the City's implementation and maintenance of BMPs.

Table 3.10 NPDES Storm Water Regulatory Compliance (2019 U.S. Dollars)

	Year 1 Cost (2019 Dollars)
Labor/personnel/vehicles	$ 60,000

3.4.4.4 Trash Amendment Implementation Costs

Trash Amendment Implementation is a cost component that is included in this Feasibility Study to estimate the City's required budget needed to implement this MS4 unfunded mandate. The State Water Board adopted the "Trash Amendments" on December 2, 2015, when it was approved by the California Office of Administrative Law. These Trash Amendments were also approved by the U.S. Environmental Protection Agency ("EPA") on January 12, 2016. The Trash Amendments actually refer to amendments to two different Water Quality Control Plans:

- Water Quality Control Plan for Ocean Waters of California to Control Trash (Ocean Plan); and
- Part 1 Trash Provisions of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California ("ISWEBE Plan").

Following the approval of these amendments, the Regional Water Quality Control Board issued an administrative order under California Water Code section 13383 to notify the City, of the new requirements that will be required for compliance with the State Water Board policy. The City will have 10 years to comply after the first implementing permit or no later than December 2, 2030, as shown in the flow chart in Figure 3.2.

Figure 3.2 Trash Amendment Compliance

Source: waterboards.ca.gov/water_issues/programs/storm water/trash_implementation.html

The cost of Trash Amendment implementation was not included in any of the previously approved MPSDs that were described in Section **Error! Reference source not found.**. In order to comply with the Trash Amendments, the City will have to install trash capture devices or other LID BMP structures that meet the definition of a full-capture device for trash throughout the City. It is assumed the highest amount of capital costs will only be seen during the first 10 years of implementation in order for the City to meet the effective final compliance date for 100% trash capture implementation. However, it is anticipated that the O&M costs for the trash capture devices will continue in perpetuity. Based on the City's current approach to build trash capture devices or other LID BMP structures in an accelerated schedule during the first 4 years of the first 10 year-period, the total implementation cost is estimated to be $1,000,000 and the annual O&M cost after the 4th year is expected to stabilize at approximately $1,056,000 per year. The implementation costs have been summarized in the Table 3.11 below.

Table 3.11 Projected Initial Trash Amendment Budget Requirements for First Year 2019 U.S. Dollars)

Year	Year 1	Four Year Cumulative Total
CIP Cost	$250,000	$1,000,000
O&M Costs	$264,000	$2,639,000

Source: The City's Trash Program BMP Implementation Plan Scenarios.

3.4.5 Storm Drain Fee Framework Analysis

With the funding requirements defined, those requirements must be allocated to the users of the infrastructure or benefitting classes that, in the case of public storm drain systems, are the various property owners with parcels that contribute runoff to the storm drains. In addition to meeting Prop 218 and other legal requirements, the fee structure should adhere to the following goals and guidelines:

- The fee structure must be fair;
- The fee structure must be uniform and simple;
- The fee structure must be stable; and
- The fee structure must be easy to implement.

- The fee structure must include flexibility for properties with significantly less impact to petition for fee reduction

The costs of the Citywide storm drain improvements are related to the relative contribution to runoff by each land use type, as compared to the runoff contribution from a single-family unit. Rational Method Hydrology (Q=CIA) is used in this analysis, where Q is discharge, C is a runoff coefficient based on the ratio of impervious area to total parcel area, I is storm intensity, and A is total ground area. For any given storm intensity ("I"), the relative runoff contribution is directly related to the runoff coefficient.

The proposed fee structure uses relative runoff as the preferred metric to ensure a proportional relationship between the fee charged and cost of service to a parcel. When applied consistently to the various land uses, this ensures that the charges are fair and uniform. The relative runoff method uses proportionate runoff from the various land uses to allocate costs, thereby reducing the complexity of quantifying complex hydrologic systems to manageable and understandable terms. Where necessary, fee stabilization funds can be used to inject or accept funds from storm drain operations to ensure that annual fees do not fluctuate erratically, thus stabilizing the impact to the users.

3.4.6 Funding Alternatives

Four different mathematical financial models were used to analyze a range of funding levels and fee structures. Three models looked at Pay-As-You-Go funding while a fourth model looked at bond funding alternative. In keeping with industry standards and the recommendations of the American Water Works Association[1] these models assumed a five year study period. The reliability with regard to accurately predicting future outcomes drops significantly beyond five years. Model 1 and Model 2 look at C.I.P. funding levels of $177.5M and $363M respectively, representing the minimum and maximum funding levels, or "bookends", identified in Section 3.4.4.2.1. Model 3 looks at funding levels that might be achieved using a fee structure commensurate with national average fees. While Models 1, 2, and 3 use pay-as-you-go funding, Model 4 looks at a combination of bonds financing and pay-as-you-go funding.

In order to account for increases in budget and cost projections over time, in all four models the proposed storm drain fees were escalated at 3% per year, while operations and maintenance and construction costs were increased at 3% per year and NPDES administrative costs were inflated at 8% per year, for years 2 through 5.

In Model 1 the capital improvement program targets spending $177,500,000 over a 30 year period as identified in Table 3.8, "Storm Drain Priority 1 CIP Implementation Costs by Age Summary (2019 U.S. Dollars.)". Because the exact timing of specific projects is not defined at this time, for the purposes of this model, it is assumed that the $177,500,000 is spent evenly over 30 years. Therefore, the first year expenditure is assumed to be $5,916,667 ($177.5M divided by 30 years). This amount is then escalated by 3% per year in years 2-5, as mentioned previously. The 5 year funding total is expected to be $31.4M.

In Model 2 the capital improvement program targets spending $363,000,000 over a 30 year period, as identified in Table 3.8 This funding level represents the total cost of the City's Priority 1 Capital Improvement Plan. Please refer to Table 3.8. Because the exact timing of specific projects is not defined at this time, for the purposes of this model, it is assumed that the $363,000,000 is spent evenly over 30 years. The first year expenditure is assumed to be $12,100,000 ($363M divided by 30 years.) This amount is then escalated by 3% per year in years 2-5, as mentioned previously. The 5 year funding total is expected to be $64.2M.

Model 3 calculates the maximum funding level that can be achieved based on a monthly single family fee of $5.85, which represents the national average storm water fee according to the Western Kentucky University Storm Water Utility Survey 2019. This model assumes that all net funding (annual fees less annual funding requirements) will be used for implementing the Storm Drain Capital Improvement Program (C.I.P.) which will vary year to year. The model shows that approximately $35.4M can be funded over 5 years

Model 4 assumes that all capital improvements are financed by a combination of a bond with a term of 30 years as well as pay-as-you-go funding. This bond model uses standard bonding assumptions (includes interest rate, cost of issuance, reserve requirements, debt service, coverage, etc.). Any remaining budget after satisfying debt service requirements will then be available for C.I.P. (pay-as-you-go) in later years. This model assumes that the bond proceeds will be spent over the first three years after issuance (years 1, 2 and 3). This bond model also confirms what is intuitive: The advantage of bond financing is that larger funds are available in early years as opposed to all pay-as-you-go financing. However, the total funding amount, as compared to the pay-as-you-go scenarios, is less over a 30 year period, primarily due to bond costs. This model also calculates the maximum funding level that can be achieved using a fee structure based on the same starting monthly single family fee of $5.85, as explained in Model 3 above. The model shows that over 5 years this alternative can fund approximately $74.3M from bond proceeds and $8.1M for pay-as-you-go contributions for a total 5 year funding level of $82.4M.

In all of the four models the timing of capital improvement expenditures was not defined, therefore it is assumed that the improvements that are expected to be funded in the various alternatives will be completed within a 30 year period. In all cases, assumptions were made as to timing, costs, escalators and funding reliability. This study is a feasibility study that looks at funding and costs over a five year period. This will give a reasonable expectation that projected fees can cover the expected future budget requirements over that 5 year period. Given the uncertainties in a longer term projections, there is no guarantee that all of the costs and facilities identified in each model can and will be funded over the 30 year period using the fee structures identified in each model, without further fee increases.

EXAMPLE MODEL

Table 3.12 below is an example of the fee model's Year 1 (2020) showing the City's funding requirements balanced by funding resources from a calculated fee structure that includes a monthly fee for a single-family parcel of $5.85, or $70.20 on an annual basis.

Table 3.12 Fee Model (Year 1 FY 2020) – Single Family Monthly Fee of $5.85

	Fee ($ per dwelling unit of gross acre)	Number of Resi-dential Units	Number of Gross Acres	Study Year 1 2020
Single-Family High-Density – Monthly Fee				$5.85
Single-Family High-Density – Annual Fee				$70.20
FUNDING RESOURCES				
Single-Family Residential (High)	$70.20	42,724	-	2,999,225
Single-Family Residential (Medium)	$332.34	336	-	111,665
Single-Family Residential (Low)	$843.37	44	-	37,108
Multi-Family Residential	$452.54	-	3,336	1,509,681
Commercial/Industrial	$603.39	-	7,048	4,252,692
Municipal	$565.68	-	1,661	939,495
Schools	$377.12	-	1,056	398,350
Parks/Open Space	$113.14	-	5,067	573,258
TOTAL FUNDING RESOURCES				$10,821,475
FUNDING REQUIREMENTS				
A) O&M related to Public Works Infrastructure				
Labor/personnel				$845,099
Administrative				$32,302
Contracted Services				$20,000
Infrastructure Maintenance				$417,000
Vehicles				$92,780
Subtotal O&M				$1,407,181
B) Capital Improvements				
Capital Expenses Related to Public Works Infrastructure				$7,644,696
Subtotal Capital Improvements				$7,644,696
C.1) NPDES Stormwater Regulatory Compliance Administration				
Labor/personnel				$227,206
Contracted Services				$800,000
Permit Fees				$600,000
Subtotal NPDES Stormwater Regulatory Compliance Administration				$1,627,206

Table 3.12 (Cont.) Fee Model (Year 1 FY 2020) – Single Family Monthly Fee of $5.85

	Fee ($ per dwelling unit of gross acre)	Number of Resi-dential Units	Number of Gross Acres	Study Year 1 2020
C.2) NPDES Stormwater Regulatory Compliance Maintenance*				
Labor/personnel/vehicles				$60,000
Subtotal NPDES Stormwater Regulatory Compliance Maintenance*				$60,000
D) Trash Amendment/ BMP Installations				
Capital Expenditures				$250,000
Operations and Maintenance				$264,000
Subtotal Trash Amendment/ BMP Installations				$514,000
TOTAL FUNDING REQUIREMENTS				$10,821,475
FUNDING RESOURCES MINUS FUNDING REQUIREMENTS				$0

*O&M and Minor Repair of New BMPs within City Right-of-Way

Funding Source

Parcel information included in Section 3.4.2 and average impervious area ratios described in Section 3.4.3 are used to calculate the average impervious areas for residential parcels and nonresidential in square feet. ERUs for each land use is then determined by dividing the average impervious area for each land use by the average impervious area for a Single-Family Residential (High) land use, which is representative of a typical single-family parcel. Using the calculated ERUs for each land use the relative runoff contribution to the storm drain system can be determined.

City land use data was used to sum the total residential units and nonresidential square feet within the City. By multiplying these summations by the corresponding ERUs for that land use, the total Citywide ERUs can be determined. The cost per ERU is then calculated by simply dividing the total program costs, or funding requirements, by the total ERUs. The fee structure is then calculated by multiplying the cost per ERU by the number of ERUs for each land use. The column titled "Fee ($ per dwelling unit or gross acre)" in Table 3.12 shows the fee structure based on a Single-Family (High) annual fee of $70.20 per year.

The funding for Year 1 is determined by multiplying the fee structure described above by the residential units and nonresidential acreage for each land use. Table 3.12 indicates a total fund for Year 1 to be approximately $11M.

Funding Requirements

Section 3.4.4 discusses in detail the four major cost categories included in the fee model:

- O&M Related to Public Works Infrastructure (Section 3.4.4.1)
- Capital Improvements (Section 3.4.4.2)
- NPDES Compliance (Section 3.4.4.3)
- Trash Amendment/ Best Management Practices (Section 3.4.4.4)

Table 3.12 shows the budgeted costs for the above categories for Year 1 (FY 2020). The total costs are then summed for Year 1. Net operating budget is simply the difference between total funding resources and total funding requirements. The expenditures for capital improvements shown on its corresponding line item is assigned a value that forces the net of funding resources less funding requirements to be zero. In other words, the level of capital improvement expenditures in any given year is the surplus funds (total funds less total costs.)

Summary

This model format was used to analyze the four model scenarios discussed above and the results are summarized in Table 3.13 below.

Table 3.13 Summary of Preliminary Model Scenarios for Priority CIP and O&M Funding Requirements

Model Scenario	Funding Goal	Monthly Starting Single-Family Residence Fee*	Finance Type	Aggregate Funding at 5 Years
1	$177,500,000	$5.45	Pay-As-You-Go	$31,400,000
2	$363,000,000	$8.79	Pay-As-You-Go	$64,200,000
3	Starting Rate @$5.85**	$5.85	Pay-As-You-Go	$35,400,000
4	Starting Rate @$5.85**	$5.85	Bond	$82,400,000

*Single-Family Residence Fee is High Density Residential. See report for other land use designations.

**National Average per WKUSU Survey 2019.

4. Conclusion and Recommendations

4.1 Conclusion

To obtain the storm drain funding requirements, projected capital improvements and maintenance costs were determined. Capital improvements from previously adopted MPSDs identify existing storm drain infrastructure capital improvements that primarily consist of storm drains with hydraulic deficiencies.

Maintenance funding requirements were primarily determined based on the City's experience with its wastewater collection system, known storm drain permitting requirements and costs, and upcoming regulations for storm drains. Based on this, the following four major cost categories were determined for use in the fee model:

1. Operations and Maintenance (O&M) of Storm Drains
2. Capital Improvements (Priority CIPs), funding of priority storm drain projects in the MPSDs
3. Current Regulatory Compliance Costs
4. Implementation of New Regulations (i.e. Trash Amendments and Best Management Practices)

Four scenarios were evaluated that either determined fee levels that could generate desired funding levels or identified funding levels that could be achieved with assumed first-year rates. These scenarios are summarized in Table 3.13. All scenarios cover the costs of O&M, Regulatory Compliance, and Trash Amendments (Items 1, 3, and 4 above). Scenario 1 looks at CIP funding level 1 (Section 3.4.4.2.2) spread evenly over 30 years and determines the required first-year single-family rate upon which a rate structure is developed. Scenario 2 is the same as Scenario 1 except that it looks at funding level 2 (Section 3.4.4.2.2). Scenario 3 assumes a first-year single-family rate of $5.85 per month (national average) and determines the approximate funding level that can be achieved with that rate structure using a pay-as-you-go program. Scenario 4 is the same as Scenario 3 except that it uses bond financing in addition to as pay-as-you-go funds. Given the uncertainties in longer-term projections, all scenarios were limited to 5-year projections.

In summary, this Study looked at four scenarios that could meet funding or rate level requirements for storm drain maintenance, compliance with regulations, and funding of priority capital improvements identified in the City's MPSDs. The scenarios follow a cost of services methodology that is based on a parcel's relative contribution of storm water to the City's storm drain system. The parcel's contribution was based its land use type and from engineering principles established from the County of Orange, available parcel database, geospatial data, and digital aerial images with remote sensing software. The results of the Study show that the City's near-term funding requirements for maintenance, regulatory, and select priority capital improvements can be met with, for example, a Single-Family Residential (SFR) monthly amount of $5.45 (escalated by 3% per year), below the National average of $5.85.

Should the City not implement the Storm Drain Fee, there is the potential for significant physical and property damage resulting from flooding events and reduction of emergency services due to flooding. In addition, the City may face the potential for significant regulatory fines up to $37,500 per day per violation plus civil and/or criminal penalties resulting from upcoming regulations. Recently in January 2020, a United States Army Corps of Engineers contractor agreed to pay approximately $741,500 to the San Diego Regional Water Quality Control Board for violating the Board's Construction General Permit due to unauthorized sediment and stormwater discharges to Murrieta Creek for 18 months during the building of the United States Army Corps of Engineers flood control project in the City of Temecula. In 2018, Caltrans settled with the North Coast Regional Water Quality Control Board for $2 Million for inadequate pollution prevention measures and erosion protection during the construction of the Highway 101 Willits Bypass project that resulted in the discharge of approximately 3.4 million gallons of sediment-laden stormwater to Haehl Creek. In 2017, the City of San Diego settled with the San Diego Regional Water Quality Control Board for $3.2 Million on allegations the city failed to ensure that construction sites throughout the city between 2010-15 protected waterbodies from Los Peñasquitos Lagoon in the north to the Tijuana River Estuary in the south from loose sediment. And in 2015, the City of Encinitas settled with the San Diego Regional Water Quality Control Board for violations of storm water requirements during the construction of a community park that led to sediment pollution in Rossini Creek, a tributary of the San Elijo Lagoon. The San Elijo Lagoon is a federally listed impaired water body for damage to the salt marshes caused by excess sedimentation and silt.

4.2 Recommendations

GHD's and DTA's recommendations are for the City to further pursue implementing a storm drain fee that follows Prop 218 with SB231 that would be further supported by the development of a detailed cost of services study that would including the following:

- Development and refinement of a long-term CIP (i.e., 20 or 30-year with a list of projects, updated cost, and year needed);
- Further refinement of the City's parcel database (i.e., reconciliation of City GIS data and County Assessor's parcel data);
- Weigh the feasibility and appropriate level of bond financing vs. Pay-As-You-Go options or other financing mechanisms, in coordination with implementation of long-term CIP;
- Establish a storm drain fee structure based on the individual parcel contribution;
- Determine Storm Drain Fee collecton method or mechanism; and
- Legal counsel oversight and involvement throughout, development of public relations program and the engagement of public outreach citywide.

Implementation of a storm drain fee would fund measures and projects to address the current storm drain infrastructure needs, address deficient capacity in the storm drain system, implement flood mitigation projects, and begin compliance with future regulations in an effort to avoid potential fines from regulatory agencies. In addition, the establishment of a program with dedicated funding will demonstrate the City's commitment and effort at improving its level of service and reducing it contribution of trash, debris, and pollutants to natural waterways and the Pacific Ocean.

GHD and DTA recommend a storm drain fee in accordance with Prop 218 and SB 231. However, in the event decision makers choose not to follow this method, the Pre-SB231 ballot measure process can also be followed, whereby simple majority of property owners, or at least a two-thirds voter approval by registered voters, is required.

Appendix

Appendix A
Technical Memorandum Citywide Impervious Area Analysis

Technical Memorandum

11/27/2019

To:	Kyle Aube	Ref. No.:	11185416
From:	Larry Tortuya, PE	Tel:	949-585-5210
CC:	Ulysses Fandino, Hector Ruiz,		
Subject:	**Citywide Impervious Area Analysis**		

1. Introduction

GHD was selected by the City of Anaheim to prepare a feasibility study for the establishment of a city wide stormwater fee. The City requested GHD to field verify the geospatial data used to establish baseline parameters for the stormwater fee, in order to comply with grant funding requirements outlined in the City's application for Metropolitan Water District's (MWD's) Future Supply Actions Funding Program (FSAFP). This study supplements the Technical Memorandum to the Stormwater Fee Study and addresses goals and objectives for the FSAFP Grant Project Objectives

The following project objectives have been identified for this analysis:

- Define existing City geographic information systems (GIS) data and identify and list (if applicable) discrepancies and data gaps.
- Summarize the GIS data associated with the feasibility study for developing a stormwater fee, including baseline land uses and impervious area percentages.
- Delineate impervious/pervious areas within the City limits using remote sensing (infrared) and high resolution aerial photography.
- Development of a menu of low-impact development techniques for retaining storm water runoff.
- Provide Recommendations for amending the existing City GIS Database

2. Background

Research[1] has shown that one of the most common methods to determine a Stormwater Fee is to use commonly available parcel data, where the area and type of the parcel is used to calculate the parcel's contribution to Stormwater runoff. A parcel's pervious/impervious ratio is integral in the calculation of the runoff contribution for the parcel. As part of the financial model developed in the Stormwater Fee Feasibility Study, a baseline of *land use categories* and corresponding *impervious area percentages* were established from documented land use data in the Orange County Hydrology Manual (OCHM).

This study explains the process by which land use designations and associated impervious area percentages outlined in the OCHM were verified.

2.1 Existing City GIS Data Evaluation

The existing City Geospatial data was downloaded from the City of Anaheim Open Data Portal website at http://data-anaheim.opendata.arcgis.com/. The City spatial data was cross-referenced with the County Assessor's Tax Parcel Database which is available from the County for a fee.

The following data was downloaded and provided the basis for establishing existing City spatial data:

- Existing Land Use, Shapefiles (Updated 7/31/2019)
- Assessed Parcels, Shapefiles (Updated 3/15/2017)
- City Limits, Shapefiles (Updated 8/8/2019)
- Legal lot lines, Shapefiles (Updated 8/14/2019)
- Street Right of Way limits,

2.2 Existing Data Assessment

Based on discrepancies found in comparing the existing City parcel data with the existing available County data, it was determined that further reconciliation between the two data sources was required in order to establish a baseline methodology for calculating a storm water fee. The Stormwater Fee Study financial model was established using land area as the base for the model in lieu of a parcel based analysis. Section 4.5.2 (Future Actions/Implementation) of the Stormwater Fee Feasibility Study identifies requirements to further refine data prior to implementation of a stormwater fee.

The City land use data is comprised of over 30 different designations that break down parcel information further than what is needed to establish impervious area percentages. Some land uses carried over into City ROW, however most of the City's ROW was classified as "undesignated." The classifications for residential were assessed for level of density by looking through the GIS attribute table for characteristics such as number of residential units per acre and although some classifications populated cells in the attribute table

[1] Western Kentucky University Stormwater Utility Survey 2019 pg. 2. See **Appendix A** for excerpts from this survey.

with number of units. It was also noted that the City's land use data did not include a designation for impervious area percentage.

2.3 Baseline Condition Impervious Area Percentages

The City's geospatial (land use) data does not include impervious area attributes. To complete this study impervious area attributes were determined through the use of existing, approved, documented information from the County Hydrology Manual. Also, during the assessment of the data, the City land uses were found to be *over-classified* for the purposes of this study and the 30 City classifications were consolidated into categories and cross referenced with land use data in the OCHM. The OCHM, Section C.5 associates land uses with impervious area percentages. The OCHM land uses and corresponding impervious area percentages were used as the baseline for consolidating the City land use designations and associating them with corresponding OCHM land uses and impervious area percentages. See **Appendix A** for excerpts from the OCHM. Recommended typical land use classes and impervious percentage values are shown in **Table 2.1**.

Table 2.1 Feasibility Study City Land Use Impervious Percentages

Land Use (LU)	Recommended Value for Typical LU Conditions-Percent
Parks or Open Space	10
Municipal Facilities, Police, Fire	90
Public Schools	40
Single-Family Residential:	
(High) 4-8 Dwelling Units ("DUs")/Acre	50
(Med) 1-3 DUs/Acre	35
(Low) >1 DUs/Acre	20
Multi-Family Residential (Includes >8+ DUs/Acre)	75
Commercial, Industrial	90

3. Delineation, Verification, and Accuracy Methodologies

This section will discuss the methodologies used for:

- Delineating of Impervious/Pervious Areas within the City limits using aerial infrared imagery
- Desktop Verification of Impervious/Pervious Areas
- Assessing accuracy of the remote sensing results

3.1 Aerial Imagery Impervious/ Pervious Delineation

GHD mapped the impervious and pervious area within the City of Anaheim via remote sensing of 6 inch resolution, 4-Band aerial photography from June 2018 captured by Eagle Aerial. This imagery was imported to ArcGIS V10.6.1 software where the Feature Analyst extension by Textron Systems, v 5.2.0 was used to sweep the aerial photography and capture impervious surface areas as a mapped data layer. “Training Sets” were manually created to identify different types of polygons that would be associated with impervious or pervious areas (such as roofs, sidewalks, pavement, trees, lawns, etc.). The 4-Band characteristics (RGBI – red, green, blue and infrared reflectivity) and geometrical shape of these training sets were then used to teach and assist the software in digitizing similar polygon surface areas. Digitized polygon shape files for impervious/ pervious surfaces areas were delineated and created for all areas within the City limits. Sample imagery of what these impervious and pervious polygons looked like is shown in **Figure 1**.

Impervious Area
Pervious Area

Figure 1 Sample Area of Impervious VS. Pervious Surface Results

3.2 Hybrid Verification Process

A manual desktop review was performed to QA/QC software-driven identification of impervious surface areas. The remotely sensed impervious surface layer was compared against 6" aerial imagery displayed in natural color. Computer generated random points were dispersed across land use types and then manually determined to be pervious or impervious. Selective sites were initially field verified to assess the accuracy of the aerial photo, infrared imagery, and results of the remote sensing. Based on the field verification, the team determined a hybrid of field and desktop verification would allow for greater coverage of the City, and provide a level of accuracy similar to that of a field verification alone. Also, points not easily accessible in the field could be verified, and a hybrid verification reduces liability, and increases the safety of our field personnel. The desktop verification portion of the process was completed using ArcGIS Online.

ESRI ArcGIS Desktop was used to generate and publish random points to ArcGIS Online where the City's aerial imagery web service was accessed to use as the imperviousness verification data. Staff determined from the high quality aerial whether each point was in fact impervious or pervious surface. The random points were then downloaded to ArcGIS Desktop where they were intersected with the remotely sensed impervious surface layer and statistics were generated. See Error Matrix (**Table 4.2**) Points that were indistinguishable were removed from the error matrix analysis.

3.3 Accuracy Assessment

An accuracy assessment of the remotely sensed data was performed to quantify mapping errors. The assessment involved comparison of the results produced from the remoted sensed data against the desktop verification. The process to perform the accuracy assessment included the following steps:

- Design the Sample
- Desktop Verify Data
- Build and Populate the Error Matrix
- Analyze the Results

The land use classifications were used to design the sample point data for the accuracy assessment. Random points were produced for each of the eight (8) land use categories across the entire City. These points represent a range of area within each land use category.

4. Verification Results

4.1 Aerial Imagery

The project team noted during the verification process that the Municipal Land use type showed a low overall confidence level in the accuracy of the data. The municipal LU shows 42% accurate (**Table 4.1**) and excluding it gives 84% accuracy across 7 land use types. (As opposed to 79% when included). The significant error of commission in this category is very likely due to the ground water recharge basins around the Santa Ana River, which are indicated as Municipal LU are being classified as impervious, yet these areas are considered to be pervious.

Table 4.1 Aerial Imagery City LU Impervious Percentages

Land Use (LU)	Documented LU Impervious Area Percentage	Mapped LU Impervious Area Percentage	Overall Accuracy % (Confidence Level)
Parks or Open Space	10	17	87%
Municipal Facilities, Police, Fire	90	75	42%
Public Schools	40	52	92%
Single-Family Residential:			
(High) 4-8 Dwelling Units (“DUs”)/Acre	50	52	82%
(Med) 1-3 DUs/Acre	35	33	76%
(Low) >1 DUs/Acre	20	28	79%
Multi-Family Residential (Includes >8+ DUs/Acre)	75	61	85%
Commercial, Industrial	90	78	90%

4.2 Desktop Verification

The Error Matrix describes the points that were correctly assigned by the remote sensing algorithm. It also describes the error and whether those were errors of commission – the remote sensing results labeled it as impervious when it fact it was not – or errors of omission – the remote sensing results missed an area that should have been labeled impervious. This gives a sense of where the algorithm may have over- or under-estimated the amount of impervious surface.

Table 4.2 Verification Data / Error Matrix

Land Use Category	Number Correct	Number Incorrect (Impervious Commission: Omission)
Parks or Open Space	131	19 (19:0)
Municipal Facilities, Police, Fire	63	87 (85:2)
Public Schools	138	12 (5:7)

Table 4.2 Verification Data / Error Matrix

Land Use Category	Number Correct	Number Incorrect (Impervious Commission: Omission)
Single-Family Residential:		
(High) 4-8 Dwelling Units ("DUs")/Acre	123	27 (5:22)
(Med) 1-3 DUs/Acre	113	36 (2:34)
(Low) >1 DUs/Acre	118	32 (13:19)
Multi-Family Residential (Includes >8+ DUs/Acre)	126	23 (3:20)
Commercial, Industrial	131	15 (10:5)

Once the remotely sensed impervious surface results were reviewed for quality control, and desktop verified, impervious area percentages were calculated for each land use type. The remotely sensed impervious areas were overlaid with the project land use (LU) data, and new corresponding impervious area percentages were established for each LU category. The results were compared with the documented land use and corresponding impervious area percentage.

4.3 Accuracy

Table 4.3 shows the number of points sampled in each land use versus the ratio of area each land use occupies in the City. Although land use categories vary widely in how much each occupy City area, the project team determined 150 random points for each land use category was sufficient in providing confidence levels for each land use.

Table 4.3 Sample Point Distribution

Land Use Category	% Area of City	No. Of Random Points
High Density Single Family Residential	29.6	150
Medium Density Single Family Residential	1.6	150
Low Density Single Family Residential	0.6	150
Multi-Family Residential	12.4	150
Commercial/Industrial	26.3	150
Schools	3.9	150
Municipal Facilities	6.2	150
Open Space/Agricultural	18.9	150

5. LID Menu

The FSAFP Grant project objectives included the creation of a Low Impact Development (LID) menu to assist the City in determining which techniques to use in specific land use applications. The City of Anaheim resides in the County of Orange, and the majority of the LID techniques were referenced from the Orange County Technical Guidance Document (OCTGD) which gives direction on approved methods for stormwater quality compliance. However, these LID techniques are also referenced in other compliance documents published by agencies including Cities and Counties of Los Angeles & San Diego, and the Best Management Practices Handbook published by the California Stormwater Quality Association (CASQA). See **Appendix B** for excerpts from these compliance documents.

LID techniques may not be appropriate for all land use types. Each technique on the menu was reviewed to see if it was suitable for the following land use conditions:

- Public right of way
- Public Lands (Parks, Fire & Police Stations, etc.)
- Residential
- Commercial
- Industrial
- Schools

Where applications may not be suitable for a certain land use type, explanations have been provided. The FSAFP Grant specifically references retention applications so each technique that does include a retention component has also been marked. The LID menu can be found in **APPENDIX B.**

The intent of this menu is to have a reference that the City can use to determine what types of LID Techniques are compatible with each land use condition. These recommendations are a general guideline. Individual projects shall identify the techniques that are applicable to the specific project. Ultimate selection of a certain stormwater LID techniques will be determined by cost, expectation of maintenance, footprint and space, and targeted pollutants, and suitable type versus site layout.

6. City Street ROW, Medians, and Parkways Assessment

The FSAFP Grant project objectives include a requirement to specifically assess the City Street Right-of-Way (ROW), parkways, and medians to determine the total pervious and impervious area ratio.

The street ROW was identified by isolating the negative area (i.e. not contained within any parcel) within the City's parcel dataset that also overlapped the street centerline layer. These areas were merged into a shapefile and manually edited to remove canals and other features not associated with roadways. Additional areas were added that both overlapped street centerlines and existed within the parcel dataset but were identified in the land use reclassification step as "undetermined." The resulting area was determined to be the resulting total area of street ROW with in the City of Anaheim. The total area of street ROW was then overlaid with the results of the impervious surface area delineated from remote sensing. Impervious areas within the street ROW can be assumed to be roadway and paved or concrete medians, and pervious areas can be assumed to be parkways, or vegetation areas.

This assessment determined that 22% of the existing street ROW (a total of 1,415 acres) of pervious area. This information can be used to determine prospective sites for future LID and stormwater improvements projects. See **Table 6.1** for the results of the City Street ROW assessment.

Table 6.1 Right-of-Way (ROW) Impervious and Pervious Percentages

Street ROW	Percentage	Acres
Impervious	78%	4,975
Pervious	22%	1,415
Total		**6,390**

7. Conclusion & Recommendations

The remote sensing and corresponding field verification was used to determine final land use category impervious area percentages to be used in establishing a Stormwater Fee. The table below depicts the final recommendations.

Table 7.1 Final Recommendations for City LU Impervious Percentages

Land Use (LU)	Impervious LU Conditions-Percent
Parks or Open Space	15
Municipal Facilities, Police, Fire	75
Public Schools	50
Single-Family Residential:	
(High) 4-8 Dwelling Units ("DUs")/Acre	50
(Med) 1-3 DUs/Acre	35
(Low) >1 DUs/Acre	30
Multi-Family Residential (Includes >8+ DUs/Acre)	60
Commercial, Industrial	80

8. References

C. Warren Campbell. (2019). *Western Kentucky UNiversity Stormwater Utility Survey.* Bowling Green: SEAS Faculty Publications by TopSCHOLAR.

California Stormwater Quality Association. (2003). *Stormwater Best Manamgement Practice: Municipal.* California Stormwater Quality Association.

California Stormwater Quality Association. (2003). *Stormwater Best Manamgement Practice: New Development and Redevelopment.* California Stormwater Quality Association.

California Stormwater Quality Association. (2014). *Stormwarer Best Management Practivce Handbook Portal: Industrial and Commercial.* California Stormwater Quality Association.

City of Anaheim. (2018). *2018 Request for Proposals for Future Supply Actions Funding Program.* City of Anaheim: City of Anaheim.

City of Los Angeles. (2016). *Development Best Management Practices Handbook, Part B Planning Activities, 5th Edition.* Los Angeles: City of Los Angeles, Board of Public Works.

City of San Diego Stormwater. (2011). *San Diego Low Impact Development Design Manual.* San Diego: City of San Diego.

County of Los Angeles Department of Public Works. (2014). *Low Impact Development.* County of Los Angeles: County of Los Angeles.

County of Orange. (2013). *Technical Guidance Document for the Preparation of Conceptual/ Preliminary and/or Project Water Quality Management Plans (WQMPs).* County of Orange: County of Orange.

County of San Diego Department of Public Works. (2014). *Low Impact Development Handbook: Stormwater Management Strategies.* San Diego: County of San Diego.

Williamson & Schmid. (1986, October). *Orange County Hydrology Manual.* County of Orange: Orange County Environmental Management Agency.

Appendices

Appendix A
Excerpts and Supporting Documentation

ORANGE COUNTY

HYDROLOGY MANUAL

Submitted By

A. J. Nestlinger, Civil Engineer
RCE #33815 Expires June 30, 1990

Reviewed By

R. D. Runge, Chief, Section Engineer
RCE #28580 Expires March 31, 1990

Recommended By

J. M. Natsuhara, Manager, Flood Program Division
RCE #12550 Expires March 31, 1989

Approved By

C. R. Nelson, Director of Public Works

ORANGE COUNTY ENVIRONMENTAL MANAGEMENT AGENCY
M. STORM, DIRECTOR

OCTOBER 1986

AUTHOR'S ACKNOWLEDGEMENTS

Special acknowledgements are paid to Richard H. McCuen, Ph.D., for his overall review of the several project products and for the preparation of several contributions to the work effort.

Key contributors to the project effort include Tim J. Durbin, MS, RCE, for his work in the stream gage analysis and adjustment for urbanization; Bob Whitley, Ph.D. for his statistical evaluation of the stream gage data confidence levels and the coupling of modeling uncertainty; and Joe DeVries, Ph.D., RCE for his work on the channel routing studies and certainty of results.

Particular acknowledgements are paid to the Los Angeles District Corps of Engineers (COE); Chief of Hydrologic Engineering Section, Andy Sienkiewich; and Chief, Hydrologic Engineering Unit 1, John Pedersen, for their generous cooperation and time.

Other acknowledgements are paid to the several engineering firms and governmental agencies who have contributed time through the course of four drainage committees over the last 5 years, or through the attendance of the public presentations, or through the review of this manuscript.

Finally, acknowledgements are paid to the several engineers who have contributed to the development of this Hydrology Manual. Special acknowledgements are paid to Alan J. Nestlinger, BSAP, MPA, RCE who has been closely involved with Agency hydrology studies and the subsequent manual since 1967. Several sections of this manual were authored or co-authored by Alan. Special acknowledgments are also paid to the many key Agency staff members including (alphabetically) Joe Natsuhara, BS, RCE, Carl Nelson, MSCE, RCE, Dick Runge, BS, RCE and Jim Williams, MSCE, RCE.

C.4. WATERSHED DEVELOPMENT CONDITIONS

Ultimate development of the watershed should normally be assumed since watershed urbanization is reasonably likely within the expected life of most hydraulic facilities. Long range master plans for the County and incorporated cities should be reviewed to insure that reasonable land use assumptions are made for the ultimate development of the watershed. A field review shall also be made to confirm existing use and drainage patterns. Particular attention shall be paid to existing and proposed landscape practices, as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. Appropriate actual impervious percentages can then be selected from Figure C-4. It should be noted that the recommended values from these figures are for average conditions and, therefore, some adjustment for particular applications may be required.

C.5. ANTECEDENT MOISTURE CONDITION (AMC)

The definitions for the AMC classifications are:

AMC I: Lowest runoff potential. The watershed soils are dry enough to allow satisfactory grading or cultivation to take place.

AMC II: Moderate runoff potential; an average study condition.

AMC III: Highest runoff potential. The watershed is practically saturated from antecedent rains. Heavy rainfall or light rainfall and low temperatures have occurred within the last five days.

In the rainfall based hydrology methods it is normally assumed that a low AMC index (high loss rates) will be used in developing short return period storms (2-5 years), and a moderate to high AMC index (low loss rates) will be used in developing longer return period storms (10-100 year). For the

ACTUAL IMPERVIOUS COVER

Land Use (1)	Range-Percent	Recommended Value For Average Conditions-Percent (2)
Natural or Agriculture	0 - 0	0
Public Park	10 - 25	15
School	30 - 50	40
Single Family Residential: (3)		
2.5 acre lots	5 - 15	10
1 acre lots	10 - 25	20
2 dwellings/acre	20 - 40	30
3-4 dwellings/acre	30 - 50	40
5-7 dwellings/acre	35 - 55	50
8-10 dwellings/acre	50 - 70	60
More than 10 dwellings/acre	65 - 90	80
Multiple Family Residential:		
Condominiums	45 - 70	65
Apartments	65 - 90	80
Mobile Home Park	60 - 85	75
Commercial, Downtown Business or Industrial	80 - 100	90

Notes:

1. Land use should be based on ultimate development of the watershed. Long range master plans for the County and incorporated cities should be reviewed to insure reasonable land use assumptions.

2. Recommended values are based on average conditions which may not apply to a particular study area. The percentage impervious may vary greatly even on comparable sized lots due to differences in dwelling size, improvements, etc. Landscape practices should also be considered as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. A field investigation of a study area shall always be made, and a review of aerial photos, where available, may assist in estimating the percentage of impervious cover in developed areas.

3. For typical equestrian subdivisions increase impervious area 5 percent over the values recommended in the table above.

ORANGE COUNTY

HYDROLOGY MANUAL

ACTUAL IMPERVIOUS COVER FOR DEVELOPED AREAS

Figure C-4

purposes of design hydrology, AMC I will be used for the 2- and 5-year storm events. The watershed condition AMC II will be used for the 10-, 25-, and 50-year return frequency storms. For the case of the 100-year return frequency design storm, AMC III will be used.

C.5.1. Adjustment of Curve Numbers (CN) for AMC

The CN values selected for a particular soil cover type and quality also depend upon the AMC condition assumed. The CN values listed in Figure C-3 correspond to AMC II and require adjustment in order to represent either AMC I or AMC III. Table C.1 provides the necessary CN adjustments to account for AMC.

TABLE C.1. CURVE NUMBER RELATIONSHIPS

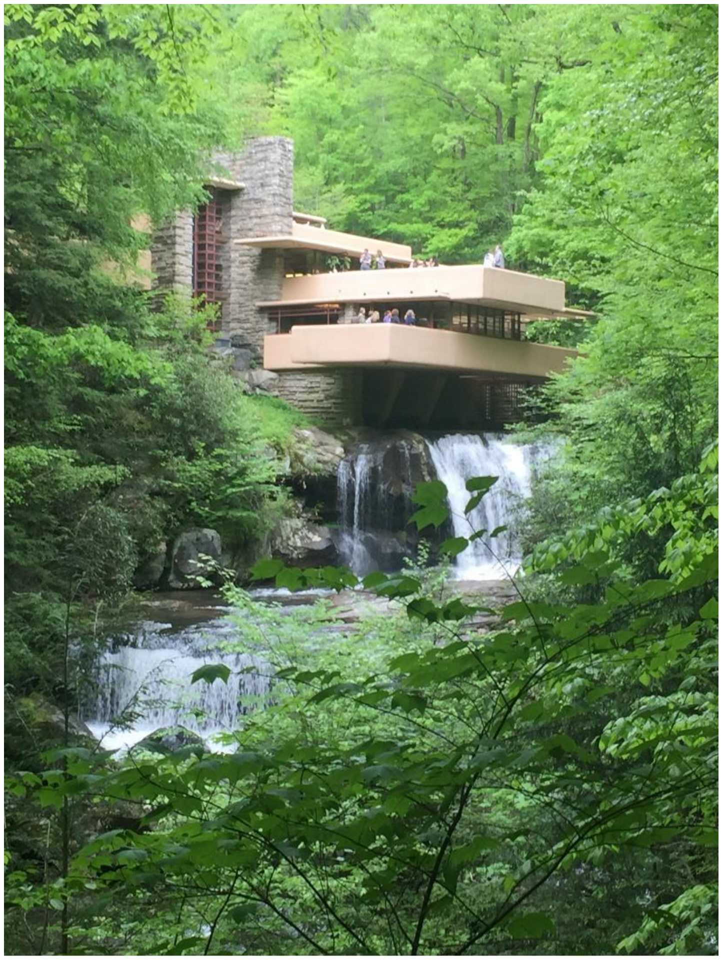
CN for AMC Condition II	Corresponding CN for AMC Condition I	Corresponding CN for AMC Condition III
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
70	51	87
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

6-2019

Western Kentucky University Stormwater Utility Survey 2019

C. Warren Campbell

Western Kentucky University Stormwater Utility Survey 2019



C. Warren Campbell

WKU School of Engineering & Applied Sciences

Cover

The cover flood picture shows Frank Lloyd Wright's iconic Falling Water house named in a survey of American Institute of Architects members as the "best all-time work of American architecture." The house is not insurable under the National Flood Insurance Program because it is built over water.

Preface to the 2019 Survey

This is a very exciting year for stormwater utilities. First, New London formed the first stormwater utility in Connecticut. Secondly, New Jersey passed a state law that allows communities to form stormwater utilities in the state. To my knowledge, none have formed yet, but they are progressing. Third, communities in Rhode Island are exploring the possibility of enacting stormwater utilities. Finally, Anchorage, Alaska has contracted for a SWU feasibility study. Their popularity is growing.

I am always surprised by how worked up people get regarding stormwater fees. When I was the City Hydrologist for Huntsville, Alabama we formed a Flood Mitigation Committee to look at ways of protecting Huntsville people and properties from flooding. After a 10-month long process of education for Committee members, we decided that the best and fairest option was a stormwater utility. The Committee voted unanimously to propose that to the City Council. Our very supportive mayor said we needed to set up a meeting with the Huntsville Times Editorial Board. We did this and presented our case. To their credit, they backed us all the way. They wrote an editorial laying out the idea and backing it fully. I always say that the reaction by a small group of people could not have been stronger than if we had proposed to kill the first-born child of every family in Huntsville. At the public meeting these ill-informed people ranted and raved. They deluged the mayor's and Council member's offices with phone calls, emails, and letters. For residential customers we were planning on asking for less than the cost of a glass of wine at a restaurant each month. About 200 committed people controlled the destiny of 170,000 Huntsville residents. After the public meeting the Flood Mitigation Committee Chair wisely asked the committee to vote again on the proposal to develop a stormwater utility for Huntsville. Again, the vote was unanimous in support of a stormwater utility. This was quite a political science lesson for me. You can always educate a few, reasonable, well-informed people of the need for adequate stormwater funding. However, informing the general population is much more difficult. Once the few who shoot from the hip without thinking hit the editorial pages and the television stations freely expressing their opinions, community opinion becomes fixed and it is an uphill battle to change it. If I had it to do over again, I would not have mentioned the fee before a yearlong public education campaign. I would approach those who had experienced floods and ask them to support the idea with letters and emails to the Council and mayor. Going to the Editorial Board seemed like a really good idea at the time, but it was premature. The purpose of this survey has always been to provide information for public education campaigns for those communities who need adequate funding for stormwater programs. I hope it fulfills that purpose.

Warren Campbell
Bowling Green, Kentucky
June 4, 2019

Methods

The main goal of this survey is to identify as many U.S. Stormwater Utilities (SWUs) as possible. Because many stormwater professionals do not have the time to respond to questionnaires, our primary method of identification was Internet searches. We searched on key terms such as "stormwater utility", "stormwater fee", and "drainage fee". We scoured on-line municipal codes such as Municode, AmLegal, Sterling, LexisNexis, and others. We searched through many city web sites trying to find utilities. We have also had many people contact me to update fees and identify new utilities. However, the data primarily comes from Internet sources and is prone to errors. Some community websites are not very clear on whether the fee given is monthly, bi-monthly, quarterly, of annually. In cases like that I made the best guess I could. We hope the readers of this document will continue to help us correct mistakes. However, it is difficult to keep up with fee changes in more than 1700 utilities, so if you discover errors in our data please contact me at warren.campbellwku.edu.

Disclaimer

The opinions expressed in this document are those of the author. They are not official opinions of Western Kentucky University, its administration, or of any other individuals associated in any way with WKU. The author is an engineer so that any opinions expressed should not in any way be construed by any individual or organization as sound legal advice. The use or misuse of any of the data and information provided herein is the sole responsibility of the user and is not the responsibility of Western Kentucky University, its employees, students, or of any organization associated with the University.

ACKNOWLEDGEMENTS

This year I am seriously indebted to Jerry Bradshaw of SCI Consulting Group in Fairfield, California who provided many citations for stormwater utilities not previously in my database. Thank you, Jerry.

I am also indebted to the Wisconsin chapter of the American Public Works Association for their excellent survey of Wisconsin SWUs (Wisconsin APWA [2019]). Their 2019 survey came out just days before mine.

I want to thank Mike Gregory of Computational Hydraulics International for his updates on Canadian stormwater utilities. Also, the University of North Carolina Environmental Finance Center has identified several SWUs that I have included in this survey.

Black and Veatch (2018) publishes an excellent stormwater utility survey with more detailed information about the SWUs in their survey. In 2018 seventy-five SWUs responded to their survey. It is a very worthwhile survey and should be read by anyone interested in stormwater utilities.

The author is grateful to Professor Randel Dymond and his graduate students Kandace Kea and Amanda Dritschel at Virginia Tech for work they did on past surveys and the database.

Since 2007, many of the SWUs in this survey were identified by our undergraduate students who are listed below. I am very proud of the fact that 59 of my students have passed the Certified Floodplain Manager (CFM) exam. When I came to Kentucky in 2004, I was the 7th CFM in the state. There are 11 states with fewer than 59 CFMs so we are making a contribution to floodplain management. Students contributing to the 2014 and 2016 surveys were:

Kain Kotoucek, CFM
Cory Smith, CFM
Megan Jones, CFM

Students contributing to the 2013 Survey were:

Jordon Begley
Walker Bruns
Clayton Cook
Aaron Dockery
Gabriel Goncalves de Godoy
Chris Heil
Eathan Johnson
Carson Joyce
Zach Neihof
Ashley Penrod
Tyler Sweetland
Kirk Thomas
Dylan Ward
Rory Watson, CFM
Doug Woodson, CFM

Students participating in the 2012 survey were:

Benjamin Bell, CFM
Jeremy Brown, CFM
Will Spaulding, CFM
Justin Wallace, CFM

Contributors from previous years were:

Daniel Douglas
Allison Gee
Emily Kinslow, CFM
Lacie Lawson
Kendall McClenny, CFM
Kory McDonald
Daniel Skees, CFM
Brian Vincent, CFM
Jason Walker
Russ Whatley, CFM
Alex Krumenacher, CFM
Nick Lawhon, CFM
Austin Shields, CFM
Adam Disselkamp, CFM
Kenneth Marshall
Wesley Poynter, CFM
Tyler Williams, CFM
Brittany Griggs
Lisa Heartsill, CFM
Spenser Noffsinger, CFM
Pat Stevens
Tony Stylianides, CFM
Scott Wolfe, CFM
Darren Back, CFM
Robert Dillingham, CFM
James Edmunds
Scott Embry, CFM
Clint Ervin
Catie Gay Stevens, CFM
Sean O'Bryan, CFM
Casey Pedigo
Broc Porter
Kelly Stolt, CFM
Ben Webster, CFM
Jon Allen
Karla Andrew, CFM
Eric Broomfield, CFM
Kevin Collignon, CFM
Heath Crawford, CFM

Adam Evans
Cody Humble
Steve Hupper, CFM
Christine Morgan, CFM
Jeremy Rodgers, CFM
Matt Stone, CFM
Kyle Turpin, CFM
Kal Vencill, CFM

The author is grateful to all of these students who have participated in the survey over the past years. They have worked diligently at a somewhat tedious job, but one that should have taught them something about stormwater financing, municipal codes, and websites.

We are also indebted to AMEC for sharing their list of stormwater utilities with us. In 2008, Scott Embry had the foresight to ask them for it and they obliged. We continue to have a good relationship with AMEC.

I also wish to thank the Environmental Finance Center of the University of North Carolina which provided data on several North Carolina and Georgia stormwater utilities (Environmental Finance Center, 2013).

Several companies publish municipal and county codes which serve as a source for much of our data. We are particularly indebted to the Municipal Code Corporation, American Legal Publishing Corporation, Lexis Nexis, and Sterling Codifiers, Inc.

Introduction

We have been able to identify 1716 U.S. stormwater utilities that have formed nationwide and 29 in Canada. There are now 6 states with 100 or more stormwater utilities (SWUs). Forty states and DC have at least one SWU. Figure 1 shows U.S. stormwater utilities by location.

As Figure 2 shows, one of the very disappointing aspects of the SWU map is that Louisiana and Mississippi have missed a golden opportunity to encourage stormwater utilities. Twelve years after Hurricane Katrina, neither of the hardest hit states has formed a SWU as far as we can tell. However, New Orleans is considering a stormwater utility to maintain their extensive flood protection systems. Also, until recently neither of the two states hardest hit by Hurricane Sandy (NJ and CT) had a stormwater utility. Now Connecticut has its first (New London) and New Jersey has passed a state law allowing stormwater utilities to form in the state. Anchorage, Alaska has let a contract to develop a stormwater utility. If these come to fruition, we will have more states with SWUs.

One community official said, "We are too small to have a stormwater utility." The smallest community with a stormwater utility that we have found is Indian Creek Village, Florida with a 2010 census population of 88 (no, this is not a misprint). The largest community is Los Angeles with a population exceeding 3,000,000. The average SWU community population is about 68500 and the median is 18,493. No community is too small nor too large to have a stormwater utility.

At some point, this survey will become unnecessary as every community will have some appropriate stormwater funding mechanism. When will this occur? We have identified 1681 SWUs in the U.S. and 29 in Canada, and as this is written 22,389 communities participate in the National Flood Insurance Program (NFIP) (FEMA's Community Status Book: https://www.fema.gov/cis/nation.pdf). This survey will be necessary for some years to come.

The Data

Part of our raw data is contained in the Table in Appendix A. As this is written, our survey contains data on 1716 stormwater utilities (SWUs) located in 40 states and the District of Columbia (Figure 1). Based on our current find rate, my best guess would be that there are more than 2000 SWUs in the U.S. More are being formed all the time and we are aware of several that will form within the next few months.

Figure 2 shows the number of stormwater utilities by state. It also emphasizes that SWU formation is not governed by politics. Red states supported the Republican candidate in the 2016 presidential election and blue states the Democratic candidate. At least 6 states have more than 100 SWUs. Democratic leaning Washington and Minnesota have more than 100 SWUs while conservative leaning Texas, Ohio, and Florida also have more than 100.

Nationwide, the average monthly single-family residential fee was $5.85, the standard deviation was $4.50, and the median fee was $4.75. Most fees go up over time reflecting an increase in the Consumer Price Index (CPI). Some communities actually tie the monthly fee to the CPI. However, several communities have reduced their fees. The quartile fees are: 25% - $3.00, 50 % - $4.75, and 75 % - $7.15 for an interquartile range of $4.15.

Fees ranged from zero up to $45 per month. Figure 3 shows the spatial distribution of monthly fees. As has been observed in previous surveys, no state has all high fees. Even states with the higher fees also have utilities with much lower fees. The range of fee amounts probably reflects stormwater needs and local political realities.

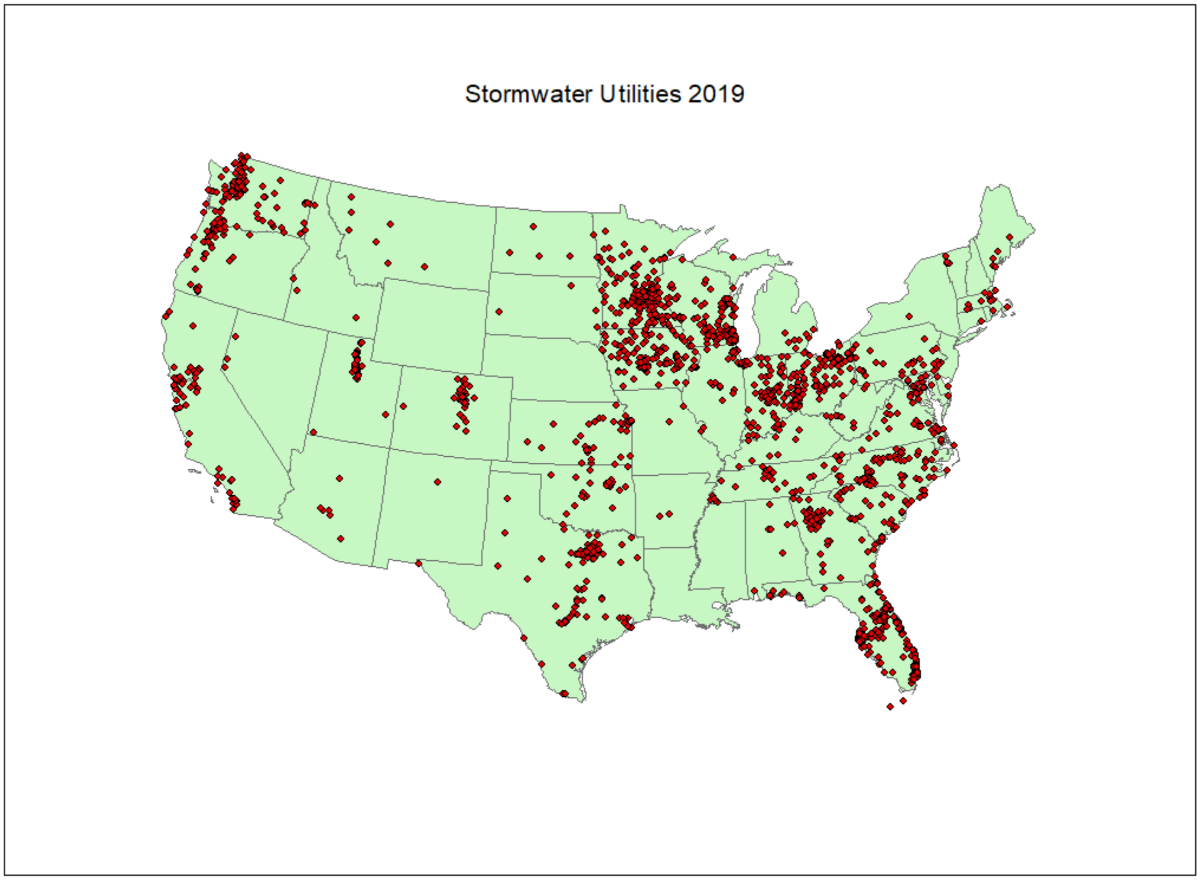


Figure 1. U.S. stormwater utilities (SWUs)

The most widely used method of funding is the ERU system. An Equivalent Residential Unit is usually the average impervious area on a single-family residential parcel, although some communities define it as the average of all residential parcels. Fees for non-residential properties are proportional to the ratio of the parcel impervious area to the ERU. For the ERUs identified in our survey, the median was 2902 square feet impervious with a standard deviation of 8757 square feet. We were able to find ERUs for 800 utilities (Figure 4). It is important to have a good estimate of the ERU because an inaccurate ERU means that someone is paying a disproportionate amount which could increase legal exposure (Campbell [2010]). The second and third most popular fee systems were the tier fee (245 SWUs) and the flat fee (236 SWUs) systems. Next in popularity was the Residential Equivalent Factor (REF) system with 140 identified. We were able to identify 110 Dual Fee systems.

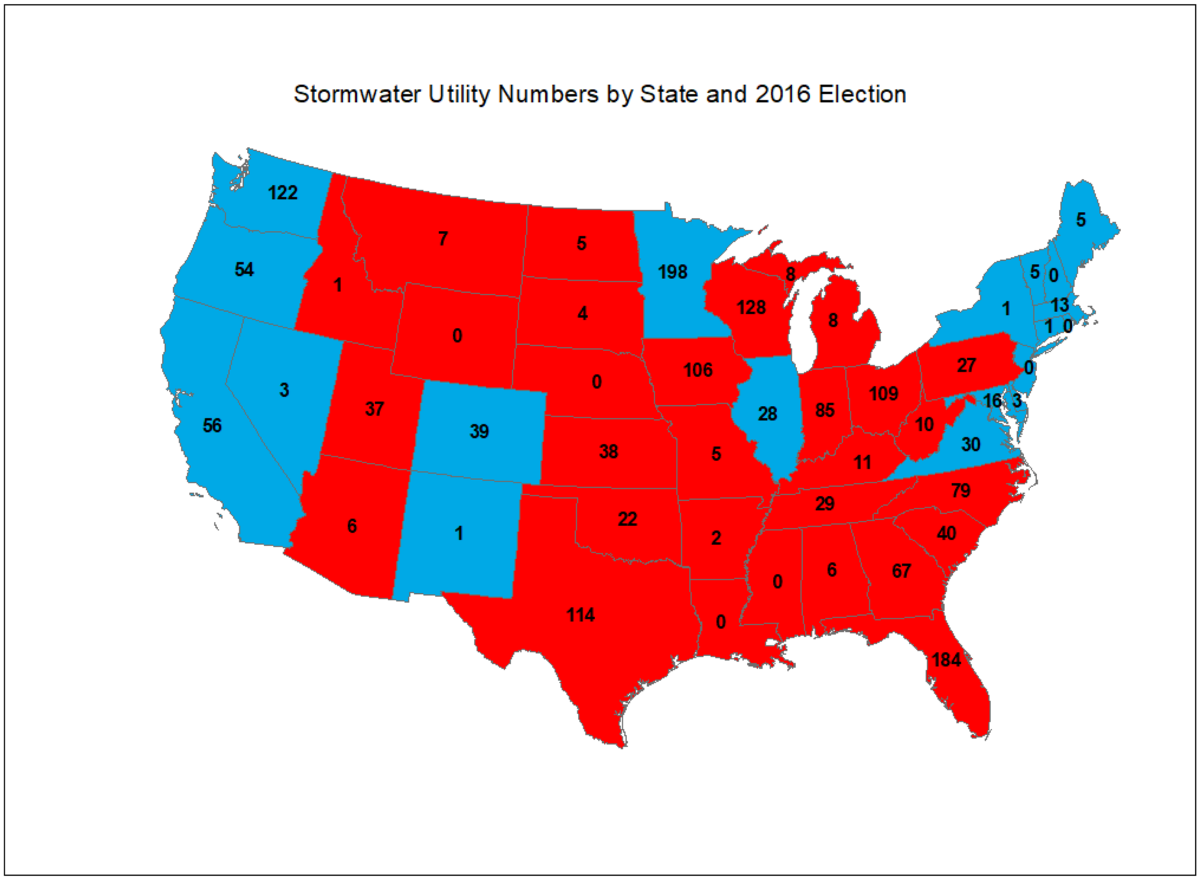


Figure 2. Number of stormwater utilities by state

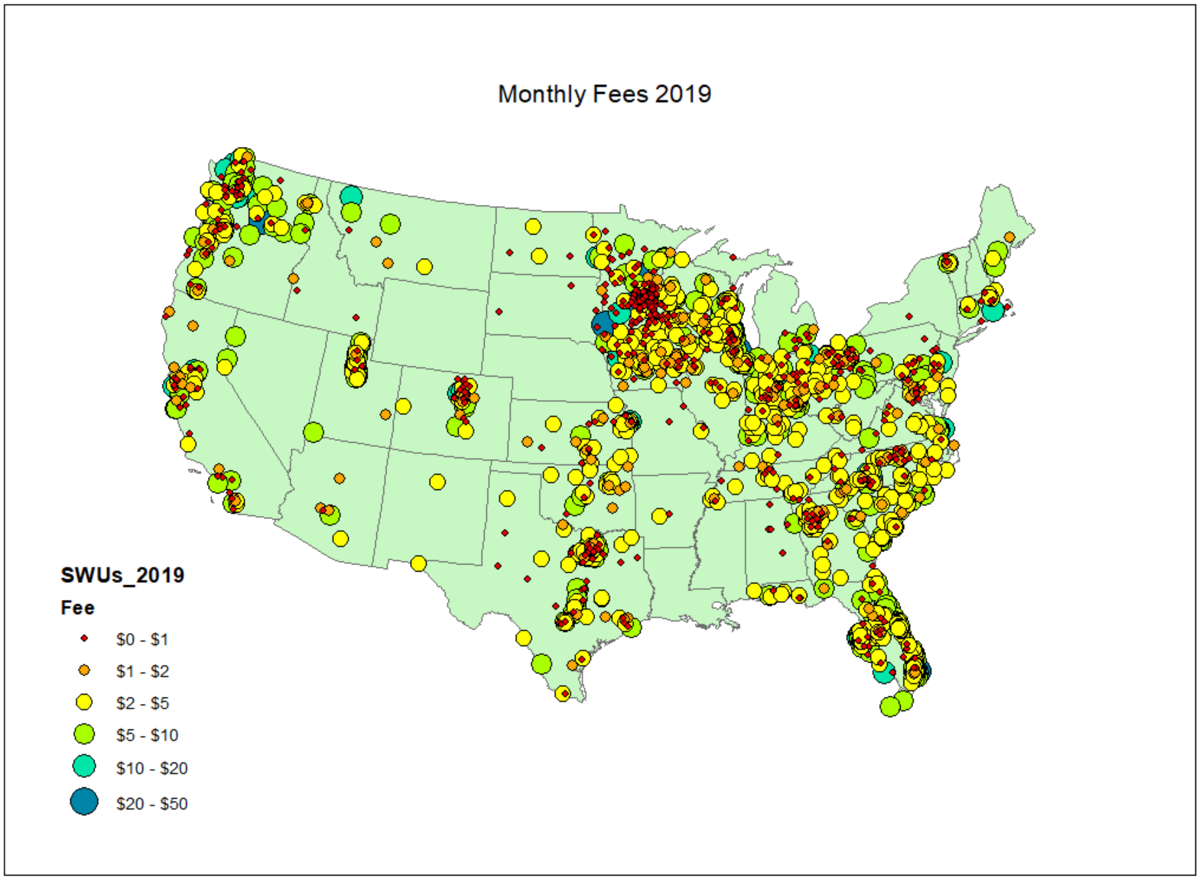


Figure 3. Spatial distribution of monthly stormwater fees

Figure 4 is another interesting way to look at the data. Figure 2 shows that the number of fees is not related to political leanings. Comparing Figure 4 to Figure 2, we see that the highest fee is in Washington state, a Democrat leaning state. However, the second highest fee is Nevada, a Republican leaning state. In the Figure, states showing a median monthly fee of zero are states without idenitifed stormwater utilities.

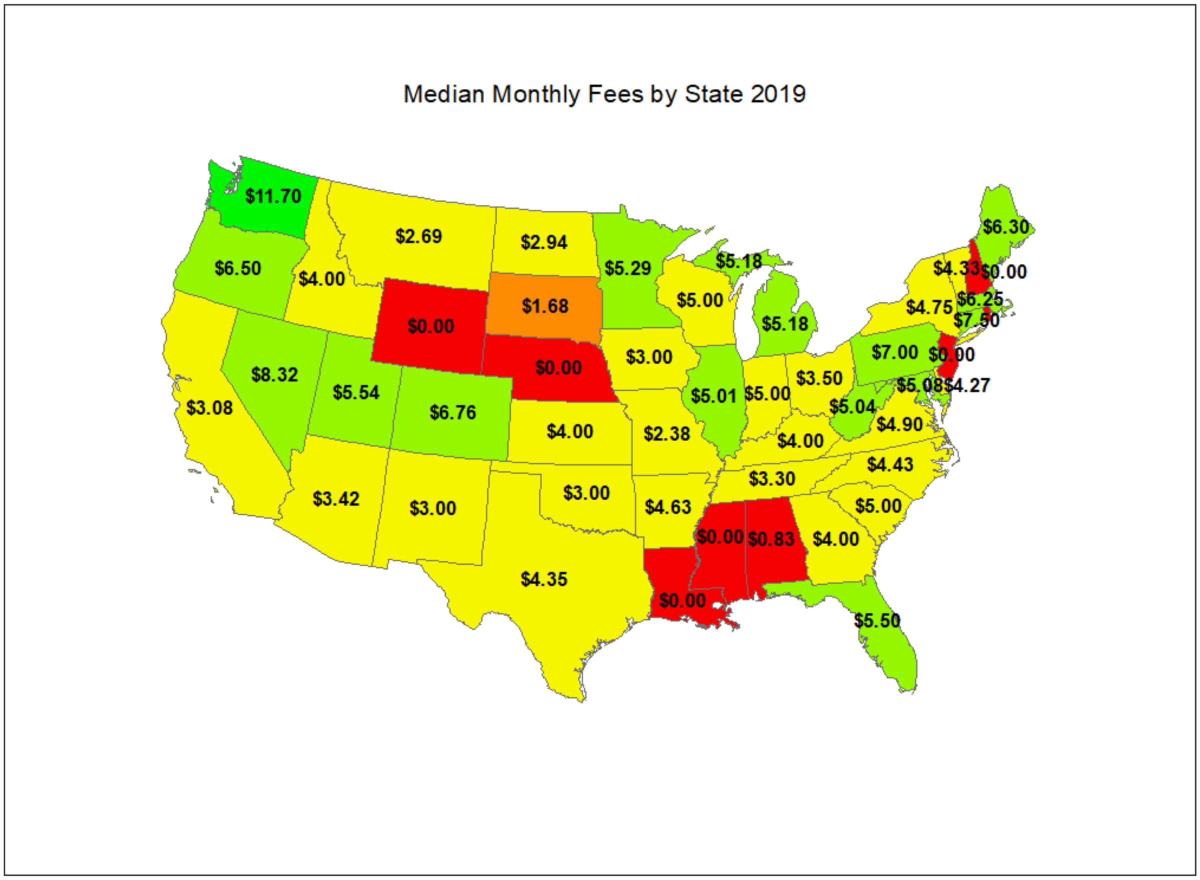


Figure 4. Median Monthly Fees by State

Canadian Stormwater Utilities

Mike Gregory found 29 Canadian communities with stormwater utilities. From Figure 5, there appears to be some cross -border communication especially in British Columbia/Washington and in Ontario/Michigan/Ohio/Indiana. Of the 29 SWUs he was able to find 7 that used an ERU fee system. In Canada the most popular system is the tier system and he was able to identify 11 of those. We received no additional information on Canadian SWUs in 2019, so the graph is the same as last year.

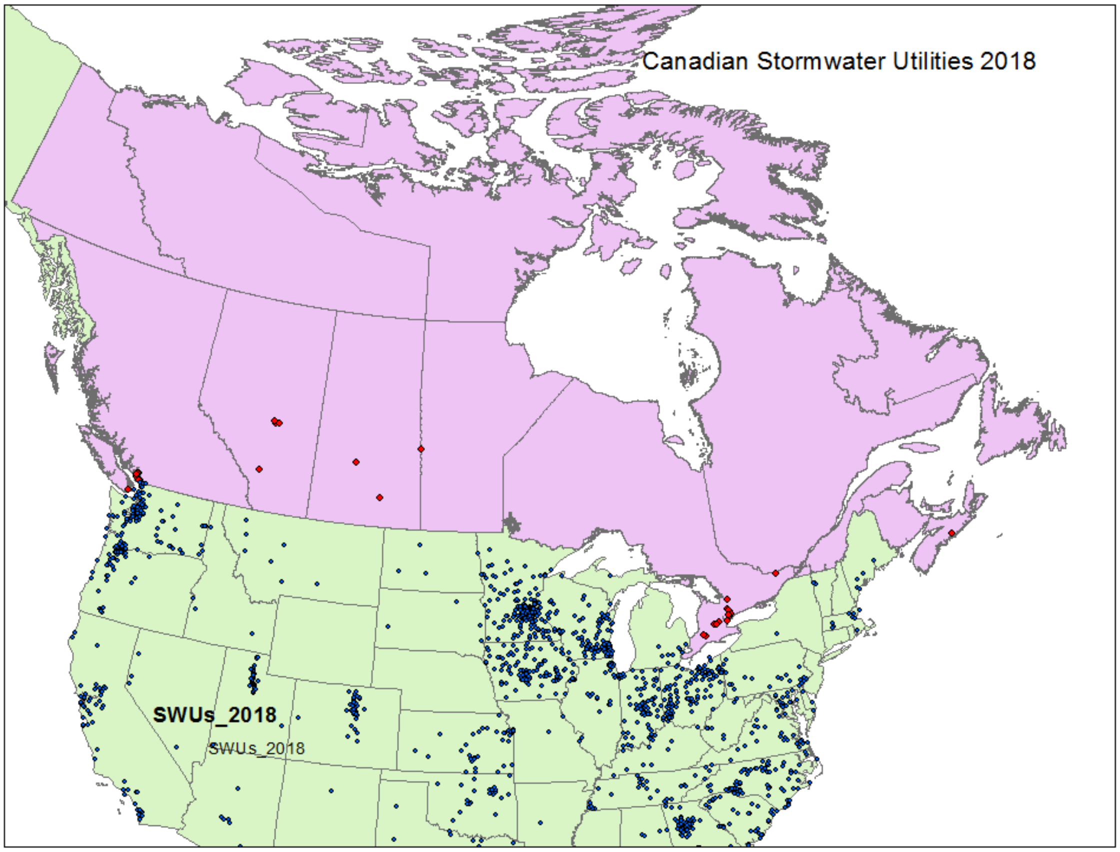


Figure 5. Canadian communities with stormwater utilities.

Summary

This was a very exciting year for stormwater utilities. Connecticut got its first, New London. New Jersey signed into law clear statutory authority to create stormwater utilities and several New Jersey communities are looking into developing them. Stormwater utilities continue to develop in Pennsylvania and now there are at least 27. About one decade ago, Philadelphia formed the first in the state. New Orleans and Anchorage, Alaska are considering them which raises the possibility that two more states will have SWUs. Once the ice is broken, more will likely form. Stormwater utilities make sense because they can be made fair and provide consistent funding for stormwater programs. While political and legal opposition have forced some SWUs to shut down, the trend is for more and more to form.

It is not clear why stormwater utilities form quickly in some states like Pennsylvania and very slowly in others. It has nothing to do with political leanings in a state as indicated in Figure 2. The only clear obstacle is lack of clear state law allowing them to form, or state law like California's Prop 218 aimed at discouraging them.

Stormwater utilities continue to be challenged in court. Usually, but not always, the utilities win. They can be set up with fee systems that are fair with a clear nexus between services rendered and fee. These have minimum legal exposure. They can also be set up in a way that increases legal exposure.

The best SWU ordinances have teeth. These allow the SWU community to turn off water and/or power for customers who refuse to pay. The worst ones only allow the utility to take non-paying customers to court. In these cases the community may have to wait years until unpaid fees accumulate so that taking the non-payers to court makes sense. Contrast this to the experience of Garden City, Georgia. A Georgia attorney general wrote an opinion that state agencies were not required to pay stormwater fees. The state Department of Agriculture wrote the Garden City utility that in accordance with the attorney general's opinion they would not be paying their stormwater fee. The utility wrote back that in accordance with their ordinance they would be turning off water and power for the Department of Agriculture. The Department reconsidered their decision.

References

Black and Veatch (2018). “2018 Stormwater Utility Survey,” https://www.bv.com/sites/default/files/18%20Stormwater%20Utility%20Survey%20Report%20WEB.pdf, 48 pp.

Black and Veatch (2014). “2014 Stormwater Utility Survey,” 24 pp.

Campbell, C. Warren (2017). "The Western Kentucky University Stormwater Utility Survey 2017," https://www.wku.edu/seas/undergradprogramdescription/stormwaterutilitysurvey.php, Bowling Green, Kentucky.

Campbell, C. Warren, Dymond, Randel, Dritschel, Amanda (2016). “The Western Kentucky University Stormwater Utility Survey 2016,” Stormwater Utility SurveysBowling Green, Kentucky.

Campbell, C. Warren, Dymond, Randel, Kea, Kandace, Dritschel, Amanda (2014). “The Western Kentucky University Stormwater Utility Survey 2014,” Stormwater Utility Surveys, Bowling Green, Kentucky.

Campbell, C. Warren (2013). “The Western Kentucky University Stormwater Utility Survey 2013,” Stormwater Utility Surveys Bowling Green, Kentucky.

Campbell, C. Warren (2012). “The Western Kentucky University Stormwater Utility Survey 2012,” Stormwater Utility Surveys, Bowling Green, Kentucky.

Campbell, C. Warren (2011). “The Western Kentucky University Stormwater Utility Survey 2011,” Stormwater Utility Surveys Bowling Green, Kentucky.

Campbell, C. Warren (2010). “The Western Kentucky University Stormwater Utility Survey 2010,” Stormwater Utility Surveys/, Bowling Green, Kentucky.

Campbell, C. Warren (2009). “The Western Kentucky University Stormwater Utility Survey 2009,” Stormwater Utility Surveys, Bowling Green, Kentucky.

Campbell, C. Warren, and Back, A. Darren (2008). “The Western Kentucky University Stormwater Utility Survey 2008,” Stormwater Utility Surveys/, Bowling Green, Kentucky.

Campbell, C. Warren (2007). “The Western Kentucky University Stormwater Utility Survey 2007,” Stormwater Utility Surveys/, Bowling Green, Kentucky.

England, Kate, New England Survey: http://kate-england.com/new-england-stormwater-utilities/#link5

Environmental Finance Center (2013). University of North Carolina, http://efc.unc.edu/index.html.

Otto, Rebecca (2011). “Minnesota City Finances: 2010 Revenues, Expenditures, and Debt,” Office of the State Auditor, St. Paul, Minnesota, 312 pp.

Wisconsin APWA Chapter (2019). “WI Stormwater User Charge System Information,” http://wisconsin.apwa.net/Content/Chapters/wisconsin.apwa.net/Documents/SUMatrix%202019%2006%2010.pdf, 3 pp.

Wisconsin APWA Chapter (2010). “WI Stormwater User Charge Information,” http://wisconsin.apwa.net/chapters/wisconsin/documents/SUMatrixAPWA%285%29.pdf, 1 p.

2018 Request for Proposals for
Future Supply Actions Funding Program

Regional Assessment of Stormwater Capture, Treatment, and Infiltration for Groundwater Enhancement

Prepared For:

The Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, California 90012
Warren Teitz

Prepared By:

City of Anaheim (Anaheim Public Utilities)
200 S. Anaheim Blvd., Suite 276
Anaheim, California 92805
Khanh Chu

August 31, 2018

TABLE OF CONTENTS

City of Anaheim
PUBLIC UTILITIES DEPARTMENT
Administration

August 30, 2018

Mr. Warren Teitz, Sr. Resource Specialist
Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, CA 90012

Transmitted via email to:
FSAfundingprogram@mwdh2o.com

PROPOSAL FOR FUTURE SUPPLY ACTIONS FUNDING PROGRAM
TITLE: Regional Assessment of Stormwater Capture, Treatment, and Infiltration for Groundwater Enhancement

Dear Mr. Teitz:

Anaheim Public Utilities (APU), as a member agency, is pleased to submit its proposal for Metropolitan Water District's 2018 Request for Proposals for the Future Action Supply Funding Program. We will be performing our proposed Study in coordination with the Anaheim Public Works Department (APW).

Our proposed Study reduces technical and legal barriers to identify future water supply by evaluating and developing engineering means and methods to establish cost-based defensible stormwater impact and users' fees that will be used by the City to install new and innovative methods for control and treatment of stormwater Citywide. These measures will ultimately provide a mechanism for recharging the groundwater aquifer that supplies much of Anaheim's (and the region's) potable water. We are excited by the potential development of an infiltration algorithm that can be utilized by other cities within our region and throughout the State.

APU and APW have a systematic and proven internal process to track grant funds and ensure timely completion of required reports. The system includes a series of checks and balances to identify fraud and abuse by contractors. We are supported by a team of internal finance specialists, contract specialists, OSHA Compliance Officers, and grant managers. When internal staff cannot complete tasks because of workload levels or lack of expertise, the City procures qualified consultants, in accordance with applicable grant requirements, to successfully complete tasks. Project specific, "all hands" meetings, are part of APU's normal operating procedures where all internal staff and external consultants are required to attend and report on pre-established milestones and budget line items.

201 S. Anaheim Blvd.
M.S. #1101
Anaheim, CA 92805
TEL: 714.765.4157
FAX: 714.765.4138

The enclosed proposal includes each section as outlined in the request for proposals, and an attachment including our Letters of Support. The following table summarizes requirements as requested per the solicitation.

SUMMARY INFORMATION PER SOLICITATION REQUIREMENT	
Name of Proposal	Regional Assessment of **Stormwater Capture**, Treatment, and Infiltration for **Groundwater Enhancement**
Water Resource Category	Groundwater, Stormwater
Member Agency Name (as it appears on W-9 Tax Form)	City of Anaheim
Federal ID #	95-6000666
Address	200 S. Anaheim Boulevard
City, State, & Zip Code	Anaheim, CA 92805
Main Telephone	714/765-5176
Contact Name	Khanh Chu
Contact Telephone	714/765-5259
Contact E-mail Address	KChu@anaheim.net
Website Address	www.anaheim.net

I am informed and believe that the information contained in this proposal is true and that the supporting data is accurate and complete.

Thank you for the opportunity to present this proposal. We believe Anaheim's proposal can benefit our community by helping to protect our groundwater resource. We hope you recognize its importance to our community, as well as others in Orange County.

Sincerely,

MRM

Dukku Lee
General Manager
Anaheim Public Utilities

Enclosures

B. ENTITIES PARTICIPATING IN PROPOSAL

Support letters are provided in Attachment A. The City of Anaheim will be the lead entity, with assistance provided by a consultant selected through the City's rigorous procurement process.

C. KEY INDIVIDUALS

Table 1 identifies the individuals from the Anaheim Public Works (APW) Department who will serve in key roles for the proposed Study. Each individual has experience directly applicable to the scope of the Study as described below.

Table 1. KEY INDIVIDUALS

Name, Title	Project Role	Telephone/Fax	Address	E-mail
Khanh Chu, Principal Civil Engineer	Program Manager	T: 714-765-5259 F: 714-765-5225	200 S. Anaheim Blvd., #276 Anaheim, CA 92805	KChu@anaheim.net
Kevin Miako, Associate Engineer	Project Manager	T: 714-765-5100 (5807) F: 714-765-5225	200 S. Anaheim Blvd., #276 Anaheim, CA 92805	KMiako@anaheim.net
Keith Linker, Principal Civil Engineer	Water Quality Specialist	T: 714-765-4141 F: 714-765-5225	200 S. Anaheim Blvd., #276 Anaheim, CA 92805	KLinker@anaheim.net
Johnny Chan, Assistant Engineer	Project Assistant	T: 714-765-5100 (5826) F: 714-765-5225	200 S. Anaheim Blvd., #276 Anaheim, CA 92805	JChan@anaheim.net

Relevant Experience

Khanh Chu is a licensed engineer with an M.S. in Civil Engineering and Construction Engineering Management. His 29+ years' experience includes the Dept. of Army Engineering and Planning Division, the City of Inglewood Engineering Division, and he has been a Principal Civil Engineer with the City of Anaheim for 13+ years.

Kevin Miako holds a degree in Civil Engineering, as well as an Engineering-In-Training Certification. Since 2005, he has worked as Project Manager on numerous projects for the City of Anaheim, including extensive work on the Anaheim Regional Transportation Intermodal Center (ARTIC).

Keith Linker, with over 20 years' experience in Stormwater Regulation and Compliance, will conduct Performance Monitoring for the project. He holds a license in Civil Engineering, is a Certified Professional in Storm Water Quality, and is Certified as a Qualified SWPPP Developer.

Johnny Chan has worked as Project Manager on various City special projects in the past 29 years with greater emphasis on Citywide Sewer and Storm Drainage Master Plans.

D. PROPOSAL DESCRIPTION

The City of Anaheim (City) is committed to maximizing stormwater infiltration, which it recognizes as one of the major contributors to: 1) recharging the groundwater basin, and 2) reducing the region's dependence on imported water resources. Through the proposed study (Study), the City intends to create an innovative and effective engineering database and resource map to identify permeable vs. non-permeable surfaces based on designated land uses.

This database will allow the City to: 1) promote stormwater infiltration through a menu of low-impact development options to maximize the use of captured stormwater run-off for future water supply and to offset user/impact fee costs, 2) plan for large-scale municipal infiltration projects as well as identify development impacts with greater accuracy based on vetted calculation methodologies, 3) establish fair and appropriate storm water impact fee and user fees, and 4) eventually support much needed stormwater improvement and infiltration projects, funded through stormwater user/impact fees.

The City has significantly shifted the focus of its stormwater management policy from one that aims to "get the water away as quickly as possible" to one that encourages retaining as much stormwater as feasible for groundwater recharge. Progress in the actual implementation of this sustainable policy has been slow, due to the lack of meaningful, real-world planning data, and the lack of municipal funding to address deficiencies in both the capacity and physical condition of the existing stormwater system. With recent legislative changes (namely, Senate Bill 231) described in Table 2, the City now has the opportunity to generate additional, much-needed revenue *dedicated to stormwater improvements and infiltration*. In addition, legislative changes allowing for the addition of accessory dwelling units (ADUs) to residential lots will result in the reduction of pervious areas on these lots. While SB 231 provides a mechanism for local agencies to generate funds for storm water management, the legislation regulating ADUs has added a new component to be addressed in the City's stormwater management approach. The development of an equitable stormwater impact and user fee schedule, based on the data collected from permit records and field reconnaissance proposed in this Study, will allow the City to better address issues of climate resiliency while also planning for future expected growth. The Study will allow the City to develop a fair and appropriate stormwater impact fee and user fee schedule to comply with the latest legal mandates from the State, as well as accommodate the growth of the City. It will provide other municipalities with the methodology and framework to implement similar efforts throughout the region and the State.

The majority of the Anaheim's storm drainage system was built in the 1950s and 1960s - long before low impact development was coined and long-term waters sustainability was a concern. The City's current storm drain system was built to push water out of the City as fast as possible to the Pacific Ocean. The proposed planning project will enable the City to create a paradigm shift in development through on-the ground LID projects that will contribute to the future water supply for Anaheim by recharging the groundwater basin.

Study Components. Anaheim Public Utilities proposes a Study for Regional Assessment of Stormwater Capture, Treatment, and Infiltration for Groundwater Enhancement (Study) with the following components:

- ***Planning Study*** - Will identify engineering methods to establish **stormwater users' fees** for designated land uses citywide. Fees will be used to pay for stormwater controls and

Table 2. REGULATORY/POLICY CHANGES DRIVING NEED FOR PROPOSED STUDY	
State Legislation	**Description**
California Senate Bill 231 (SB 231) *Signed October 2017*	• Clarifies that the definition of "sewer" includes both sanitary sewers and storm sewers • Includes legislative findings that storm waters are carried off in storm sewers, and careful management is necessary to ensure adequate water supplies, especially during drought, and to reduce pollution • Makes it easier for local agencies to finance stormwater projects by assessing fees similar to other services provided by utility agencies.
SB 229-Wieckowski; Assembly Bill 494 (AB 494-Bloom) *Signed October 2017*	• Authorizes and regulates Accessory Dwelling Units (ADUs), e.g., granny flats, in-law units, backyard cottages, etc. • Lifts barriers to building secondary homes on a single lot • Provides for an innovative, affordable option for adding much-needed housing in California • Other laws are in the process of being enacted

maintenance of stormwater systems, as well as stormwater infiltration projects on City-owned parcels. The study will also identify additional innovative stormwater control and treatment methods. ***The application of stormwater user fees is relatively new in California.*** While several Southern California cities have been able to implement them, regulatory barriers meant these fees were not widely assessed.

- ***Representative Pervious/Impervious Ratio Determination*** - Data will be evaluated, collected, and compiled as part of a Paper Study and subsequent Field Verification to identify standard baseline impervious land surface percentages for each of the City-designated land uses. **Stormwater impact fees** will be developed based on the complied data.
  - *Paper Study*: pervious/impervious land area ratios will be determined from reviews of available City records such as permits, GIS database, aerial maps, etc.
  - *Field Verification*: Data compiled during the paper study will be selectively verified for accuracy during site reconnaissance visits.
  - *Financial Impact Zone Map*: A map designating impact fee by land use throughout the City will be developed from the data compiled during the Paper Study and Field Verification.
  - *City Right-of Way, Parkway, Median Assessment* - The total area of City-owned medians, parkways, and right-of ways will be identified. Viable options will be identified for stormwater capture in these areas.
- ***Identification of Onsite Stormwater Mitigation Measures*** - A menu of low impact development (LID) choices will be identified for each land use designation. Impact fees may be reduced or waived if land owners opt to implement stormwater mitigation measures.

- ***Database*** - A database, containing permit types, volume of construction approved, storm drainage model results (pervious vs. impervious), and results of the stormwater fee assessment, will be developed.

Goals. To effectively minimize stormwater runoff and flow to the Pacific Ocean, improve stormwater infrastructure, and recharge the Orange County groundwater basin.

Objectives. This Study's objectives will be to:

- Establish storm drainage models for identifying impervious and pervious surfaces per land use and develop representative ratios for each land use;
- Investigate the impact of implementing the Trash Provisions on the City's storm drain capacity;
- Address impacts of recently adopted and upcoming legal mandates on the City's storm drainage infrastructure;
- Survey other similar sized public agencies' means and methods to mitigate the aforementioned issues, including the Los Angeles Stormwater Capture Master Plan (an MWS member agency), and establish a matrix with all ranked potential applicable alternatives for Anaheim;
- Develop menu of viable low impact development techniques for retaining storm water runoff;
- Develop citywide stormwater impact fees and users' fees to comply with current federal, state, and local laws and regulations; and
- Create a citywide financial impact fee zone map.

E. CRITERIA ONE – REDUCES BARRIERS TO FUTURE PRODUCTION

The proposed Study reduces technical and legal barriers to identifying future water supply by evaluating and developing engineering means and methods to establish cost-based defensible stormwater impact and user fees that will be used by the City to install new and innovative methods for control and treatment of stormwater Citywide. These measures will ultimately provide a mechanism for recharge of the groundwater aquifer that supplies much of Anaheim's potable water.

Anaheim's water supply is a blend of groundwater from City-owned wells (77%), and water imported from Northern California and the Colorado River by the Metropolitan Water District of Southern California (MWD) (23%). The source water for the City's wells is the Orange County groundwater basin that is replenished with water from the Santa Ana River, local runoff, imported water, and purified recycled water. Managed by the Orange County Water District (OCWD), the groundwater basin covers 350 square miles and lies beneath most of northern and central Orange County. Anaheim and more than 20 other cities and retail water districts pump from the groundwater basin to provide water to homes and businesses. The shaded area in Figure 1 shows the City's boundaries and its location relative to surrounding communities and freeways.

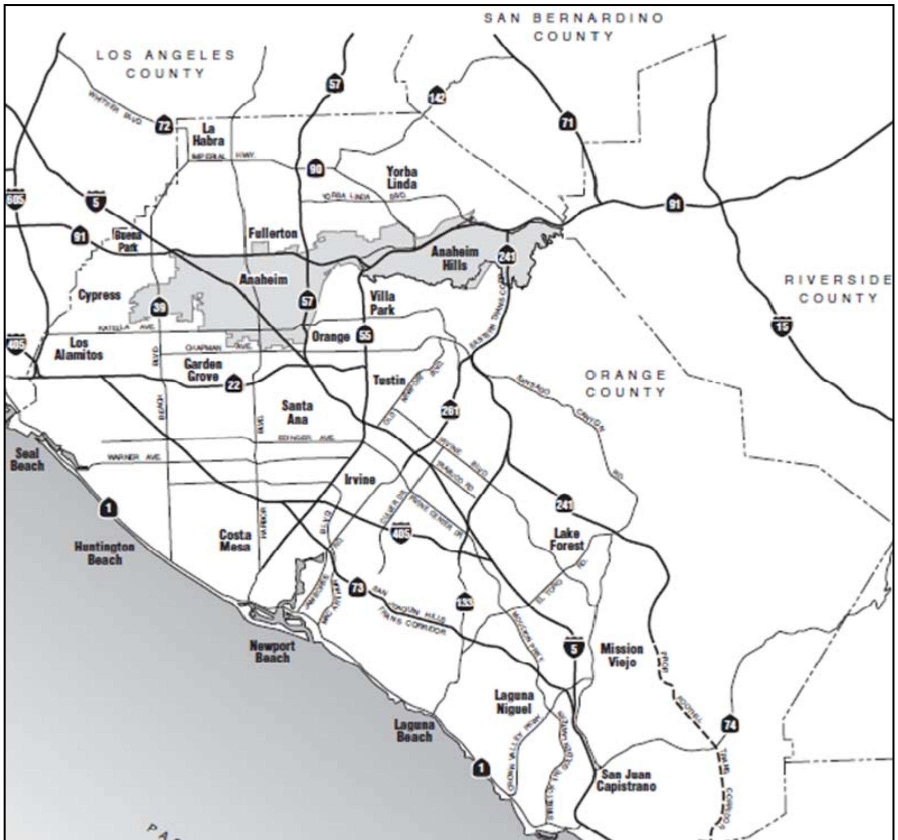


Figure 1. Site Location and Regional Vicinity

With the projected growth for Anaheim, as well as all of Orange County, measures to protect our groundwater supplies and generate new ideas to develop this resource become even more critical. Over the next 25 years, water use for Anaheim is anticipated to increase by 13 percent to approximately 64,000 acre-feet per year (AFY), serving a population of well over 400,000 people. Much of the growth will be attributed to higher population densities, but Anaheim also attracts millions of visitors due to the many entertainment venues in the City (the largest of which is the Disneyland Resort) that contribute to increased water demands. Countywide the population is expected to increase by an additional 300,000 to 500,000 people by 2020.

The development of users/impact fees will greatly aid the City in planning efforts, by having a known and constant revenue source. Currently, APW assesses fees for stormwater as a special district fee, considered storm drain impact fees. Generally, they are assessed when vacant land is developed into a subdivision and are applicable only to three areas in Anaheim: the Platinum Triangle (major redevelopment area shifting from low-density commercial/industrial zones to high-density, live/work urban environment), The Anaheim Resort, and Drainage District 27 (site of the Anaheim Regional Transportation Intermodal Center - ARTIC). Implementation of new stormwater fees will provide more equity and consistency for stormwater services throughout the City.

Increasing future local supply potential. The proposed Study includes three main components providing mechanisms for increasing future local groundwater supply:

- Identifying and establishing a database for all potential locations that can be utilized as retention/detention locations, including 1) parkways, medians, open spaces, etc., in public Right-of-Ways (ROWs), and 2) planting and grass areas, other open spaces, etc., on private land.
- Developing a menu of LID alternatives to encourage and incentivize homeowners, developers, and other property owners to implement stormwater infiltration projects during construction. These measures will retain stormwater runoff for infiltration. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water to the local groundwater basin.
- Establishing fair impact and user fees, allowing the City to generate revenue that can be used to implement larger scale stormwater infiltration and capture projects on city-owned parcels.

Expedite future permitting/Facilitate beneficial regulations for future water resources. The Study will result in a model that can be used by the City and other jurisdictions throughout the region and the State to institute fair, appropriate, and defensible stormwater impact and user fees, as well as a menu of proven LID alternatives. The transparent, replicable process will help to ensure that other jurisdictions can both fairly and quickly adopt a fee schedule based on vetted standards. By tapping into this revenue stream, the cities in our South California region will soon be able to implement groundwater recharge projects similar to the City of Anaheim's planned Modjeska Park project, maximizing the ground water recharge potential of municipally owned property, and reducing (by thousands of acre feet per year) the amount of stormwater that is lost to the Pacific Ocean. In addition, the LID alternatives will allow for widespread, calculable benefits for our groundwater basin based on project implemented directly by homeowners and business owners in lieu of impact and user fees.

Advancing the field of knowledge for development of future water resources. While other important studies have worked to identify potential sources for augmenting local water supplies (including the recently complete Stormwater Capture Master Plan developed by the City of Los Angeles using 2013 MWD grant fund), the proposed Study will result in an algorithm and methodologies for stormwater fee collection that can be utilized as a model throughout the region and the state. Financial models will be developed that can be refined and adapted to include local/regional or state regulations or site conditions specific to each user. The Study will identify long-term benefits of establishing stormwater user and impact fees in relation to the cost of the useful life of stormwater systems and their service levels. By using a systematic research approach for identifying and integrating requirements (regulations, policies, costs, other site-specific issues), a baseline can be established for evaluating the effect on fees, impact to customers, and comparability to neighboring Cities. As conditions and requirements change in the future, fees can be evaluated using the baseline model.

Unique and Innovative Actions/Current State of Technology. Public utility agencies in California face a complex set of rules and regulations regarding their ability to charge, and the amount to charge, for providing utility services. In addition to environmental requirements, utilities must also meet the requirements of ratepayer and taxpayer assurance requirements. These requirements are often general, requiring issue-specific interpretation, and in some cases, legal precedents to establish validity. Furthermore, the budget to ensure that infrastructure is maintained over the long-term is often underestimated. This can be especially true for stormwater management.

Under Proposition 218, the “Right to Vote On Taxes Act,” (implemented by CA voters in 1996 and amended into Article XIII of the States constitution), most new or increased property-related fees are required to be approved by a majority vote of property owners. Proposition 218’s impact extends to two stormwater fee issues: the aforementioned voter approval requirement, and the necessity that fees be fair and equitable. With the passage of SB 231 last year, “sewer” has been redefined to include sanitary sewer *and* storm sewer/stormwater. By changing the definition, public agencies may now move forward in establishing fair and appropriate stormwater fees, to finance much needed stormwater controls and infrastructure. Anaheim will be on the leading edge in California for developing a method and algorithm for fair, appropriate, and defensible stormwater fees on a per parcel per land type basis.

As part of the City’s strategy, and integral to the City’s stormwater impact fee assessment structure, an incentive will be offered to property owners for using low impact development (LID) practices, which mimic natural processes to maximize stormwater infiltration and manage stormwater as close to its source as possible. The City will develop a user-friendly “menu” of LID options that are applicable to designated land uses and areas, such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. The menu will be tailored based on site condition data collected during the Study.

Examples of LID projects that can be implemented in lieu of stormwater impact fees (Left - Bioswales at commercial development; Right - Rain barrel at private residence).

In addition to this proposal, the City has been aggressively seeking ways to conserve existing water sources that are currently lost to the ocean. The City has completed or is planning several projects that capture and infiltrate stormwater to recharge the valuable local aquifer (including the three examples below). In the future, accumulated user and impact fees dedicated to stormwater will be used to implement similar projects throughout the City, resulting in measurable, significant increases of groundwater recharge.

Modjeska Park Project. The Modjeska Park Project is an innovative pilot project for drought resiliency in a densely populated, urban community. The Project will utilize the footprint of an existing 37,000 square foot city-owned parking lot to install underground pre-manufactured storage modules to capture/infiltrate a 150+ acre feet per year (AFY) of dry weather urban runoff and first flush storm water into the City's groundwater. Over the project's 50-year useful life, the retention/ infiltration system will capture, retain, treat (through a natural filtration system), and recharge over 9,100 AF of water. This storm water is flowing through a completely built-out community, and it would otherwise flow untreated to the Bolsa Chica Channel and eventually to the Pacific Ocean.

***Richland/La Palma Project*.** The La Palma Avenue and Richfield Road project will replace and extend an inadequate, under-sized storm drain system at the intersection of La Palma Avenue and Richfield Road. Stormwater will be captured and reused through a newly installed diversion system that will transport stormwater from the project area to the OCWD's Foster-Huckleberry Recharge Basin. The Basin has the capacity to receive the additional stormwater from the area, up to and including a 25-year storm event, allowing the water to slowly percolate into the groundwater, thereby naturally filtering and purifying it. The project will infiltrate approximately 74 AFY of dry weather urban runoff and first flush stormwater into the City's groundwater - water that would otherwise flow untreated to the Santa Ana River and eventually to the Pacific Ocean.

Katella High School Project. Recently, through a State Water Resources Control Board's Drought Response Outreach Program for Schools (DROPS) to the Anaheim Union High School District (AUHSD), a LID project was constructed to capture storm water and recharge the groundwater under Katella High School. The project will capture 100% of the design storm event (85th percentile) through a state-of-the-art detention and infiltration system (including below- and above-ground best management practices). Rooftop and parking lot drains were connected to one of five underground infiltration tanks (total storage area of 33,205 cubic feet), which are equipped with pretreatment manholes to capture sediment and grease, and allow filtered water to percolate through the soil to the groundwater basin. The project replaced severely damaged asphalt, concrete, and compacted turf with 200,000+ square feet of permeable surfaces, bioswales, rain gardens, and native, water-wise educational gardens.

The City has calculated preliminary water infiltration estimates for other large City-owned parcels where similar projects could be implemented, and projects that another 1,800 AFY could be infiltrated into the City's groundwater with similar projects (Figure 2). Through the proposed Study, additional City-owned parcels (parkways, medians, ROWs, etc.) will be identified, mapped, and evaluated as future locations for stormwater infiltration projects.

F. CRITERIA TWO – REGIONAL BENEFIT/APPLICABILITY

The Study will provide a clearly defined process for promoting LID projects that maximize groundwater recharge. As described above, a menu of LID projects that align with specific land uses will be weighted by their resulting anticipated stormwater infiltration, creating individualized user and impact fees that reflect groundwater recharge efforts. While each jurisdiction may have slightly different land use categories identified through their General

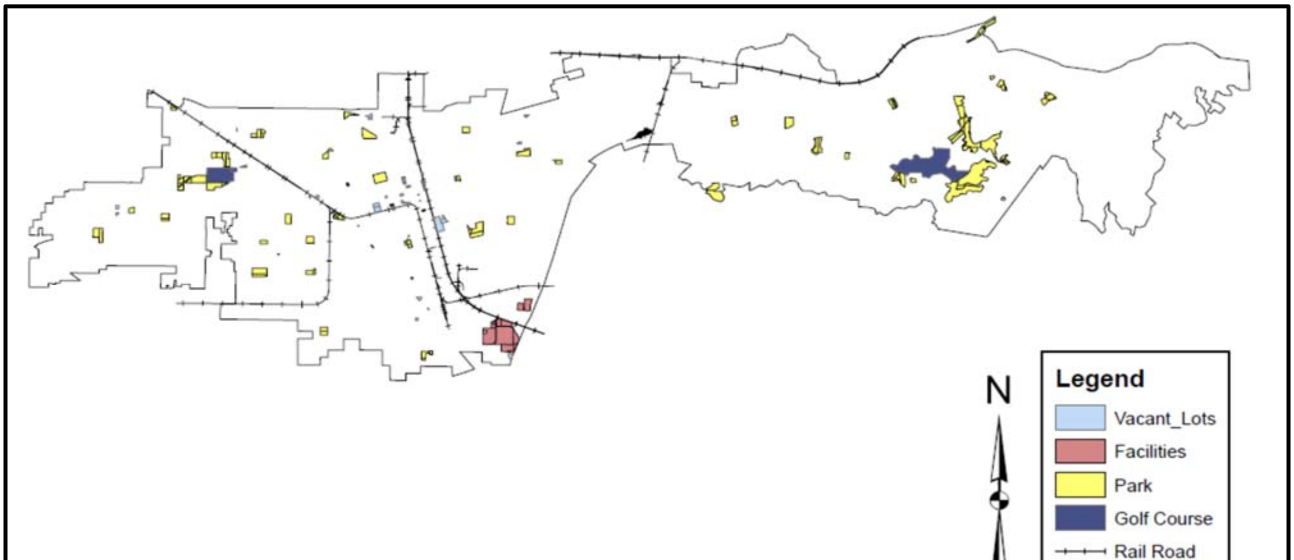


Figure 2. CITY-OWNED PARCELS AVAILABLE FOR FUTURE STORMWATER DETENTION PROJECTS

Plan, the categories utilized by the City of Anaheim are comprehensive enough to capture most, if not all other land use functions. Similarly, the City's climate and geography, stretching from the low-lying, densely developed western border just 10 miles from the Pacific Ocean, to the more sparsely populated Anaheim Hills at the eastern border of Orange County, are diverse enough to ensure proposed LID methods will be relevant throughout the region.

The time for fully investing in stormwater improvements that will lead to groundwater recharge is now. The regions' brief reprieve from drought during the 2016-17 was short lived. According to the most recent report from the U.S. Drought Monitor (released on August 23, 2018), the entire service area for the MWD is now considered to be in a severe drought (see Figure 3). In addition, according to the *Fourth National Climate Assessment (2017)*, current projections indicate several important western U.S. snowpack reservoirs will effectively *disappear* by 2100. Snowpack accounts for about one-third of the State's water supply. With the availability of imported water likely to decline, the entire region must address local water sources. Groundwater now supplies over 35% of Southern California's drinking water, and MWD anticipates local water sources will soon account for the majority of the regions' water supply.

Unfortunately, like Anaheim, many other cities in our region are hindered by an aging stormwater infrastructure and are struggling to minimally maintain crumbling and antiquated conveyance systems that fail to incorporate new best practices for infiltration. During the 2016-17 rainy season, for example, only 15% of stormwater in the Los Angeles River watershed was captured and used for water supply. Billions of gallons of stormwater instead were lost to the Pacific Ocean. Meanwhile, rainfall produced flooding and extensive damage in many parts of the state with little or no infrastructure in place to capture or redirect the water.

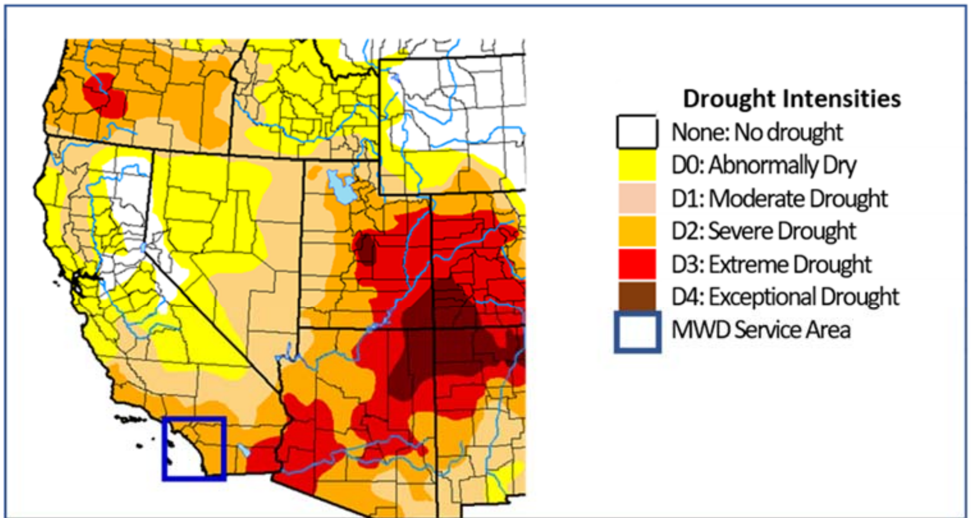


Figure 3. US DROUGHT MONITOR – WESTERN REGIONAL CLIMATE CENTER – AUGUST 21, 2018

The proposed project will help our partner agencies to quickly establish a new funding stream to undertake these much-needed stormwater infrastructure improvements to prepare for anticipated extreme weather events, construct capital improvement projects that best utilize city-owned parcels to infiltrate ground water, and empower business owners, developers and homeowners to actively participate in building climate resiliency in our region.

The Study proposed by Anaheim will also provide MWD's member agencies, from Camarillo to San Diego, with a data-driven model for establishing equitable stormwater fees. With the recent passage of SB 231 in October 2017 (allowing for the collection of these stormwater fees), many stakeholders in the region are eager to tap into this revenue source to address aging systems and implement best practices related to groundwater recharge. The algorithm, created as a result of the proposed Study, will allow local partners to quickly calculate both user fees and impact fees within their own city or jurisdiction, using a calculation vetted through document review, studies of similar efforts, and extensive field confirmation.

In addition, the region stands to benefit from the proposed project even without utilizing the fee structure that results. Because the Study will help to generate a revenue stream earmarked for stormwater projects, the City of Anaheim will be able to implement multiple infrastructure improvements throughout the City that will help to recharge the Orange County Water Basin, increasing the local supplies for the multiple MWD members located within the basin. Figure 4 shows municipalities that receive water supplies from the Orange County Water Basin.

During a preliminary analysis of *only* larger city-owned parcels, the City estimated that it has the capacity to capture and infiltrate up to *1,800 AFY* at these sites. The proposed Study will identify additional locations for groundwater recharge projects, including medians and right-of-way property.

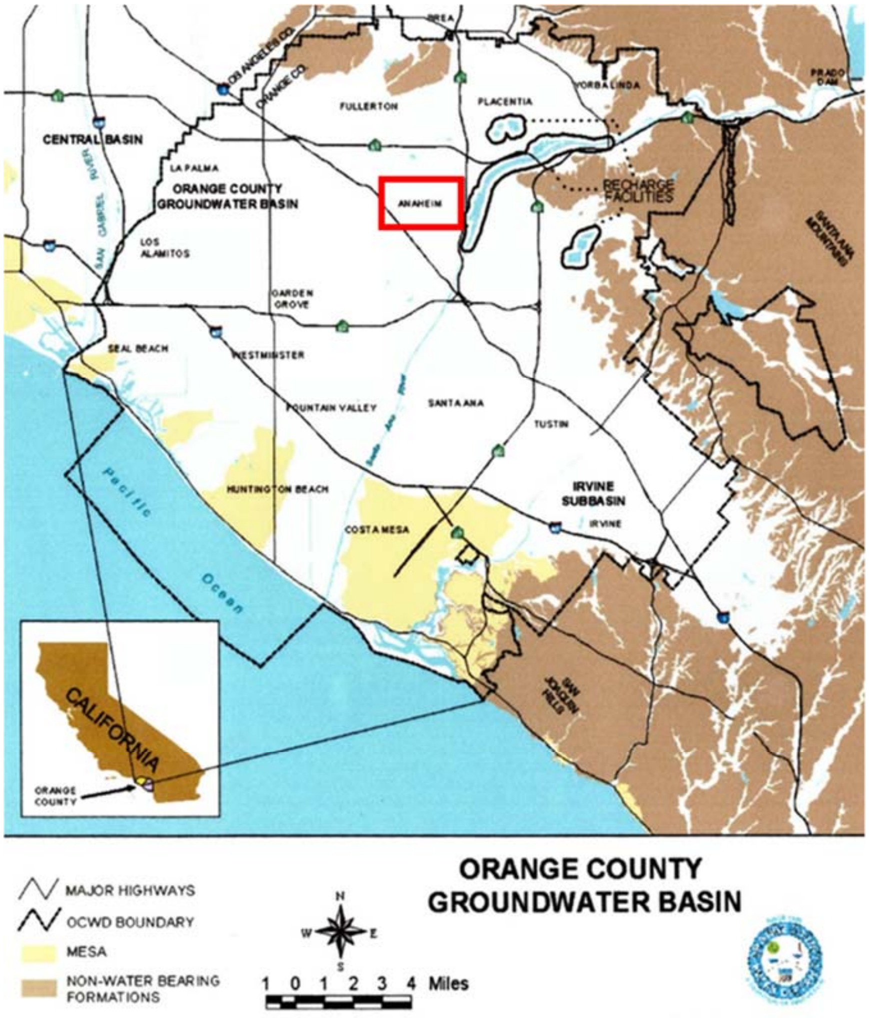


Figure 4. LOCATION OF MUNICIPALITIES TO BENEFIT FROM FUTURE ANAHEIM RECHARGE PROJECTS

Other benefits, such as water quality, energy, wastewater, infrastructure, environmental, etc.
The proposed Study has many benefits beyond groundwater recharge, both for the City of Anaheim and as a model for the region and beyond.

- Many proposed LID projects designed to infiltrate stormwater into the groundwater basin are also designed to remove pollution from surface water and improve ***water quality***, either through engineered infiltration boxes/chambers, or through the natural infiltration process. For the Modjeska Park project, for example, in addition to groundwater recharge the project also supports sustained, long-term water quality improvement, reducing the levels of ammonia flowing into Bolsa Chica Channel (which have exceeded total maximum daily load (TMDL) limits) from urban runoff by an estimated 0.13 pounds of ammonia per day (in addition to anticipated reductions in indicator bacteria).

- As noted earlier, in addition to implementing stormwater infiltration projects, the project will create an ongoing funding stream for the continued maintenance of ***stormwater infrastructure*** – putting an end to a decades-long strain on city finances which have primarily only been able to address infrastructure emergencies.

- Utilizing local groundwater requires ***significantly less energy*** than importing water from the California Bay Delta. The City of Anaheim imports just 24% of their water supply, but estimates that imported water accounts for more than 87% of energy costs related to pumping water (see Table 3). Extracting water from rivers and streams or pumping it from aquifers, and then conveying it over hills and into storage facilities is a highly energy intensive process. The State Water Project (SWP) is the largest single user of energy in California, in part because it has to pump water almost 2,000 feet over the Tehachapi Mountains. The SWP consumes an average of 5 billion kWh/yr, accounting for about 2 to 3% of all electricity consumed in California.

- The proposed project will ***remove a technical barrier*** for most jurisdictions in the region by providing a thoroughly researched and vetted methodology or system for calculating user and impact fees. The Study will include public outreach and input and, most importantly, includes field reconnaissance to ensure that reviews of permitting documents and GIS mapping data are aligned with actual site conditions.

Table 3. ENERGY USED TO PUMP WATER FOR ANAHEIM'S WATER SUPPLY

(1) Source	(2) MWh per Million Gallons Pumped	(3) MWh per AF Pumped (Col 2 x 3.07)	(4) AF Used in Water Supply	(5) Total MWh for AF of Water Supply (Col 3 X Col 4)	(6) Percent of Energy Used by Water Source
Colorado River*	6.066	18.623	7,238	134,793	43.6%
State Water Project*	13.606	41.770	7,238	134,793	43.6%
Local Wells**	0.276	0.847	46,586	39,687	12.8%
Total			61,065	309,273	

*Based on CA Dept. of Water Resources established energy intensities for imported water from point of diversion.
**Based on actual kWh usage vs. Water Produced at a comparable municipal water district

G. CRITERIA THREE – WORK PLAN / SCHEDULE

DETAILED WORK PLAN & DELIVERABLES. The scope of work and Study tasks are described in this section. The major Study components include project and grant administration, planning study, pervious/impervious ratio determination, identification of mitigation measures, assessment of City ROW, parkways and medians, database development, and final report. The schedule begins with contract execution in December 2018. The project duration is 13 months, with project closeout completed by November 2019. The schedule is provided in Table 4.

Task 1: Project Management

This task includes all actions necessary to manage the project to include ensuring adherence with the budget and schedule and also managing all grant proceeds in compliance with regulations and policies. The City will implement all necessary reporting as outlined by the final agreement.

Task 1.1: Grant Kick-Off Meeting and Execution of Grant Agreement

The City will meet with MWD to review the grant agreement, review the project timeline and deliverables, review procedures for consultant procurement, invoicing and reporting, the auditing checklist, and next steps. The City will document the meeting's minutes and action items. The City will process the grant agreement through the City Attorney's office and City Council and provide a fully executed copy of the grant agreement.

- ✓ *Deliverables:* Meeting agenda, minutes, action items; Fully executed grant agreement.

Task 1.2: Project and Grant Administration

Throughout the duration of the Study, the City will conduct monthly project team meetings with selected consultant(s) and internal support staff to monitor project progress, prepare for upcoming tasks, debrief on completed tasks, conduct problem-solving, and ensure the project

Table 4. SCHEDULE

CRITICAL DEADLINES:
Mandatory Start Date: February 28, 2019
Mandatory Completion Date: February 28, 2021
Project Completion Date: November 30, 2019

#	Tasks	2018						2019											
	Quarter:	*3*			*4*			*1*			*2*			*3*			*4*		
	Month:	J	A	S	*O*	*N*	*D*	J	F	M	A	M	J	J	A	S	O	N	D
	Submit proposal to MWD (8/31/18)																		
	MWD Grant Award (11/6/18)																		
1	**Project Management**																		
	1.1 Grant Kick-Off Meeting and Execution of Grant Agreement (Executed 12/31/18)																		
	1.2 Project and Grant Administration																		
2	Consultant Procurement and Kick-off Meeting																		
3	Planning Study																		
4	Representative Pervious/Impervious Ratio Determination																		
	4.1 Paper Study																		
	4.2 Field Verification																		
	4.3 Financial Impact Zone Fee Map																		
	4.4 City Right-of-Way, Parkway, Median Assessment																		
5	Mitigation Measures																		
6	Database/Modeling																		
7	Final Report																		
	Project Completed (November 2019)																		

remains on schedule and within budget. The City's project manager will develop a schedule of monthly check-in/progress meetings and arrange for a conference call line for all parties to participate. The project schedule will be used as the standing agenda item for all calls. In addition, the City will conduct invoicing and quarterly reporting and will also manage and track the funding in compliance with the signed agreement. All expenditures will be recorded and appropriate backup will be maintained. Specifics (prescribed in the grant agreement) include:

- Developing/submitting invoices to MWD in a timely manner.
- Developing/submitting quarterly reports to MWD detailing project progress and obstacles and including copies of required deliverables, and any other requirements.
- Developing and submitting other reports or data, as required by MWD.
- ✓ *Deliverables:* Schedule of monthly check-in calls with contractors/State staff; Request for reimbursement forms/documents, including receipt of grant funds; Quarterly progress reports; Project/Grant completion reports; Post-performance reports and forms; Audit findings, etc.; and Records retention for specified time (per grant contract).

Task 2: Consultant Procurement and Kick-off Meeting

The City will develop and issue a Request for Proposal (RFP) for a qualified consultant(s) to conduct a stormwater user fee planning study, performing paper and field studies for determination of pervious versus impervious areas for specific land uses. The consultant will also develop an engineering database to compile Study data, to be used for development of an impact fee map and structure for stormwater and to identify stormwater runoff mitigation measures. The competitive procurement process will follow the City's established procedures to select the most qualified, cost-effective consultant. Once the consultant is procured, the City will conduct a kick-off meeting to discuss the work plan, schedule, and expected deliverables. All key staff (City and Consultant) will be required to attend.

- ✓ *Deliverables:* Executed agreement with consultant; Agenda/ meeting minutes from kick-off meeting; List of tasks (schedule) necessary for successful completion of Study.

Task 3: Planning Study

The planning study will identify a method to establish stormwater impact and user fees for designated land uses. Governing requirements will be researched, identified, and summarized. Governing requirements include industry standards for fee determinations (benefit identification, cost allocation, and defensibility), regulatory requirements (applicable local, state, and federal laws and regulations), and federal and City policies. Financial models will be developed to evaluate the incorporation of identified requirements into the user fee design.

- ✓ *Deliverables*: Summary of requirements review, financial model, summary of impact and user fee design, preliminary study report

Task 4: Representative Pervious/Impervious Ratio Determination

Data will be collected and compiled to determine representative percentages of impervious surface areas throughout the City for each designated land use. A paper study and a field verification will be conducted. The ratios of impervious to pervious surface areas are important in considering drainage of water and for quantifying volume of stormwater runoff.

Task 4.1: Paper Study

Existing data will be used to evaluate designated land uses within the City for determining the ratio of impervious to pervious surfaces. The land uses, as defined in the Anaheim General Plan, include: 1) Residential, 2) Commercial/Offices, 3) Entertainment/ Lodging, 4) Industrial/ Manufacturing, 5) Parks/Open Space, 6) Agricultural/Vacant Land, and 7) Governmental. Construction permits from the City's database, along with aerial maps, will be used to identify representative areas to aid in establishing baseline conditions for providing input into developing impact and user fees. Upon the identification of representative locations for each land use, ratios of pervious to impervious surfaces will be calculated using aerial maps of the locations. A database will be developed that includes: permits reviewed, project type, entity issued permit, pervious areas prior and post construction, and field data. Representative pervious/impervious ratios for each land use will be developed. The volume of stormwater runoff for each land use will also be calculated.

- ✓ *Deliverables:* Database, representative land use areas, representative impervious/ pervious ratios, stormwater runoff volume calculations.

Task 4.2: Field Verification

The overall goal of this task will be to field verify the percentages of pervious impervious and pervious areas identified by the paper study in Task 4.1, for a representative sampling of each specific designated land use. Technical teams will conduct on-site visits at representative site locations and document actual field conditions. The field verification is intended to present a more accurate representation of site conditions and provide for a full-scale study. Collected information will be complied into a database management system for comparison, evaluation, and calibration. This data will be used to identify the low impact development measures for specific land use designations as input to the stormwater impact and user fees development (Planning Study -Task 1).

- ✓ *Deliverables:* Field validated pervious/impervious areas per land use, stormwater runoff volume calculations, input for impact fee map

Task 4.3: Financial Impact Zone Fee Map

A map or maps will be developed designating impact fee by land use throughout the City using results from developed during the Planning Study, Paper Study, and Field Verification Tasks.

- ✓ *Deliverables: Financial Impact Zone Fee map for Anaheim*

Task 4.4: City Right-of-Way, Parkway, Median Assessment

Based on available City records, the City identified large City-owned parcels (totaling 1,500 acres) for potential detention and infiltration projects. Preliminary rough estimates anticipated that these locations could contribute 1,800 AFY of infiltrated stormwater to the City's groundwater (without actual field verification of the site conditions). Under task 4.4, the consultant will identify and map all City-owned parcels (including right-of-ways, parkways, and medians) to create a Citywide comprehensive database. The consultant will evaluate these locations for placement of LID systems for additional contribution to groundwater infiltration.

- ✓ *Deliverables: Map of City-owned right-of-ways, parkways and medians; database with calculations of potential stormwater capture and infiltration*

Task 5: Mitigation Measures

Using data and results from the previous tasks, mitigation measures (low impact development options) will be identified for each end user. A "menu" of these measures, such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels and permeable pavements will be developed. The menu will be tailored based on site condition data collected during the Study. Property owners may choose from a "menu" based on type of use and volume of water displaced. Offset measures will also be developed. If an appropriate on site or cost-effective mitigation solution does not exist for homeowners or developers, the City may offset the impact in an alternate location (see Task 6).

- ✓ *Deliverables:* Menu of applicable mitigation measures

Task 6: Database/Modeling

Data collected during the paper and field studies will be entered into a database and used to create a model for each land use to determine the impacts of changes to the percentage of impervious land surface to the stormwater system. A recommended acceptable ratio will be developed for each land use, as well as mitigation measures that can be taken to offset impacts. New data will be also used to update the City's Storm Drain Master Plans.

- ✓ *Deliverables:* Database model, Land Use Ratios, Impact Fees, User Fees

Task 7: Final Report

A report of the Study methodologies and its findings will be prepared. The database, modeling, and storm water ratios plan will be shared with other MWD member agencies for duplication in their jurisdictions.

- ✓ *Deliverables:* Draft and Final Report

H. CRITERIA FOUR – COSTS

Table 5 contains the project costs and supporting details (including labor rates, consultant costs, and funding source).

- ***Salaries and Wages/Fringe Benefits –*** Total salaries, including fringe benefits, are estimated at $ 20,000 for City of Anaheim staff. The City estimates that staff will spend 140 hours over the 13-month project period to manage the field and office components of the Study. The team will include a Program Manager (Project Director), Project Manager, Project Assistant, and a Water Quality Specialist. Duties will include developing an RFP, reviewing proposals and selecting the consultants, coordinating and participating in monthly meetings with consultants, and oversight and review of Study tasks and results. In addition, the Project Assistant and Project Manager will be responsible for managing the reporting, payments, and invoicing associated with the grant project. Fringe benefits (which also includes burden for non-billable hours) for the staff identified above vary by position, and average approximately 73% of salary.
- ***Contractual*** – Total contractual costs ($380,000) represent the bulk of the project costs, $380,000. A qualified technical engineering consultant will perform Tasks 3 through 7 and attend

meetings as noted for Task 2. A grant management consultant has been included in the costs for Task 1.2.

- ***Travel, Equipment, Supplies/Materials and Other Costs -*** Not Applicable.

STATUS OF MATCHING FUNDS
The funds for this Study are committed by the City and are readily available as local cash. Upon grant award, the APW will obtain approval from City Council to adjust the City budget by fiscal year to provide the matching costs.

COST EFFECTIVENESS
The City has determined that conducting a citywide study is the most cost-effective way to implement the study, resulting in consistent methodologies throughout the Study as well as economy of scale. Addressing each region or smaller portions of the City separately would require additional time and resources – the City anticipates the proposed study will be completed within 13 months. In addition, as a citywide study – addressing multiple land use – the resulting methodology and finding can easily be replicated in other Cities as a basis for application to their own stormwater fee assessment and stormwater management programs thus saving additional time and money.

The outcomes of the Study can also lead to greater cost effectiveness for the City of Anaheim and other regions, as they shift from traditional stormwater infrastructure systems (such as pipes, pumps and lined ditches) to more environmentally focused and sustainable approaches utilizing LID practices. Managing stormwater runoff solely through traditional stormwater infrastructure means results in: high construction, maintenance, and repair costs; environmental and public impacts; funding limitations; and the introduction of pollutants to protected water of the state. Costs are magnified as population and development continue to increase and new challenges, such as changing weather patterns, increasing energy costs, new environmental concerns, and aging water infrastructure rise. These issues have made Anaheim increasingly aware that a new, integrated approach to stormwater management can provide sustainability of resources and benefits to multiple stakeholders in the future.

Table 5. COST TABLE[1]

Project Task	Project Role/ Consultant	Supporting Budget Details						Non-Metropolitan Share (Funding Match)		Requested MWD Funding[3]	Total
		Anaheim Labor Costs			Consultant Costs						
		Rate[2]	#	Total	Unit Cost	Unit	Total	Source	Amount		
1 Project Management								**Anaheim**	**$15,000**	**$15,000**	**$30,000**
1.1 Grant Kick-Off/Execution	Prog. Manager	$186.92	2	$374						$2,000	$2,000
	Proj. Manager	$144.92	3	$435							
	Proj. Assistant	$129.97	5	$650							
	WQ Specialist	$144.92	5	$725							
1.2 Project & Grant Admin.	Prog. Manager	$186.92	10	$1,870						$13,000	$28,000
	Proj. Manager	$144.92	20	$2,900							
	Proj. Assistant	$129.97	30	$3,900							
	WQ Specialist	$144.92	30	$4,350							
	Grant Mgmt.				$15,000	LS	$15,000	Anaheim	$15,000		
2 Consultant Procurement & Project Kick-off Meeting								**Anaheim**	**$5,000**	**$5,000**	**$10,000**
	Prog. Manager	$186.92	4	$748						$5,000	
	Proj. Manager	$144.92	7	$1,015							
	Proj. Assistant	$129.97	13	$1,690							
	WQ Specialist	$144.92	11	$1,594							
	Engineering							Anaheim	$5,000		
3 Planning Study								**Anaheim**	**$25,000**	**$25,000**	**$50,000**
	Consultant				$50,000	LS	$50,000				
4 Representative Pervious/Impervious Ratio Determination								**Anaheim**	**$100,000**	**$100,000**	**$200,000**
4.1 Paper Study	Consultant				$40,000	LS	$40,000	Anaheim	$20,000	$20,000	$40,000
4.2 Field Verification	Consultant				$130,00	LS	$130,00	Anaheim	$65,000	$65,000	$130,000
4.3 Impact Zone Map	Consultant				$10,000	LS	$10,000	Anaheim	$5,000	$5,000	$10,000
4.4 City Parcel Assess.	Consultant				$20,000	LS	$20,000	Anaheim	$10,000	$10,000	$20,000
5 Mitigation Measures								**Anaheim**	**$5,000**	**$5,000**	**$10,000**
	Consultant				$10,000	LS	$10,000				
6 Database/Modeling								**Anaheim**	**$37,500**	**$37,500**	**$75,000**
	Consultant				$75,000	LS	$75,000				
7 Final Report								**Anaheim**	**$12,500**	**$12,500**	**$25,000**
	Consultant				$25,000	LS	$25,000				
							TOTAL		**$200,000**	**$200,000**	**$400,000**

[1]Cost categories and funding sources may be adjusted during contract negotiation per agreement between MWD and City of Anaheim.
[2]Rates include salary and fringe benefits.
[3]Costs are rounded to the nearest thousand.

Attachment A
Support Letters

Orange County Water District
City of Placentia
City of Fullerton
Anaheim Unified High School District

SINCE 1933

ORANGE COUNTY WATER DISTRICT

ORANGE COUNTY'S GROUNDWATER AUTHORITY

August 31, 2018

Warren Teitz
Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, CA 90012

Subject: Metropolitan Water District Future Supply Actions Funding Program

Dear Mr. Teitz:

The Orange County Water District (OCWD) supports Anaheim Public Utilities' (APU's) proposal for the Metropolitan Water District's Future Supply Actions Funding Program. The focus of the proposed study (Study) is to collect data and develop an engineering database that will be used to estimate expected stormwater runoff that can be captured and reused for future water supplies for areas of projected growth and development in Anaheim. The Study will also provide important data to assist residential/business owners and developers in identifying and implementing new management methods to maximize stormwater infiltration for groundwater recharge.

The OCWD, formed in 1933, is primarily responsible for managing the groundwater basin that provides drinking water to most of northern and central Orange County. This groundwater basin supplies water to 19 cities and water agencies that serve approximately 2.5 million Orange County residents, which includes the City of Anaheim. As part of our groundwater management, OCWD maintains one of the world's most advanced aquifer recharge systems to replace the water that is pumped from wells belonging to local water agencies, cities and other groundwater users.

The Study will provide tools to augment the basin's groundwater supplies by reducing the amount of stormwater lost to surface runoff to the ocean and by promoting groundwater recharge through on-site infiltration systems. This Study's efforts to manage stormwater and sustain our groundwater resource align with OCWD's mission.

Thank you in advance for your consideration of this project. As Orange County continues to experience growth, it is critical that new ideas for stormwater management are implemented to ensure protection of our important Southern California water supplies and resources.

Sincerely,

Michael R. Markus, P.E., D.WRE, BCEE, F.ASCE.
General Manager

PO Box 8300
Fountain Valley, CA 92728-8300
18700 Ward Street
Fountain Valley, CA 92708
(714) 378-3200
(714) 378-3373 fax
www.ocwd.com

The People are the City

Mayor
CHAD P. WANKE

Mayor Pro Tem
RHONDA SHADER

Councilmembers:
CRAIG S. GREEN
WARD L. SMITH
JEREMY B. YAMAGUCHI

City Clerk:
PATRICK J. MELIA

City Treasurer
KEVIN A. LARSON

City Administrator
DAMIEN R. ARRULA

401 East Chapman Avenue – Placentia, California 92870

August 30, 2018

Mr. Warren Teitz
Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, CA 90012

Subject: Metropolitan Water District Future Supply Actions Funding Program

Dear Mr. Teitz:

On behalf of the City of Placentia, I am happy to support Anaheim Public Utilities' (APU's) Future Supply Actions proposal to the Metropolitan Water District. Placentia, with a population of approximately 51,000, borders Anaheim to the northeast. APU's proposed Study focuses on quantifying stormwater runoff from designated land uses due to projected future growth throughout Anaheim. The Study will also develop new stormwater management methods to capture and reuse runoff for future water supplies and to maximize infiltration for groundwater recharge, thus minimizing surface flow to the Pacific Ocean.

Much of the water supplied to residences and businesses in Placentia comes from the same groundwater basin that supplies Anaheim's water – the Orange County North Basin. Therefore, the data collected and analyzed as part of Anaheim's Study will also benefit our community. New ideas for stormwater management can help to ensure protection of our important Southern California water supplies and resources.

I, along with the City Council, am committed to keeping Placentia a pleasant place to live by providing a safe family atmosphere, superior public services and policies that promote the highest standards of community life. We believe Anaheim's proposal can benefit our community by helping to protect our groundwater resource, thus aiding in meeting our commitment. We hope you recognize its importance to our community, as well as others in Orange County.

We are looking forward to good news for Anaheim in its efforts.

Sincerely,

Luis Estevez
Public Works Director
City of Placentia

cc: M. Sepahi

CITY OF FULLERTON

City Manager's Office

August 31, 2018

Mr. Warren Teitz
Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, California 90012

Subject: Metropolitan Water District Future Supply Actions Funding Program

Dear Mr. Teitz:

The City of Fullerton fully supports Anaheim Public Utilities' (APU's) proposal for the Metropolitan Water District's Future Supply Actions Funding Program. APUs proposed Study will quantify stormwater runoff that can be captured and reused for future water supplies. Significant development is expected in the region in the future. The Study will allow the City to promote new stormwater management methods that will increase groundwater recharge and reduce the quantity of water lost to the Pacific Ocean.

Founded in 1887 and incorporated in 1904, the City of Fullerton borders Anaheim to the north, covers an approximate 22 square mile area and a has a population of 142,000. Much of the water supplied to Fullerton's residences and businesses is drawn from the same groundwater basin that supplies Anaheim's water. Data collected and analyzed as part of this proposed Study will directly benefit our community. New ideas for stormwater management can help to ensure protection of our important Southern California water supplies and resources.

Our community prides itself in providing an atmosphere that allows both for preservation of its historic past and opportunities to meet the challenges of the future. Thank you for your consideration of APU's forward-looking proposal. We hope you recognize its importance to communities in Orange County, as well as its potential to serve as a model for communities throughout the State of California.

Sincerely,

Ken Domer, City Manager
City of Fullerton

303 West Commonwealth Avenue, Fullerton, California 92832-1775
(714) 738-6310 • Fax (714) 738-6758 • citymanager@cityoffullerton.com • www.cityoffullerton.com

August 27, 2018

Mr. Warren Teitz
Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, CA 90012

Subject: Metropolitan Water District Future Supply Actions Funding Program

Dear Mr. Teitz,

On behalf of Katella High School, I am excited to support Anaheim Public Utilities' (APUs') Regional Assessment of Stormwater Capture, Treatment and Infiltration for Groundwater Enhancement proposal for Metropolitan Water District's Future Supply Action Funding Program. The focus of the proposed Study is to collect data and develop an engineering database that will be used to estimate expected stormwater runoff that can be captured and reused for future water supplies for areas of projected growth and development in Anaheim. The Study will also provide important data to assist residential/business owners and developers in identifying and implementing new management methods to maximize stormwater infiltration for groundwater recharge.

Katella High School is located in central Anaheim within the Anaheim Union High School District (AUHSD). Just recently, through grant funding awarded to the AUHSD from the State Water Resources Control Board's Drought Response Outreach Program for Schools (DROPS), a low impact development (LID) project was constructed to capture storm water and recharge the groundwater under Katella High School. The project was designed to capture 100 percent of the design storm event (85th percentile) through a state-of-the-art detention and infiltration system that included both below- and above-ground best management practices. The following elements were integrated into the school's environment:

1. All rooftop drains and parking lot drains were connected to one of the five proposed underground infiltration tanks (total storage area of 33,205 cubic feet), which are equipped with pretreatment manholes to capture sediment and grease, and allow filtered water to percolate through the soil to the vast Orange County groundwater basin; and

2. The project replaces severely damaged asphalt, concrete, and compacted turf with permeable pavers, two bioswales, and at least two native, water-wise educational gardens.

Learning With Purpose

ANAHEIM UNION HIGH SCHOOL DISTRICT

College and Career Ready

We recognize the benefits to our water resources from the Katella High School project and appreciate the opportunity to voice our support for APU's citywide study, which will ultimately provide similar benefits on a much larger scale. We strongly urge you to support the City of Anaheim's efforts to improve storm water infrastructure and replenish the ground water resources in our community.

Sincerely,

Patricia Neely |AIA |Architect
Director | Facilities Planning ▪ Design ▪ Construction

Anaheim Union High School District
501 Crescent Way |Anaheim |CA| 92803-3520
714 999 3505 |neely_p@auhsd.us

Appendix B
LID Menu & BMP Compliance Documents

Low Impact Development Summary

LID TYPE	OC TGD	ROW	P	R	C	I	S	Retention BMP	Comments
Biofiltration	BIO-1	X	X	X	X	X	X		
Biofiltration Planter Boxes (Above Ground)	BIO-1		X	X	X	X	X		Planter Boxes are typically attached to buildings and therefore are generally not be suitable for the public street ROW.
Biofiltration with Partial Retention	INF-4	X	X	X	X	X*	X	X	Biofiltration with retention may not suitable on industrial sites where spills may occur.
Bioretention	INF-3	X	X	X	X	X*	X	X	Bioretention may not suitable on industrial sites where spills may occur.
Blue Roof	HSC-6		X	X	X	X	X	X	Blue roofs are attached to roofs of structures or buildings and therefore are generally not suitable for the public street ROW
Constructed Wetlands	BIO-5		X	X	X	X*	X	X	Constructed wetlands are generally not suitable for the public street ROW due to space constraints. Constructed wetlands may not be suitable on industrial sites where spills may occur.
Detention (Underground)	HU-2		X	X	X	X	X		Undergound detention is generally not suitable for the public street ROW due to space constraints.
Detention Basin (Above Ground, Dry)	BIO-6		X	X*	X	X	X		Above ground dry detention is generally not suitable for the public street ROW due to space constraints.
Detention Basin (Above Ground, Wet)	BIO-4		X	X	X	X	X		Above ground wet detention is generally not suitable for the public street ROW due to space constraints.

ROW = Street Right of Way, P = Public Lands (Parks, Fire, Police),
R = Residential, C = Commercial, I = Industrial, S = Schools

Low Impact Development Summary

LID TYPE	OC TGD	ROW	P	R	C	I	S	Retention BMP	Comments
Drywells	INF-5	X	X	X	X	X	X	X	
Green Roofs	HSC-5		X	X	X	X	X		Green roofs are attached to roofs of structures or buildings and therefore are generally not suitable for the public street ROW
Infiltration (Underground)	INF-7	X	X	X	X		X	X	Underground infiltration may not be suitable for industrial sites unless hazardous materials and toxic materials are prevented from entering the system.
Infiltration Basin (Above Ground)	INF-1	X	X	X	X		X	X	Above ground infiltration basins may not be suitable for industrial sites unless hazardous materials and toxic materials are prevented from entering the system.
Infiltration Trench	INF-2	X	X	X	X		X	X	Infiltration trenches may not be suitable for industrial sites unless hazardous materials and toxic materials are prevented from entering the system.
Permeable Pavement	INF-6	X	X	X	X	X	X		Best suited for parking stalls, sidewalks or other paved areas out side of the main drive aisles.
Proprietary Biotreatment	BIO-7	X	X	X	X	X	X		
Proprietary Media Filtration	TRT-2	X	X	X	X	X	X		
Rain Barrels	HSC-4		X	X	X	X	X	X	Rain barrels typically accept funoff from roofs of structures or buildings and therefore are generally not be suitable for the public street ROW.
Rainwater Harvesting Cisterns	HU-1		X	X	X	X	X	X	Cisterns are generally not suitable for the public street ROW due to lack of demand for captured stormwater.

ROW = Street Right of Way, P = Public Lands (Parks, Fire, Police),
R = Residential, C = Commercial, I = Industrial, S = Schools

Low Impact Development Summary

LID TYPE	OC TGD	ROW	P	R	C	I	S	Retention BMP	Comments
Retention Basin (Above gound)	N/A		X	X	X	X	X	X	Above ground retention basins are generally not suitable for the public street ROW due to space constraints.
Retention Basin (Undergound)	N/A	X	X	X	X	X	X	X	
Sand Filters	TRT-1	X*	X	X	X	X	X		Sand filters are generally not be suitable for the public street ROW due to space constraints.
Street Trees	HSC-3	X	X	X	X	X	X		
Tree Wells	N/A	X	X	X	X	X	X	X	Tree wells are generally not suitable on industrial sites where spills may occur.
Vegetated Filter Strips	BIO-3	X	X	X	X	X*	X		Vegetated Filter Strips are generally not suitable on industrial sites where spills may occur.
Vegetated Swales	BIO-2	X	X	X	X	X*	X		Vegetated Swales are generally not suitable on industrial sites where spills may occur.

ROW = Street Right of Way, P = Public Lands (Parks, Fire, Police),
R = Residential, C = Commercial, I = Industrial, S = Schools

EXHIBIT 7.III

TECHNICAL GUIDANCE DOCUMENT (TGD) FOR THE PREPARATION OF CONCEPTUAL/PRELIMINARY AND/OR PROJECT WATER QUALITY MANAGEMENT PLANS (WQMPs)

December 20, 2013

Version Notes:

This release of the TGD incorporates errata approved by the Santa Ana Regional Water Quality Control Board on September 26, 2013.

This release of the TGD is intended to be used to support project development in both North Orange County and South Orange County; however requirements differ somewhat between these two Permit Areas. See the memorandum titled "*Guidance for Applying the TGD in South Orange County*" (dated December 20, 2013) for a summary of key differences between Permit Areas. Additionally, separate Model WQMPs have been developed for each Permit Area, and footnotes and clarifications have been added to the text of this TGD to distinguish and clarify criteria that apply specifically in South Orange County. These footnotes and text do not amend or revise any elements of the requirements in the North Orange County Permit Area; therefore these clarificatory revisions do not relate to the Santa Ana Regional Board's approval of the TGD and errata.

APPENDIX XIV. BMP FACT SHEETS

This appendix contains BMP fact sheets for the following BMP categories:

Note: ET plays an important role in the performance of HSC, INF, HU, and BIO BMPs. However, specific fact sheets for ET are not included. Criteria for designing BMPs to achieve the maximum feasible infiltration and ET are contained in **Appendix XI***.*

** Indicates BMPs that can potentially meet the South Orange County definition of "biofiltration BMPs". Biofiltration BMPs are vegetated treat-and-release BMPs that filter stormwater through amended soil media that is biologically active, support plant growth, and also promote infiltration and/or evapotranspiration. For projects in South Orange County, the total volume of storage in surface ponding and pores spaces is required to be at least 75% of the remaining DCV that the biofiltration BMP is designed to address. This prevents significant down-sizing of BMPs which otherwise may be possible via routing calculations. Biotreatment BMPs that do not meet this definition are not considered to be LID BMPs, but may be used as treatment control or pre-treatment BMPs.*

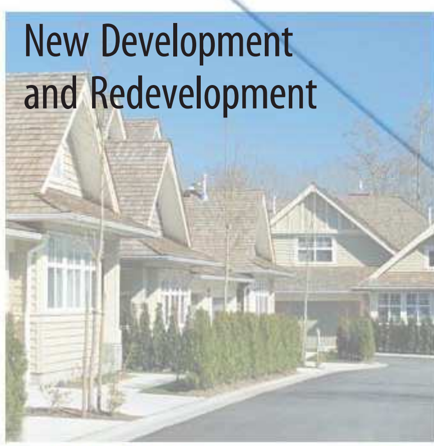
The BMP designs described in these fact sheets and in the referenced design manuals shall constitute what are intended as LID and Treatment Control BMPs for the purpose of meeting stormwater management requirements. Other BMP types and variations on these designs may be approved at the discretion of the reviewing agency if documentation is provided demonstrating similar functions and equivalent or better expected performance.

California Stormwater Quality Association

Stormwater Best Management Practice

Handbook

Municipal


New Development and Redevelopment


Construction


Industrial and Commercial

Municipal

Section 4
Treatment Control BMPs

4.1 Introduction

This section discusses the inspection and maintenance requirements for treatment control BMPs shown in Table 4-1. The specific design requirements, performance specifications, and limitations of each of these BMPs are discussed in detail in the New Development and Redevelopment BMP Handbook. Inspection and maintenance requirements are necessary to verify that each treatment control BMP performs efficiently throughout its design life. Although specific inspection and maintenance frequencies are presented in the following fact sheets, these are only suggested and should be adapted to each site situation to best accommodate environmental, economic, and local regulatory concerns.

For the purpose of this Handbook, treatment control BMPs have been classified according to whether they are public domain or proprietary controls. Public domain controls, as the name implies, are controls that are available to the general public, while proprietary controls are typically patented devices and are purchased from a vendor.

Table 4-1 Treatment Control BMPs

Public Domain	
TC-10	Infiltration Trench
TC-11	Infiltration Basin
TC-12	Retention/Irrigation
TC-20	Wet Pond
TC-21	Constructed Wetland
TC-22	Extended Detention Basin
TC-30	Vegetated Swale
TC-31	Vegetated Buffer Strip
TC-32	Bioretention
TC-40	Media Filter
TC-50	Water Quality Inlet
TC-60	Multiple Systems
Manufactured (Proprietary)	
MP-20	Wetland
MP-40	Media Filter
MP-50	Wet Vault
MP-51	Vortex Separator
MP-52	Drain Inlet

4.2 Fact Sheet Format

A BMP fact sheet is a short document that gives pertinent maintenance and inspection information about a particular treatment control BMP. Typically, each fact sheet contains the information outlined in Figure 4-1. Completed fact sheets for each of the treatment control BMPs shown in Table 4-1 are provided in Section 4.3.

The fact sheets also contain side bar presentations with information on BMP maintenance concerns, objectives, and goals; targeted constituents; and removal effectiveness if known.

TC-xx Example Maintenance Fact Sheet

General Description

Inspection/Maintenance Considerations

Inspection Activities

Maintenance Activities

Additional Information

References

Figure 4-1
Example Fact Sheet

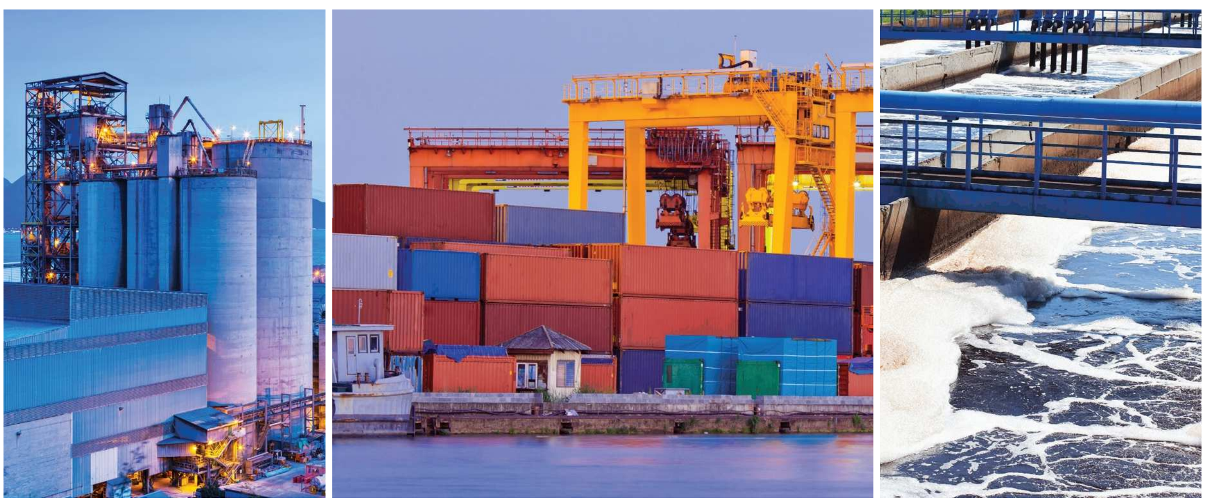
4.3 BMP Fact Sheets

Maintenance BMP fact sheets for public domain and manufactured BMPs follow. The BMP fact sheets are individually page numbered and are suitable for photocopying and inclusion in stormwater quality management plans. Fresh copies of the fact sheets can be individually downloaded from the California Stormwater BMP Handbook website at www.cabmphandbooks.com . As noted previously, the reader should refer to the New Development and Redevelopment BMP Handbook for details regarding BMP design, performance, and installation. In addition to the references at the end of each fact sheet, the 1993 version of the California Stormwater BMP Handbook was used as a general reference and starting point for the preparation of the maintenance fact sheets that follow.

In addition, it is worth noting that there are numerous proprietary treatment control devices available. Manufacturers typically have recommended inspection schedules and maintenance requirements for each device. If your facility utilizes proprietary treatment control devices for stormwater runoff, a maintenance agreement and detailed maintenance plan should be developed to ensure that they are well maintained, and operate according to design specifications. For many manufactured devices, municipalities can contract with the manufacturer or representative to provide maintenance services.

Stormwater Best Management Practice Handbook Portal:

Industrial and Commercial



CASQA
CALIFORNIA STORMWATER QUALITY ASSOCIATION®

4 Treatment Control BMPs

4.1 Introduction

This section discusses the inspection and maintenance requirements for treatment control BMPs for stormwater runoff. The specific design requirements, performance specifications, and limitations of each of these BMPs are discussed in detail in the New Development and Redevelopment BMP Handbook. Inspection and maintenance requirements are necessary to verify that each treatment control BMP performs efficiently throughout its design life. Although specific inspection and maintenance frequencies are presented in the following fact sheets, these are only suggested and should be adapted to each site situation to best accommodate environmental, economic, and local regulatory concerns.

Table 4-1 Maintenance Fact Sheets for Public Domain Treatment Control BMPs

TC-10	Infiltration Trench
TC-11	Infiltration Basin
TC-12	Harvest and Reuse
TC-20	Wet Pond
TC-21	Constructed Wetland
TC-22	Extended Detention Basin
TC-30	Vegetated Swale
TC-31	Vegetated Buffer Strip
TC-32	Bioretention
TC-40	Media Filter
TC-50	Water Quality Inlet
TC-60	Multiple Systems

For the purpose of this Handbook, treatment control BMPs have been classified according to whether they are public domain or proprietary controls. Public domain controls, as the name implies, are controls that are available to the general public, while proprietary controls are typically patented devices and are purchased from a vendor.

4.2 Public Domain BMPs

The public domain treatment control BMPs discussed in this section are listed in **Table 4-1**. Maintenance fact sheets for each treatment control BMP are provided in **Section 4.5**.

4.3 Manufactured (Proprietary) Treatment Control Devices

Numerous proprietary treatment control devices are available as well. Manufacturers typically have recommended inspection schedules and maintenance requirements for each device. If your industry utilizes proprietary treatment control devices for stormwater runoff, a maintenance agreement and detailed maintenance plan should be developed to ensure that that they are well maintained and operate according to design specifications. For many manufactured devices, industry owners can contract with the manufacturer or representative to provide

Table 4-2 Maintenance Fact Sheets for Manufactured (Proprietary) Treatment Control BMPs

MP-20	Biotreatment
MP-40	Media Filter
MP-50	Wet Vault
MP-51	Gravity Separator
MP-52	Drain Inlet Insert

maintenance services. **Table 4-2** shows a list of available manufactured stormwater treatment control devices. Maintenance fact sheets for each BMP are provided in **Section 4.5**.

4.4 Maintenance BMP Fact Sheet Format

Name of Treatment Control BMP

General Description

Inspection/Maintenance Considerations

Inspection Activities

Maintenance Activities

Additional Information

References

Figure 4-1 Example Fact Sheet

A maintenance BMP fact sheet is a short document that gives guidance information about inspecting and maintaining a particular BMP including suggested frequencies for inspection and maintenance activities. Typically, each fact sheet contains the information outlined in **Figure 4-1.**

The fact sheets also contain side bar presentations with information on BMP maintenance concerns, objectives and goals; targeted constituents; and removal effectiveness if known.

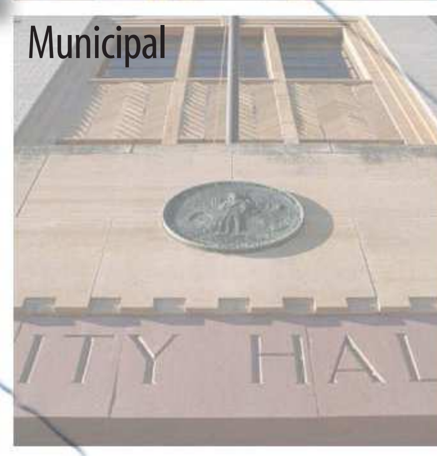
4.5 Maintenance BMP Fact Sheets

Maintenance fact sheets for public domain and manufactured treatment control BMPs follow. The BMP fact sheets are individually page numbered and are suitable for photocopying and inclusion in SWPPPs. Current copies of the fact sheets can be individually downloaded from the California Stormwater BMP Handbook web site at http://www.casqa.org. As noted previously, the reader should refer to the New Development and Redevelopment BMP Handbook for details regarding BMP design, performance, and installation. In addition to the references at the end of each fact sheet, the 2003 version of the California Stormwater BMP Handbook was used as a general reference and starting point for the preparation of the maintenance fact sheets that follow.

California Stormwater Quality Association

Stormwater Best Management Practice Handbook

New Development and Redevelopment



Section 5
Treatment Control BMPs

5.1 Introduction

This section describes treatment control Best Management Practices (BMPs) to be considered for incorporation into newly developed public and private infrastructure, as well as retrofit into existing facilities to meet stormwater management objectives. BMP fact sheets are divided into two groups: public domain BMPs and manufactured (proprietary) BMPs. In some cases, the same BMP may exist in each group, for example, media filtration. However, treatment BMPs are typically very different between the two groups.

Brand names of manufactured BMPs are not stated. Descriptions of manufactured BMPs in this document should not be inferred as endorsement by the authors.

5.2 Treatment Control BMPs

Public domain and manufactured BMP controls are listed in Table 5-1.

Table 5-1 Treatment Control BMPs

Public Domain		Manufactured (Proprietary)	
Infiltration		**Infiltration**	
TC-10	Infiltration Trench		
TC-11	Infiltration Basin		
TC-12	Retention/Irrigation		
Detention and Settling		**Detention and Settling**	
TC-20	Wet Pond	MP-20	Wetland
TC-21	Constructed Wetland		
TC-22	Extended Detention Basin		
Biofiltration		**Biofiltration**	
TC-30	Vegetated Swale		
TC-31	Vegetated Buffer Strip		
TC-32	Bioretention		
Filtration		**Filtration**	
TC-40	Media Filter	MP-40	Media Filter
Flow Through Separation		**Flow Through Separation**	
TC-50	Water Quality Inlet	MP-50	Wet Vault
		MP-51	Vortex Separator
		MP-52	Drain Inserts
Other		**Other**	
TC-60	Multiple Systems		

5.3 Fact Sheet Format

A BMP fact sheet is a short document that gives all the information about a particular BMP. Typically, each public domain and manufactured BMP fact sheet contains the information outlined in Figure 5-1. The fact sheets also contain side bar presentations with information on BMP design considerations, targeted constituents, and removal effectiveness (if known).

Treatment BMP performance, design criteria, and other selection factors are discussed in 5.4 – 5.6 below. BMP Fact sheets are included in 5.7.

TCxx / MPxx Example Fact Sheet

Description
California Experience
Advantages
Limitations
Design and Sizing Guidelines
Performance
Siting Criteria
Design Guidelines
Maintenance
Cost
References and Sources of Additional Information

Figure 5-1
Example Fact Sheet

5.4 Comparing Performance of Treatment BMPs

With a myriad of stormwater treatment BMPs from which to choose, a question commonly asked is "which one is best". Particularly when considering a manufactured treatment system, the engineer wants to know if it provides performance that is reasonably comparable to the typical public-domain BMPs like wet ponds or grass swales. With so many BMPs, it is not likely that they perform equally for all pollutants. Thus, the question that each local jurisdiction faces is which treatment BMPs will it allow, and under what circumstances. What level of treatment is desired or reasonable, given the cost? Which BMPs are the most cost-effective? Current municipal stormwater permits specify the volume or rate of stormwater that must be treated, but not the specific level or efficiency of treatment: These permits usually require performance to the specific maximum extent practicable (MEP), but this does not translate to an easy to apply specific design criteria.

Methodology for comparing BMP performance may need to be expanded to include more than removal effectiveness. Many studies have been conducted on the performance of stormwater treatment BMPs. Several publications have provided summaries of performance (ASCE, 1998; ASCE, 2001; Brown and Schueler, 1997; Shoemaker et al., 2000; Winter, 2001). These summaries indicate a wide variation in the performance of each type of BMP, making effectiveness comparisons between BMPs problematic.

5.4.1 Variation in Performance

There are several reasons for the observed variation.

The Variability of Stormwater Quality

Stormwater quality is highly variable during a storm, from storm to storm at a site, and between sites even of the same land use. For pollutants of interest, maximum observed concentrations commonly exceed the average concentration by a factor of 100. The average concentration of a storm, known as the event mean concentration (EMC) commonly varies at a site by a factor of 5. One aspect of stormwater quality that is highly variable is the particle size distribution (PSD) of the suspended sediments. This results in variation in the settle ability of these sediments and the pollutants that are attached. For example, several performance studies of manufactured BMPs have been conducted in the upper Midwest and Northeast where deicing sand is commonly used. The sand, washed off during spring and summer storms, skews the PSD to larger sizes not commonly found in stormwater from California sites except in mountainous areas. Consequently, a lower level efficiency may be observed if the same treatment system is used in California.

Most Field Studies Monitor Too Few Storms

High variability of stormwater quality requires that a large number of storms be sampled to discern if there is a significant difference in performance among BMPs. The smaller the actual difference in performance between BMPs, the greater the number of storms that must be sampled to statistically discern the difference between them. For example, a researcher attempting to determine a difference in performance between two BMPs of 10% must monitor many more storms than if the interest is to define the difference within 50%. Given the expense and difficulty, few studies have monitored enough storms to determine the actual performance with a high level of precision.

Different Design Criteria

Performance of different systems within the same group (e.g., wet ponds) differs significantly in part because of differing design criteria for each system. This in turn can make it problematic to compare different groups of treatment BMPs to each other (e.g., wet ponds to vortex separators).

Differing Influent Concentrations and Analytical Variability

With most treatment BMPs, efficiency decreases with decreasing influent concentration. This is illustrated in Figure 5-2. Thus, a low removal efficiency may be observed during a study not because the device is inherently a poorer performer, but possibly because the influent concentrations for the site were unusually low. In addition, as the concentration of a particular constituent such as TSS approaches its analytical detection limit, the effect of the variability of the laboratory technique becomes more significant. This factor also accounts for the wide variability of observations on the left of Figure 5-2.

The variability of the laboratory results as the TSS approaches its analytical detection limit may also account for negative efficiencies at very low influent concentrations (e.g., TSS less than 10 mg/L). However, some negative efficiencies observed at higher concentrations may not necessarily be an artifact of laboratory analysis. The cause varies to some extent with the type of treatment BMP. Negative efficiencies may be due to the re-suspension of previously deposited pollutants, a change in pH that dissolves precipitated or sorbed pollutants, discharge of algae in the case of BMPs with open wet pools, erosion of unprotected basin side or bottom, and the degradation of leaves that entered the system the previous fall.

Different Methods of Calculating Efficiency

Researchers (1) have used different methods to calculate efficiency, (2) do not always indicate which method they have used, and (3) often do not provide sufficient information in their report to allow others to recalculate the efficiency using a common method.

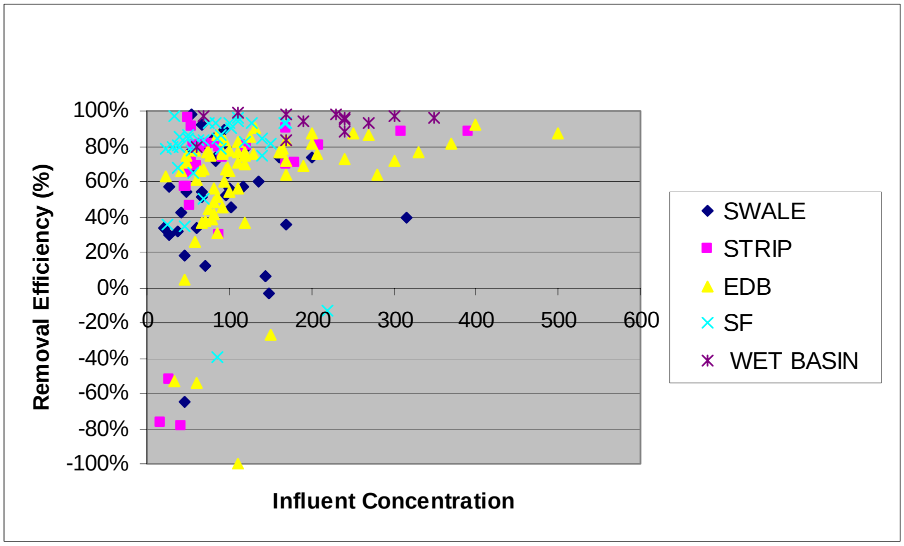


Figure 5-2
Removal Efficiency Versus Influent Concentration

One approach to quantifying BMP efficiency is to determine first if the BMP is providing treatment (that the influent and effluent mean event mean concentrations are statistically different from one another) and then examine either a cumulative distribution function of influent and effluent quality or a standard parallel probability plot. This approach is called the Effluent Probability Method. While this approach has been used in the past by EPA and ASCE, some researchers have experienced problems with the general applicability of this method. A discussion of these issues is included in Appendix B.

A second approach to comparing performance among BMPs is to compare effluent concentrations, using a box-whisker plot, the basic form of which is illustrated in Figure 5-3. The plot represents all of the data points, of one study, several studies, or of individual storms. The plots provide insight into the variability of performance within each BMP type, and possible differences in performance among the types. To explain the plot: 50% of the data points as well as the median value of all the data points is represented by the box. That is, the median falls within the 75th and 25th percentile of data (top and bottom of the box). The whisker extends to the highest point within a range of 1.5 times the difference between the first and third quartiles. Individual points beyond this range are shown as asterisks.

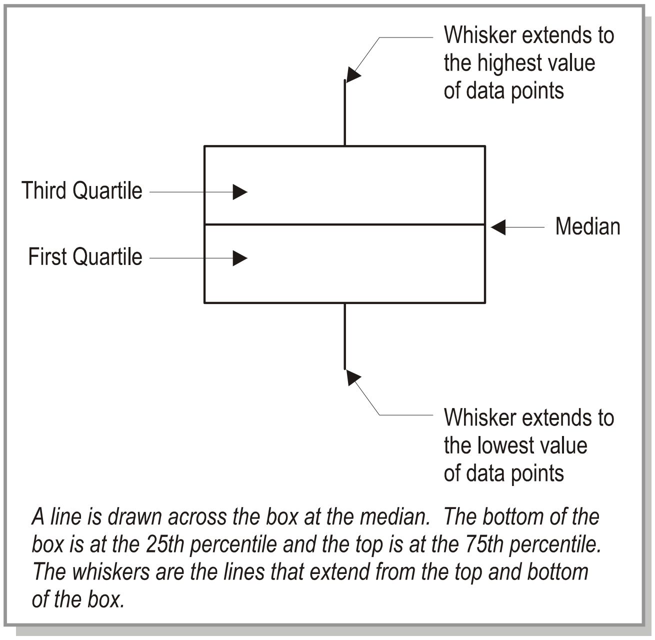


Figure 5-3
Box-Whisker Plot

Recognizing the possible effect of influent concentration on efficiency, an alternative is to compare effluent concentrations. The reasoning is that regardless of the influent concentration, a particular BMP will generate a narrower range of effluent concentrations. Figure 5-4 shows observed effluent concentrations for several different types of BMPs. These data were generated in an extensive field program conducted by the California Department of Transportation (Caltrans). As this program is the most extensive effort to date in the entire United States, the observations about performance in this Handbook rely heavily on these data. The Caltrans study is unique in that many of the BMPs were tested under reasonably similar conditions (climate, storms, freeway stormwater quality), with each type of BMP sized with the same design criteria.

An additional factor to consider when comparing BMPs is the effect of infiltration. BMPs with concrete or metal structures will have no infiltration, whereas the infiltration in earthen BMPs will vary from none to substantial. For example, in the Caltrans study, infiltration in vegetated swales averaged nearly 50%. This point is illustrated with Figure 5-4 where effluent quality of several BMPs is compared. As seen in Figure 5-4, effluent concentration for grass swales is higher than either filters or wet basins (30 vs. 10 to 15 mg/L), suggesting that swales in comparison are not particularly effective. However, surface water entering swales may infiltrate into the ground, resulting in a loading reduction (flow times concentration) that is similar to those BMPs with minimal or no infiltration.

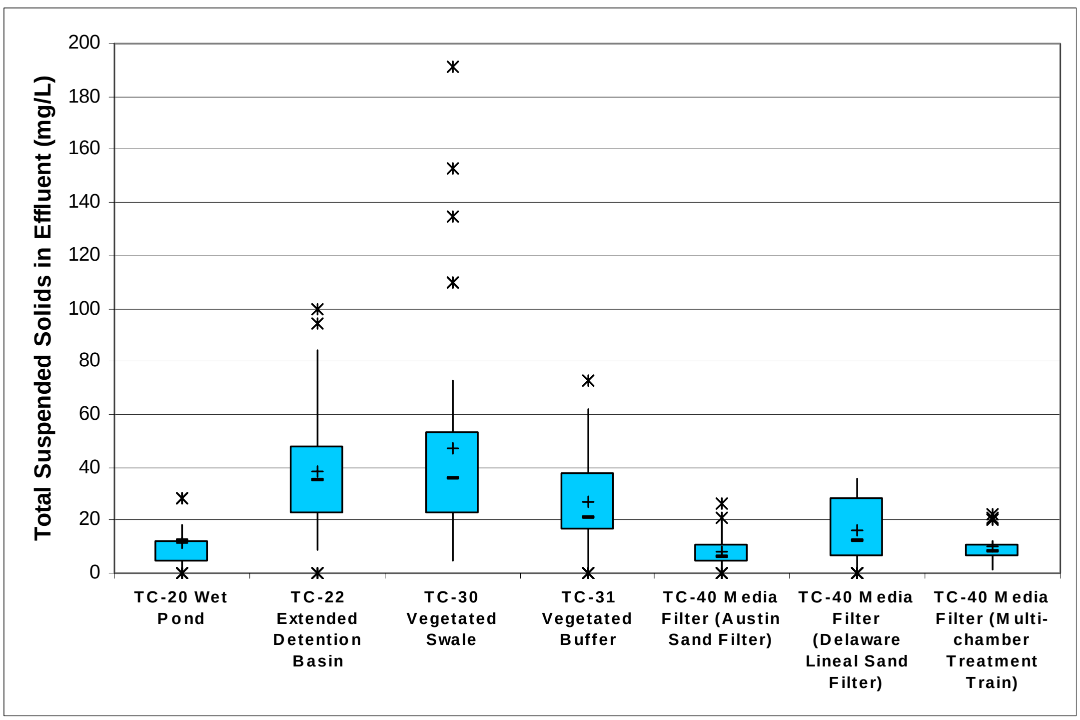


Figure 5-4
Observed Effluent Concentrations for Several Different Public Domain BMPs

With equation shown below, it is possible using the data from Figure 5-4 to estimate different levels of loading reduction as a function of the fraction of stormwater that is infiltrated.

EEC = (1-I)(EC) + (I)(GC)

Where:

EEC = the effective effluent concentration

I = fraction of stormwater discharged by infiltration

EC = the median concentration observed in the effluent

GC = expected concentration of stormwater when it reaches the groundwater

To illustrate the use of the equation above, the effect of infiltration is considered on the effective effluent concentration of TSS from swales. From Figure 5-4, the median effluent concentration for swales is about 30 mg/L. Infiltration of 50% is assumed with an expected concentration of 5 mg/L when the stormwater reaches the groundwater. This gives:

EEC = (1-0.5)(30) + (0.5)(5) = 17.5 mg/L.

The above value can be compared to other BMPs that may directly produce a lower effluent concentration, but do not exhibit infiltration, such as concrete wet vaults.

5.4.2 Other Issues Related to Performance Comparisons

A further consideration related to performance comparisons is whether or not the treatment BMP removes dissolved pollutants. Receiving water standards for most metals are based on the dissolved fraction; the form of nitrogen or phosphorus of most concern as a nutrient is the dissolved fraction.

The common practice of comparing the performance of BMPs using TSS may not be considered sufficient by local governments and regulatory agencies, as there is not always a strong, consistent relationship between TSS and the pollutants of interest, particularly those identified in the 303d list for specific water bodies in California. These pollutants frequently include metals, nitrogen, nutrients (but often nutrients without specifying nitrogen or phosphorus), indicator bacteria (i.e., fecal coliform), pesticides, and trash. Less commonly cited pollutants include sediment, PAHs, PCBs, and dioxin. With respect to metals, typically, only the general term is used. In some cases, a specific metal is identified. The most commonly listed metals are mercury, copper, lead, selenium, zinc, and nickel. Less frequently listed metals are cadmium, arsenic, silver, chromium, molybdenum, and thallium. Commonly, only the general term "metals" is indicated for a water body without reference to a particular metal.

It is desirable to know how each of the treatment BMPs performs with respect to the removal of the above pollutants. Unfortunately, the performance data are non-existent or very limited for many of the cited pollutants, particularly trash, PAHs, PCBs, dioxin, mercury, selenium, and pesticides. Furthermore, the concentrations of these constituents are very low, often below the detection limit. This prevents the determination of which BMPs are most effective. However, with the exception of trash and possibly dioxin, these pollutants readily sorb to sediments in stormwater, and therefore absent data at this time can be considered to be removed in proportion to the removal of TSS (i.e., sediment.) Therefore, in general, those treatment systems that are most effective at removing TSS will be most effective at removing pollutants noted above.

While there is little data on the removal of trash, those treatment BMPs that include a basin such as a wet pond or vault, or extended detention basin should be similarly effective at removing trash as long as the design incorporates a means of retaining the floating trash in the BMP. Whether or not manufactured products that are configured as a basin (e.g., round vaults or vortex separators) are as effective as public domain BMPs is unknown. However, their ability to retain floating debris may be limited by the fact that many of these products are relatively small and therefore may have limited storage capacity. Only one manufactured BMP is specifically designed to remove floating debris.

There are considerable amounts of performance data for zinc, copper, and lead, with a less substantial database for nickel, cadmium, and chromium. An exception is high-use freeways where metals in general are at higher concentrations than residential and commercial properties. Lead sorbs easily to the sediments in stormwater, with typically only 10% in the dissolved phase. Hence, its removal is generally in direct proportion to the removal of TSS. In contrast, zinc, copper, and cadmium are highly soluble with 50% or more in the dissolved phase. Hence, two treatment BMPs may remove TSS at the same level, but if one is capable of removing dissolved metals, it provides better treatment overall for the more soluble metals.

5.4.3 Comparisons of Treatment BMPs for Nitrogen, Zinc, Bacteria, and TSS

Presented in Figures 5-5 through 5-8 are comparisons of the effluent concentrations produced by several types of treatment BMPs for nitrogen, zinc, and fecal coliform, respectively (TSS is represented in Figure 5-4). Graphs for other metals are provided in Appendix C. These data are from the Caltrans study previously cited. Total and the dissolved effluent concentrations are shown for zinc. (Note that while box-whisker plots are used here to compare BMPs, other methodologies, such as effluent cumulative probability distribution plots, are used by others.)

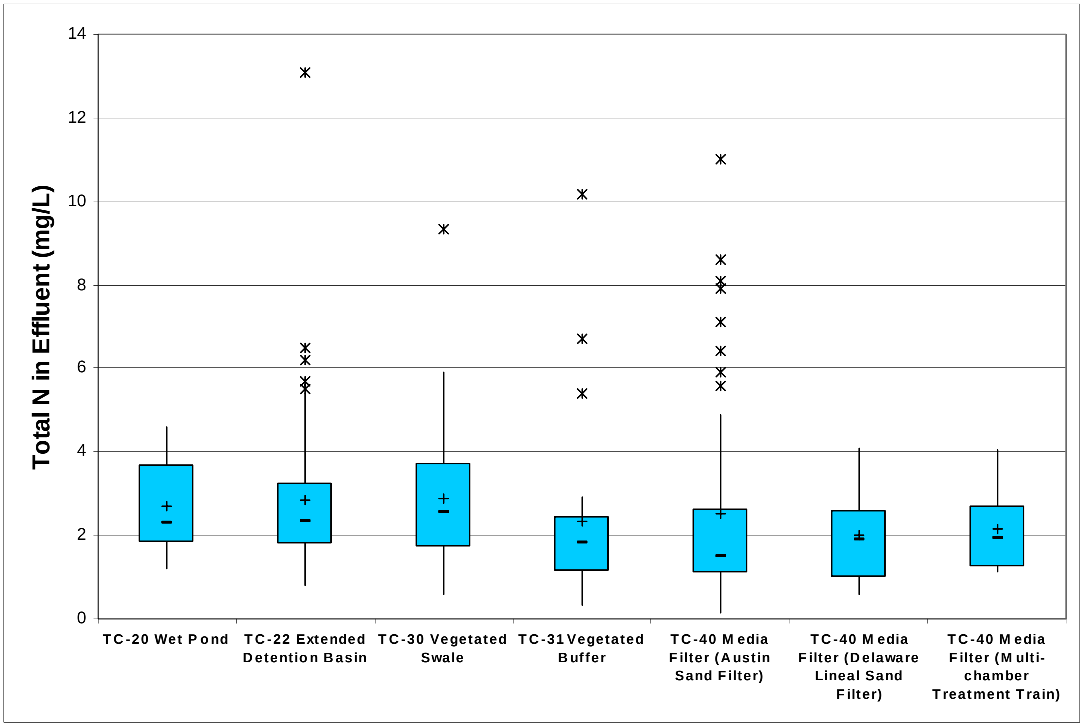


Figure 5-5
Total Nitrogen in Effluent

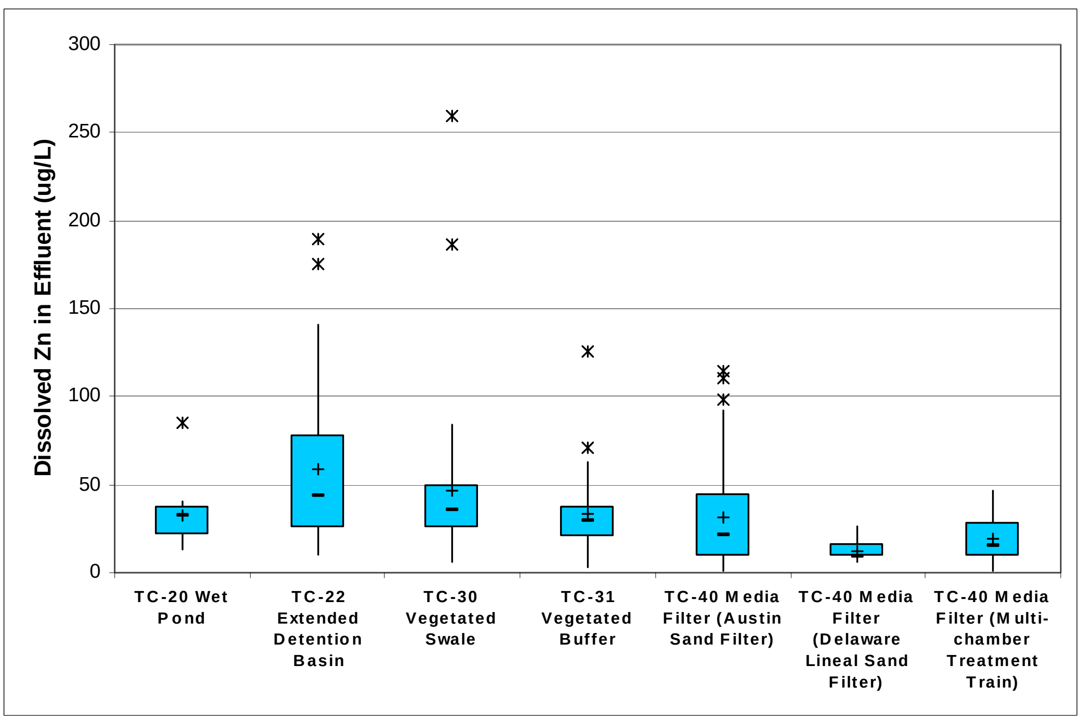


Figure 5-6
Total Dissolved Zinc in Effluent

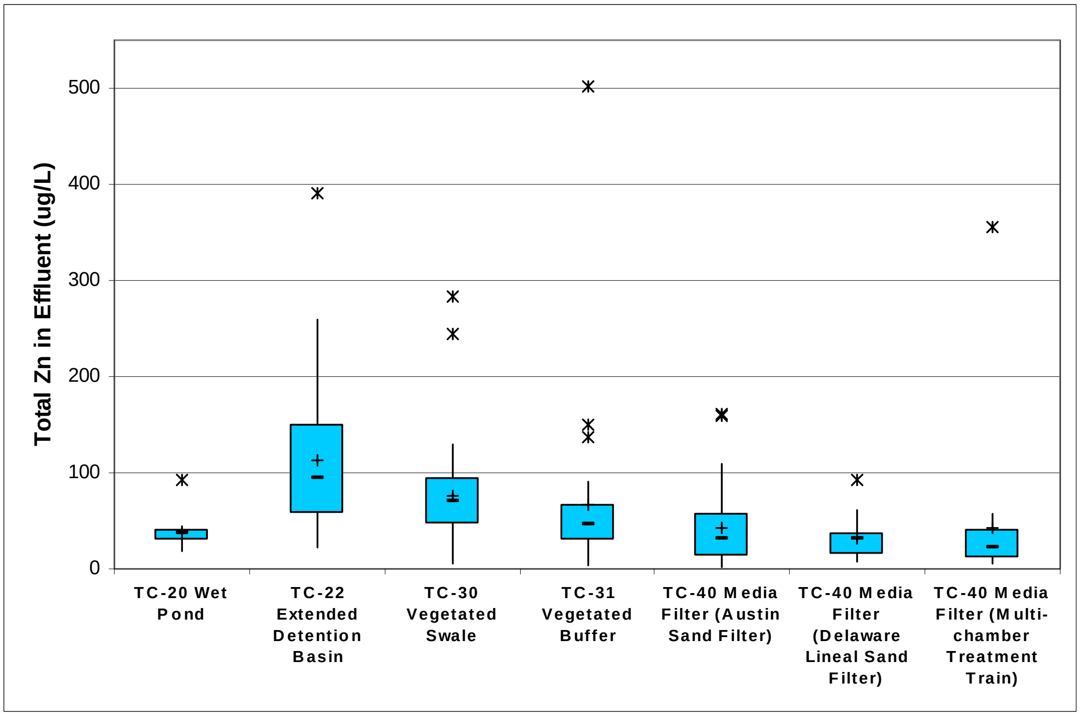


Figure 5-7
Total Zinc in Effluent

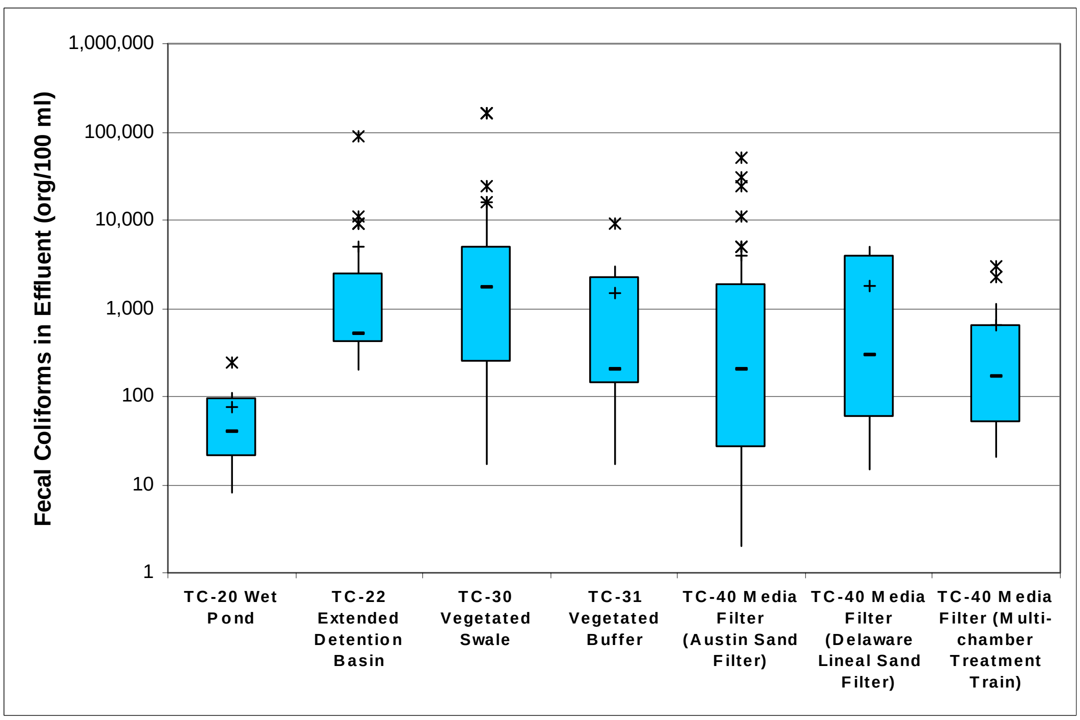


Figure 5-8
Total Fecal Coliforms in Effluent

While a figure is provided for fecal coliform, it is important to stress that the performance comparisons between BMPs is problematic. Some California BMP studies have shown excellent removal of fecal coliform through constructed wetlands and other BMPs. However, BMP comparisons are complicated by the fact that several BMPs attract wildlife and pets, thereby elevating bacteria levels. As bacteria sorb to the suspended sediments, a significant fraction may be removed by settling or filtration. A cautionary note regarding nitrogen: when comparing nitrogen removal between treatment systems it is best to use the parameter total nitrogen. It consists of Total Kjeldahl Nitrogen – TKN (organic nitrogen plus ammonia) plus nitrate. Comparing TKN removal rates is misleading in that in some treatment systems the ammonia is changed to nitrate but not removed. Examination of the performance data of many systems shows that while TKN may decrease dramatically, the nitrate concentration increases correspondingly. Hence, the overall removal of nitrogen is considerably lower than implied from looking only at Kjeldahl Nitrogen.

5.4.4 General Performance of Manufactured BMPs

An important question is how the performance of manufactured treatment BMPs compares to those in the public domain, illustrated previously in Figures 5-4 through 5-8. Figure 5-9 (and Figure 5-10 in log format) presents box-whisker plots of the removal of TSS for the manufactured systems. Data are presented for five general types of manufactured BMPs: wet vaults, drain inserts, constructed wetlands, media filters, and vortex separators. The figures indicate wide ranges in effluent concentrations, reflecting in part the different products and design criteria within each type. Comparing Figures 5-4 and 5-9 suggests that manufactured products may perform as well as the less effective publicdomain BMPs such as swales and extended detention basins (excluding the additional benefits of infiltration with the latter). Manufactured wetlands may perform as well as the most effective publicdomain BMPs; however, the plot presented in Figure 5-9 for the manufactured wetlands represents only five data points. It should be noted that each type of BMP illustrated in Figure 5-9 contains data from more than one product. Performance of particular products within that grouping may not perform as well as even the least effective publicdomain BMPs. This observation is implied by the greater spread within some boxes in Figure 5-9, for example, manufactured wet vaults and vortex separators.

Product performance within each grouping of manufactured BMPs vary as follows:

- Filters – TSS effluent concentrations range from 2 to 280 mg/L, with a median value of 29 mg/L
- Inserts - TSS effluent concentrations range from 4 to 248 mg/L with a median value of 27 mg/L
- Wetlands – TSS effluent concentrations vary little, and have a median value of 1.2 mg/L
- Vaults – TSS effluent concentrations range from 1 to 467 mg/L, with a median value of 36 mg/L
- Vortex – TSS effluent concentrations range from 13 to 359 mg/L, with a median value of 32 mg/L

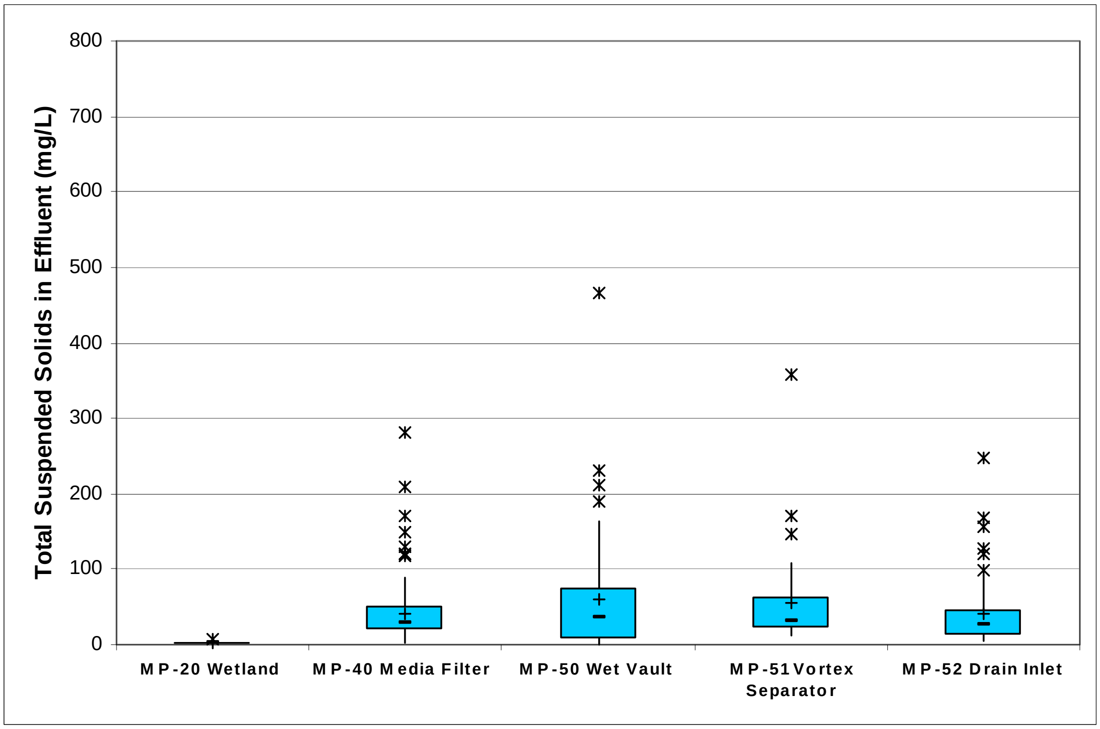


Figure 5-9
Total Suspended Solids in Effluent

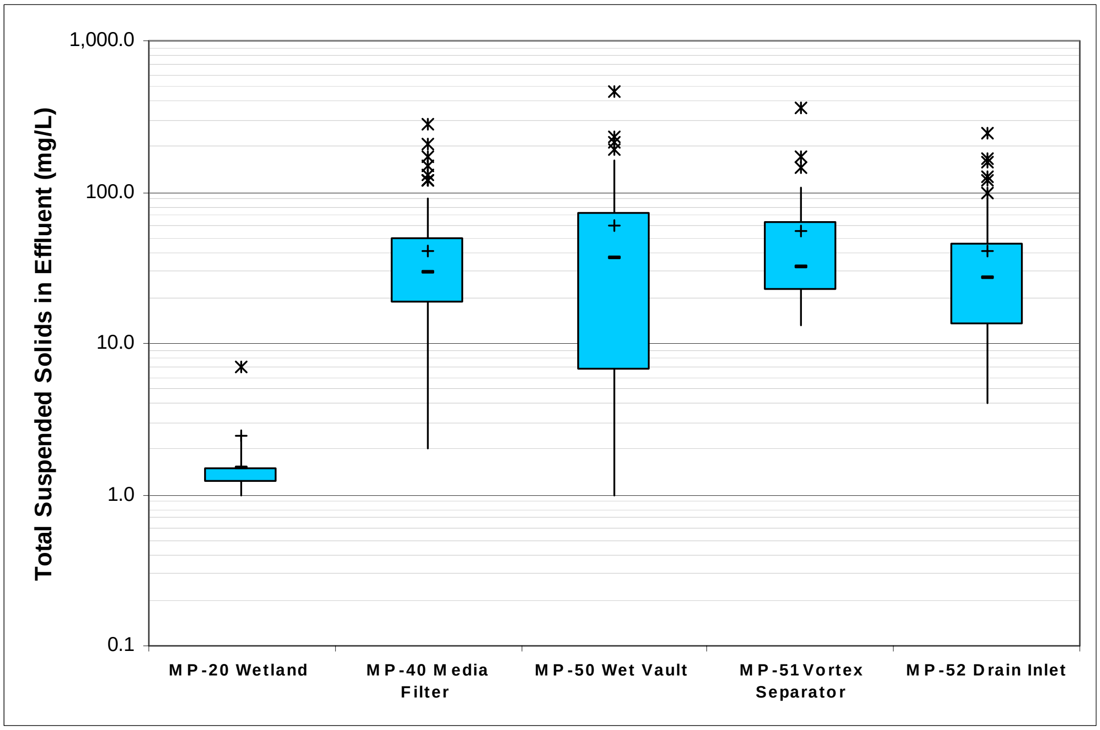


Figure 5-10
Total Suspended Solids in Effluent (log-format)

As noted earlier, performance of particular products in a grouping may be due to different design criteria within the group. For example, wet vault products differ with respect to the volume of the permanent wet pool to the design event volume; filter products differ with respect to the type of media.

5.4.5 Technology Certification

This Handbook does not endorse proprietary products, although many are described. It is left to each community to determine which proprietary products may be used, and under what circumstances. When considering a proprietary product, it is strongly advised that the community consider performance data, but only performance data that have been collected following a widely accepted protocol. Protocols have been developed by the American Society of Civil Engineering (ASCE BMP Data Base Program), and by the U.S.Environmental Protection Agency (Environmental Technology Certification Program). The local jurisdiction should ask the manufacturer of the product to submit a report that describes the product and protocol that was followed to produce the performance data.

It can be expected that subsequent to the publishing of this Handbook, new public-domain technologies will be proposed (or design criteria for existing technologies will be altered) by development engineers. As with proprietary products, it is advised that new public-domain technologies be considered only if performance data are available and have been collected following a widely accepted protocol.

5.5 BMP Design Criteria for Flow and Volume

Many municipal stormwater discharge permits in California contain provisions such as Standard Urban Stormwater Mitigation Plans, Stormwater Quality Urban Impact Mitigation Plans, or Provision C.3 New and Redevelopment Performance Standards, commonly referred to as SUSMPs, SQUIMPs, or C.3 Provisions, respectively. What these and similar provisions have in common is that they require many new development and redevelopment projects to capture and then infiltrate or treat runoff from the project site prior to being discharged to storm drains. These provisions include minimum standards for sizing these treatment control BMPs. Sizing standards are prescribed for both volume-based and flow-based BMPs.

A key point to consider when developing, reviewing, or complying with requirements for the sizing of treatment control BMPs for stormwater quality enhancement is that BMPs are most efficient and economical when they target small, frequent storm events that over time produce more total runoff than the larger, infrequent storms targeted for design of flood control facilities. The reason for this can be seen by examination of Figure 5-11 and Figure 5-12.

Figure 5-11 shows the distribution of storm events at San Jose, California where most storms produce less than 0.50 in. of total rainfall. Figure 5-12 shows the distribution of rainfall intensities at San Jose, California, where most storms have intensities of less than 0.25 in/hr. The patterns at San Jose, California are typical of other locations throughout the state. Figures 5-11 and 5-12 show that as storm sizes increase, the number of events decrease. Therefore, when BMPs are designed for increasingly larger storms (for example, storms up to 1 in. versus storms of up to 0.5 in.), the BMP size and cost increase dramatically, while the number of additional treated storm events are small. Table 5-2 shows that doubling the design storm depth from 0.50 in. to 1.00 in. only increases the number of events captured by 23%. Similarly, doubling the design rainfall intensity from 0.25 in/hr to 0.50 in/hr only increases the number of events captured by 7%.

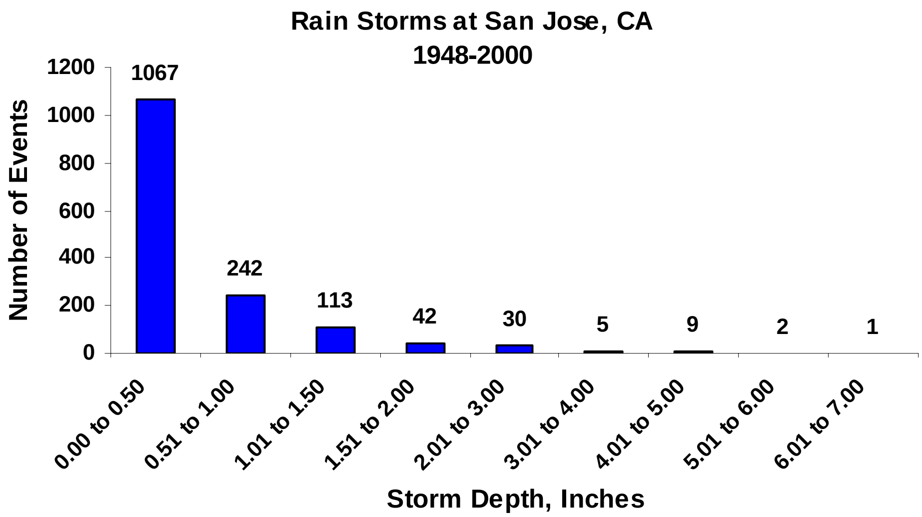


Figure 5-11
Rain Storms at San Jose, CA

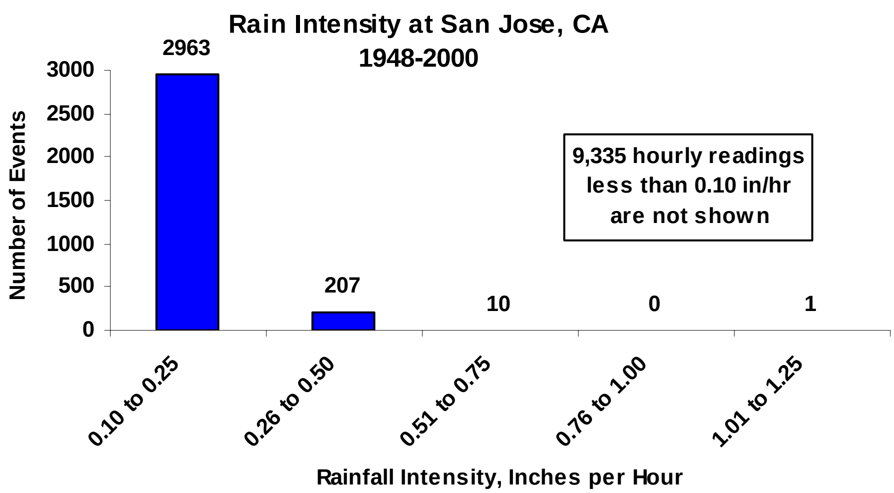


Figure 5-12
Rain Intensity at San Jose, CA

Table 5-2 Incremental Design Criteria VS Storms Treated at San Jose, CA

Proposed BMP Design Target	Number of Historical Events in Range	Incremental Increase in Design Criteria	Incremental Increase in Storms Treated
Storm Depth 0.00 to 0.50 in.	1,067	+100%	+23%
Storm Depth 0.51 to 1.00 in.	242		
Rainfall Intensity 0.10 to 0.25 in/hr	2,963	+100%	+7%
Rainfall Intensity 0.26 to 0.50 in/hr	207		

Due to economies of scale, doubling the capture and treatment requirements for a BMP are not likely to double the cost of many BMPs, but the incremental cost per event will increase, making increases beyond a certain point generally unattractive. Typically, design criteria for water quality control BMPs are set to coincide with the "knee of the curve," that is, the point of inflection where the magnitude of the event increases more rapidly than number of events captured. Figure 5-13 shows that the "knee of the curve" or point of diminishing returns for San Jose, California is in the range of 0.75 to 1.00 in. of rainfall. In other words, targeting design storms larger than this will produce gains at considerable incremental cost. Similar curves can be developed for rainfall intensity and runoff volume.

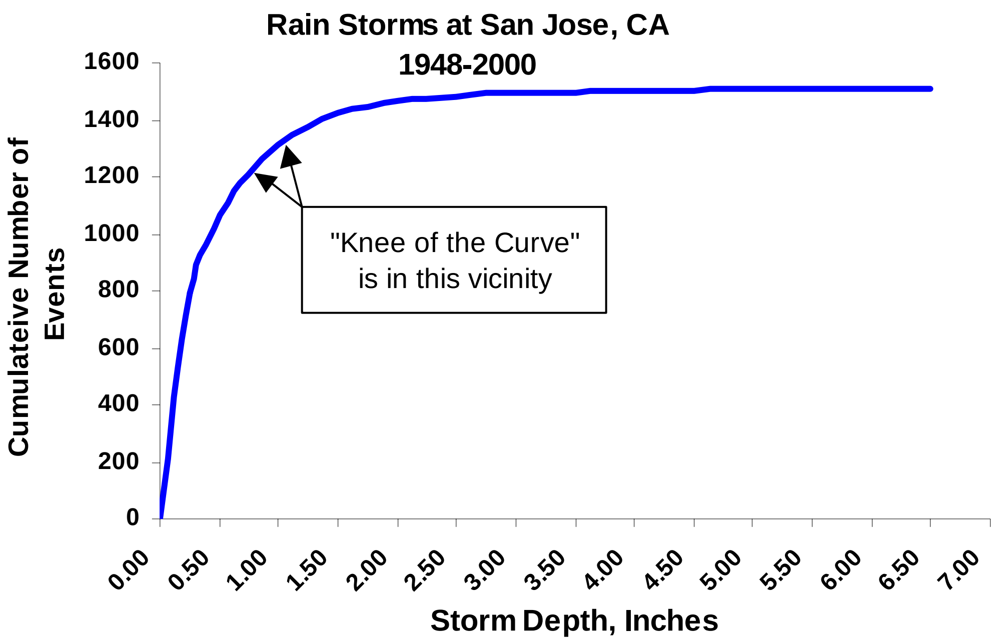


Figure 5-13
Rain Storms at San Jose, CA

It is important to note that arbitrarily targeting large, infrequent storm events can actually reduce the pollutant removal capabilities of some BMPs. This occurs when outlet structures, detention times, and drain down times are designed to accommodate unusually large volumes and high flows. When BMPs are over-designed, the more frequent, small storms that produce the most annual runoff pass quickly through the over-sized BMPs and therefore receive inadequate treatment. For example, a detention basin might normally be designed to capture 0.5 in. of runoff and to release that runoff over 48 hrs, providing a high level of sediment removal. If the basin were to be oversized to capture 1.0 in. of runoff and to release that runoff over 48 hrs, a more common 0.5 inch runoff event entering basin would drain in approximately 24 hrs, meaning the smaller, more frequent storm that is responsible for more total runoff would receive less treatment than if the basin were designed for the smaller event. Therefore, efficient and economical BMP sizing criteria are usually based on design criteria that correspond to the “knee of the curve” or point of diminishing returns.

5.5.1 Volume-Based BMP Design

Volume-based BMP design standards apply to BMPs whose primary mode of pollutant removal depends on the volumetric capacity of the BMP. Examples of BMPs in this category include detention basins, retention basins, and infiltration. Typically, a volume-based BMP design criteria calls for the capture and infiltration or treatment of a certain percentage of the runoff from the project site, usually in the range of the 75th to 85th percentile average annual runoff volume. The 75th to 85th percentile capture range corresponds to the “knee of the curve” for many sites in California for sites whose composite runoff coefficient is in the 0.50 to 0.95 range.

The following are examples of volume-based BMP design standards from current municipal stormwater permits. The permits require that volume-based BMPs be designed to capture and then to infiltrate or treat stormwater runoff equal to one of the following:

- Eighty (80) percent of the volume of annual runoff, determined in accordance with the methodology set forth in Appendix D of the California Storm Water Best Management Practices Handbook (Stormwater Quality Task Force, 1993), using local rainfall data.

- The maximized stormwater quality capture volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in Urban Runoff Quality Management (WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998), pages 175-178).

The reader is referred to the municipal stormwater program manager for the jurisdiction processing the new development or redevelopment project application to determine the specific requirements applicable to a proposed project.

California Stormwater BMP Handbook Approach

The volume-based BMP sizing methodology included in the first edition of the *California Storm Water Best Management Practice Handbook* (Stormwater Quality Task Force, 1993) has been included in this second edition of the handbook and is the method recommended for use.

The California Stormwater BMP Handbook approach is based on results of a continuous simulation model, the STORM model, developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers (COE-HEC, 1977). The Storage, Treatment, Overflow, Runoff Model (STORM) was applied to long-term hourly rainfall data at numerous sites throughout California, with sites selected throughout the state representing a wide range of municipal stormwater permit areas, climatic areas, geography, and topography. STORM translates rainfall into runoff, then routes the runoff through detention storage. The volume-based BMP sizing curves resulting from the STORM model provide a range of options for choosing a BMP sizing curve appropriate to sites in most areas of the state. The volume-based BMP sizing curves are included in Appendix D. Key model assumptions are also documented in Appendix D.

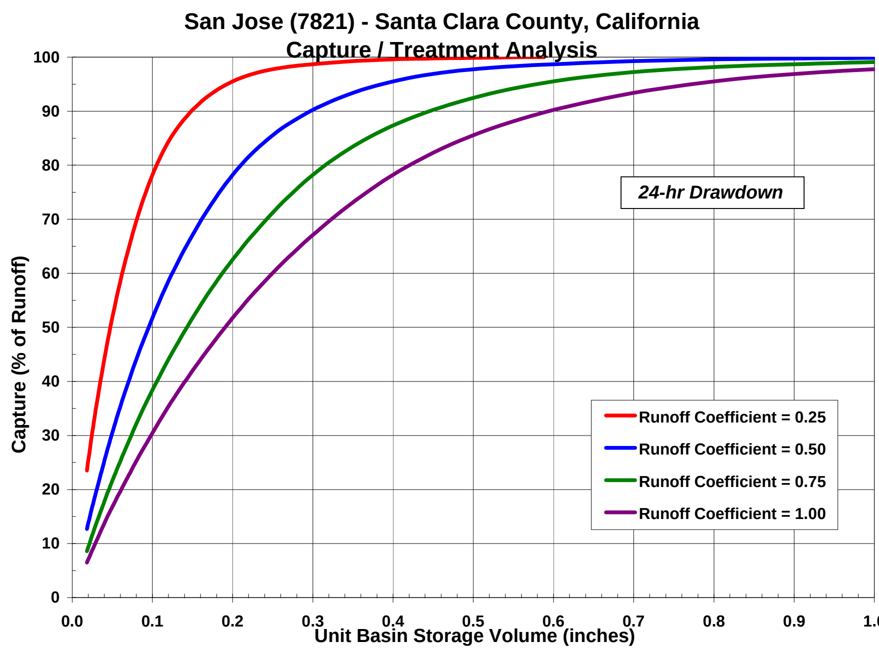


Figure 5-14
Capture / Treatment Analysis at San Jose, CA

The California Stormwater BMP Handbook approach is simple to apply, and relies largely on commonly available information about a project. The following steps describe the use of the BMP sizing curves contained in Appendix D.

1. Identify the "BMP Drainage Area" that drains to the proposed BMP. This includes all areas that will contribute runoff to the proposed BMP, including pervious areas, impervious areas, and off-site areas, whether or not they are directly or indirectly connected to the BMP.

2. Calculate the composite runoff coefficient "C" for the area identified in Step 1.

3. Select a capture curve representative of the site and the desired drain down time using Appendix D. Curves are presented for 24-hour and 48-hour draw down times. The 48-hour curve should be used in most areas of California. Use of the 24-hour curve should be limited

to drainage areas with coarse soils that readily settle and to watersheds where warming may be detrimental to downstream fisheries. Draw down times in excess of 48 hours should be used with caution, as vector breeding can be a problem after water has stood in excess of 72 hours.

4. Determine the applicable requirement for capture of runoff (Capture, % of Runoff).

5. Enter the capture curve selected in Step 3 on the vertical axis at the "Capture, % Runoff" value identified in Step 4. Move horizontally to the right across capture curve until the curve corresponding to the drainage area's composite runoff coefficient "C" determined in Step 2 is intercepted. Interpolation between curves may be necessary. Move vertically down from this point until the horizontal axis is intercepted. Read the "Unit Basin Storage Volume" along the horizontal axis. If a local requirement for capture of runoff is not specified, enter the vertical axis at the "knee of the curve" for the curve representing composite runoff coefficient "C." The "knee of the curve" is typically in the range of 75 to 85% capture.

6. Calculate the required capture volume of the BMP by multiplying the "BMP Drainage Area" from Step 1 by the "Unit Basin Storage Volume" from Step 5 to give the BMP volume. Due to the mixed units that result (e.g., ac-in., ac-ft) it is recommended that the resulting volume be converted to cubic feet for use during design.

Urban Runoff Quality Management Approach

The volume-based BMP sizing methodology described in *Urban Runoff Quality Management* (WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998), pages 175-178) has been included in this edition of the handbook as an alternative to the California Stormwater BMP Handbook approach described above. The Urban Runoff Quality Management Approach is suitable for planning level estimates of the size of volume-based BMPs (WEF/ASCE, 1998, page 175).

The Urban Runoff Quality Management approach is similar to the California Stormwater BMP Handbook approach in that it is based on the translation of rainfall to runoff. The Urban Runoff Quality Management approach is based on two regression equations. The first regression equation relates rainfall to runoff. The rainfall to runoff regression equation was developed using 2 years of data from more than 60 urban watersheds nationwide. The second regression equation relates mean annual runoff-producing rainfall depths to the "Maximized Water Quality Capture Volume" which corresponds to the "knee of the cumulative probability curve". This second regression was based on analysis of long-term rainfall data from seven rain gages representing climatic zones across the country. The Maximized Water Quality Capture Volume corresponds to approximately the 85th percentile runoff event, and ranges from 82 to 88%.

The two regression equations that form the Urban Runoff Quality Management approach are as follows:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

$$P_0 = (a \bullet C) \bullet P_6$$

Where

C = runoff coefficient

i = watershed imperviousness ratio which is equal to the percent total imperviousness divided by 100

P_0 = Maximized Detention Volume, in watershed inches

a = regression constant, a=1.582 and a=1.963 for 24 and 48 hour draw down, respectively

P_6 = mean annual runoff-producing rainfall depths, in watershed inches, Table #-1. See Appendix D.

The Urban Runoff Quality Management Approach is simple to apply. The following steps describe the use of the approach.

1. Identify the "BMP Drainage Area" that drains to the proposed BMP. This includes all areas that will contribute runoff to the proposed BMP, including pervious areas, impervious areas, and off-site areas, whether or not they are directly or indirectly connected to the BMP.

2. Calculate the "Watershed Imperviousness Ratio" (i), which is equal to the percent of total impervious area in the "BMP Drainage Area" divided by 100.

3. Calculate the "Runoff Coefficient" (C) using the following equation:

   $$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

4. Determine the "Mean Annual Runoff" (P6) for the "BMP Drainage Area" using Table #-1 in Appendix D.

5. Determine the "Regression Constant" (a) for the desired BMP drain down time. Use a=1.582 for 24 hrs and a=1.963 for 48 hr draw down.

6. Calculate the "Maximized Detention Volume" (P0) using the following equation:

   $$P_0 = (a \bullet C) \bullet P_6$$

7. Calculate the required capture volume of the BMP by multiplying the "BMP Drainage Area" from Step 1 by the "Maximized Detention Volume" from Step 6 to give the BMP volume. Due to the mixed units that result (e.g., ac-in., ac-ft) it is recommended that the resulting volume be converted to ft^3 for use during design.

5.5.2 Flow-Based BMP Design

Flow-based BMP design standards apply to BMPs whose primary mode of pollutant removal depends on the rate of flow of runoff through the BMP. Examples of BMPs in this category include swales, sand filters, screening devices, and many proprietary products. Typically, a flow-based BMP design criteria calls for the capture and infiltration or treatment of the flow runoff produced by rain events of a specified magnitude.

The following are examples of flow-based BMP design standards from current municipal stormwater permits. The permits require that flow-based BMPs be designed to capture and then to infiltrate or treat stormwater runoff equal to one of the following:

- 10% of the 50-yr peak flow rate (Factored Flood Flow Approach)
- The flow of runoff produced by a rain event equal to at least two times the 85th percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths (California Stormwater BMP Handbook Approach)
- The flow of runoff resulting from a rain event equal to at least 0.2 in/hr intensity (Uniform Intensity Approach)

The reader is referred to the municipal stormwater program manager for the jurisdiction processing the new development or redevelopment project application to determine the specific requirements applicable to a proposed project.

The three typical requirements shown above all have in common a rainfall intensity element. That is, each criteria is based treating a flow of runoff produced by a rain event of specified rainfall intensity.

In the first example, the Factored Flood Flow Approach, the design rainfall intensity is a function of the location and time of concentration of the area discharging to the BMP. The intensity in this case is determined using Intensity-Duration-Frequency curves published by the flood control agency with jurisdiction over the project or available from climatic data centers. This approach is simple to apply when the 50-yr peak flow has already been determined for either drainage system design or flood control calculations.

In the second example, the California Stormwater BMP Handbook Approach (so called because it is recommended in this handbook), the rainfall intensity is a function of the location of the area discharging to the BMP. The intensity in this case can be determined using the rain intensity cumulative frequency curves developed for this Handbook based on analysis of long-term hourly rainfall data at numerous sites throughout California, with sites selected throughout the state representing a wide range of municipal stormwater permit areas, climatic areas, geography, and topography. These rain intensity cumulative frequency curves are included in Appendix D. This approach is recommended as it reflects local conditions throughout the state. The flow-based design criteria in some municipal permits require design based on two times the 85^{th} percentile hourly rainfall intensity. The factor of two included in these permits appears to be provided as a factor of safety: therefore, caution should be exercised when applying additional factors of safety during the design process so that over design can be avoided.

In the third example, the Uniform Intensity Approach, the rainfall intensity is specified directly, and is not a function of the location or time of concentration of the area draining to the BMP. This approach is very simple to apply, but it is not reflective of local conditions.

The three example flow-based BMP design criteria are easy to apply and can be used in conjunction with the Rational Formula, a simplified, easy to apply formula that predicts flow rates based on rainfall intensity and drainage area characteristics. The Rational Formula is as follows:

$$Q = CiA$$

where

Q = flow in ft^3/s

i = rain intensity in in/hr

A = drainage area in acres

C = runoff coefficient

The Rational Formula is widely used for hydrologic calculations, but it does have a number of limitations. For stormwater BMP design, a key limitation is the ability of the Rational Formula to predict runoff from undeveloped areas where runoff coefficients are highly variable with storm intensity and antecedent moisture conditions. This limitation is accentuated when predicting runoff from frequent, small storms used in stormwater quality BMP design because many of the runoff coefficients in common use were developed for predicting runoff for drainage design where larger, infrequent storms are of interest. Table 5-3 provides some general guidelines on use of the Rational Equation.

Table 5-3 Use of Rational Formula for Stormwater BMP Design

	Composite Runoff Coefficient, "C"			
BMP Drainage Area (Acres)	**0.00 to 0.25**	**0.26 to 0.50**	**0.51 to 0.75**	**0.76 to 1.00**
0 to 25	Caution	Yes	Yes	Yes
26 to 50	High Caution	Caution	Yes	Yes
51 to 75	Not Recommended	High Caution	Caution	Yes
76 to 100	Not Recommended	High Caution	Caution	Yes

In summary, the Rational Formula, when used with commonly tabulated runoff coefficients in undeveloped drainage areas, will likely result in predictions higher than will be experienced under actual field conditions. However, given the simplicity of the equation, its use remains practical and is often the standard method specified by local agencies. In general, use of alternative formulas for predicting BMP design flows based on the intensity criteria above is acceptable if the formula is approved by the local flood control agency or jurisdiction where the project is being developed.

The following steps describe the approach for application of the flow-based BMP design criteria:

1. Identify the "BMP Drainage Area" that drains to the proposed BMP. This includes all areas that will contribute runoff to the proposed BMP, including pervious areas, impervious areas, and off-site areas, whether or not they are directly or indirectly connected to the BMP.

2. Determine rainfall intensity criteria to apply and the corresponding design rainfall intensity.

    a. *Factored Flood Flow Approach*: Determine the time of concentration for "BMP Drainage Area" using procedures approved by the local flood control agency or using standard hydrology methods. Identify an Intensity-Duration-Frequency Curve representative of the drainage area (usually available from the local flood control agency or climatic data center). Enter the Intensity-Duration-Frequency Curve with the time of concentration and read the rainfall intensity corresponding to the 50-yr return period rainfall event. This intensity is the "Design Rainfall Intensity."

    b. *California Stormwater BMP Handbook Approach*: Select a rain intensity cumulative frequency curve representative of the "BMP Drainage Area." See Appendix D. Read the rainfall intensity corresponding to the cumulative probability specified in the criteria, usually 85%. Multiply the intensity by the safety factor specified in the criteria, usually 2, to get the "Design Rainfall Intensity."

    c. *Uniform Intensity Approach*: The "Design Rainfall Intensity" is the intensity specified in the criteria, usually 0.2 in/hr.

3. Calculate the composite runoff coefficient" "C" for the "BMP Drainage Area" identified in Step 1.

4. Apply the Rational Formula to calculate the "BMP Design Flow"

    a. *Factored Flood Flow Approach*: Using the "BMP Drainage Area" from Step 1, the "Design Rainfall Intensity" from Step 2a, and "C" from Step 3, apply the Rational Formula and multiply the result by 0.1. The result is the "BMP Design Flow."

    b. *California Stormwater BMP Handbook Approach*: Using the "BMP Drainage Area" from Step 1, the "Design Rainfall Intensity" from Step 2b, and "C" from Step 3, apply the Rational Formula. The result is the "BMP Design Flow."

    c. *Uniform Intensity Approach*: Using the "BMP Drainage Area" from Step 1, the "Design Rainfall Intensity" from Step 2c, and "C" from Step 3, apply the Rational Formula. The result is the "BMP Design Flow."

5.5.3 Combined Volume-Based and Flow-Based BMP Design

Volume-based BMPs and flow-based BMPs do not necessarily treat precisely the same stormwater runoff. For example, an on-line volume-based BMP such as a detention basin will treat the design runoff volume and is essentially unaffected by runoff entering the basin at an extremely high rate, say from a very short, but intense storm that produces the design volume of runoff. However, a flow-based BMP might be overwhelmed by the same short, but intense storm if the storm intensity results in runoff rates that exceed the flow-based BMP design flow rate. By contrast, a flow-based BMP such as a swale will treat the design flow rate of runoff and is essentially unaffected by the duration of the design flow, say from a long, low intensity storm. However, a volume-based detention basin subjected to this same rainfall and runoff event will begin to provide less treatment or will go into bypass or overflow mode after the design runoff volume is delivered.

Therefore, there may be some situations where designers need to consider both volume-based and flow-based BMP design criteria. An example of where both types of criteria might apply is an off-line detention basin. For an off-line detention basin, the capacity of the diversion structure could be designed to comply with the flow-based BMP design criteria while the detention basin itself could be designed to comply with the volume-based criteria.

When both volume-based and flow based criteria apply, the designer should determine which of the criteria apply to each element of the BMP system, and then size the elements accordingly.

5.6 Other BMP Selection Factors

Other factors that influence the selection of BMPs include cost, vector control issues, and endangered species issues. Each of these is discussed briefly below.

5.6.1 Costs

The relative costs for implementing various public domain and manufactured BMPs based on flow and volume parameters are shown in Tables 5-4 and 5-5 below:

Table 5-4 Economic Comparison Matrix - Flow

BMP	Cost/cfs
Strip	$$
Swale	$$
Wet Vault	Not available
Media Filter	$$$$
Vortex	Not available
Drain Insert	Not available

Table 5-5 Economic Comparison Matrix - Volume

BMP	Cost/acre-ft
Austin Sand Filter Basin	$$$$
Delaware Lineal Sand Filter	$$$$
Extended Detention Basin (EDB)	$$
Multi Chamber Treatment Train (MCTT)	$$$$
Wet Basin	$$$$
Manufactured Wetland	Not available
Infiltration Basin	$
Wet Pond and Constructed Wetland	$$$$

5.6.2 Vector Breeding Considerations

The potential of a BMP to create vector breeding habitat and/or harborage should be considered when selecting BMPs. Mosquito and other vector production is a nuisance and public health threat. Mosquitoes can breed in standing water almost immediately following a BMP installation and may persist at unnaturally high levels and for longer seasonal periods in created habitats. BMP siting, design, construction, and maintenance must be considered in order to select a BMP that is least conducive to providing habitat for vectors. Tips for minimizing vector-breeding problems in the design and maintenance of BMPs are presented in the BMP fact sheets. Certain BMPs, including ponds and wetlands and those designed with permanent water sumps, vaults, and/or catch basins (including below ground installations), may require routine inspections and treatments by local mosquito and vector control agencies to suppress vector production.

5.6.3 Threatened and Endangered Species Considerations

The presence or potential presence of threatened and endangered species should also be considered when selecting BMPs. Although preservation of threatened endangered species is crucial, treatment BMPs are not intended to supplement or replace species habitat except under special circumstances. The presence of threatened or endangered species can hinder timely and routine maintenance, which in turn can result in reduced BMP performance and an increase in vector production. In extreme cases, jurisdictional rights to the treatment BMP and surrounding land may be lost if threatened or endangered species utilize or become established in the BMP.

When considering BMPs where there is a presence or potential presence of threatened or endangered species, early coordination with the California Department of Fish and Game and the U.S. Fish and Wildlife service is essential. During this coordination, the purpose and the long-term operation and maintenance requirements of the BMPs need to be clearly established through written agreements or memorandums of understanding. Absent firm agreements or understandings, proceeding with BMPs under these circumstances is not recommended.

5.7 BMP Fact Sheets

BMP fact sheets for public domain and manufactured BMPs follow. The BMP fact sheets are individually page numbered and are suitable for photocopying and inclusion in stormwater quality management plans. Fresh copies of the fact sheets can be individually downloaded from the Caltrans Stormwater BMP Handbook website at www.cabmphandbooks.com.

County of Los Angeles Department of Public Works

Low Impact Development

Standards Manual

February 2014

APPENDIX E

Stormwater Quality Control Measure Fact Sheets

Table of Contents

FINAL

County of San Diego

Low Impact Development Handbook

Stormwater Management Strategies

Wdzfè 2014

Department of Public Works

5510 Overland Avenue, Suite 410

San Diego, California 92123

APPENDIX C. FACT SHEETS

CONTENTS

This page is intentionally blank.

Siting and Suitability

Bioretention areas offer flexibility in design and can easily be incorporated into new or existing infrastructure such as parking lot islands and edges, street rights-of-way and medians, roundabouts, pedestrian walkways, public transit stops, or building drainage areas. The available space and site topography often dictate the geometry and size of the bioretention areas. Additional site objectives include incorporation into the site's natural hydrologic regime and further enhancement of natural landscape features in an urban setting. See Section 3 for details.

Drainage Area: Less than 5 acres and fully stabilized.

Head Requirements: Bioretention typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

Slopes: Slopes draining to bioretention should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and internal longitudinal slope should be 2% or less.

Setbacks: Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

Water Table & Bedrock: At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

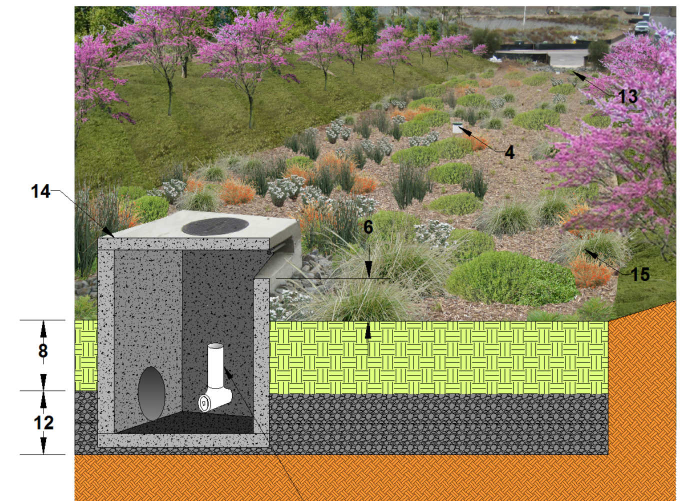
Soil Type: Bioretention can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

Areas of Concern: Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

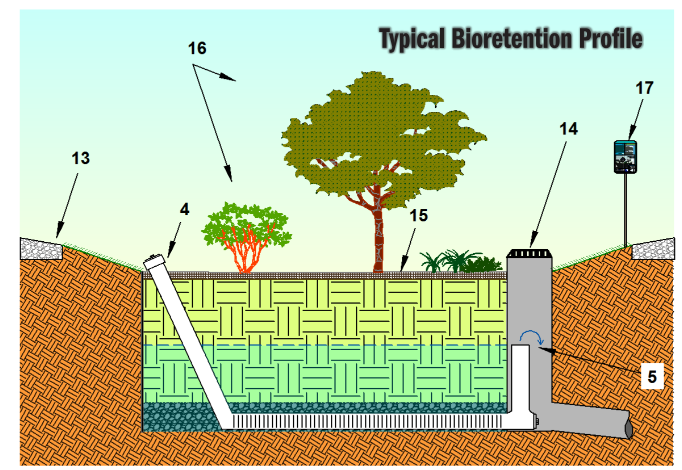
Design Considerations & Specifications
(see Appendices A & G *for details)*

		Design Component	General Specification
Drainage Design	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
Drainage Design	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral flows to adjacent subgrades, foundations, or utilities.
Drainage Design	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized.
Drainage Design	4	Cleanouts/ Observation Wells	Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe.
Drainage Design	5	Internal Water Storage (IWS)	If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention to promote plant survival and treatment. Top of IWS should be greater than 18 inches below surface.
Drainage Design	6	Temporary Ponding Depth	6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
Drainage Design	7	Drawdown Time	Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs.
Soil Media	8	Soil Media Depth	1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
Soil Media	9	Soil Media Composition	65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume.
Soil Media	10	Media Permeability	5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction).
Soil Media	11	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight.
Soil Media	12	Drainage Layer	Separate media from underdrain with 2 to 4 inches of washed sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone.
Routing	13	Inlet/Pretreatment	Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows, or vegetated swale.
Routing	14	Outlet Configuration	Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows.
Landscape	15	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
Landscape	16	Vegetation	Native, deep rooting, drought tolerant plants.
Landscape	17	Multi-Use Benefits	Provide educational signage, artwork, or wildlife amenities.

Bioretention Area Cross Section
Seaside Ridge Development, San Diego, CA



A bioretention area intercepts and treats runoff from a residential development. IWS is demonstrated in the rendered cross section by upturning the underdrain in the outlet structure. Note: photograph was enhanced by rendering additional vegetation.



This diagram shows the major design components of bioretention. Underdrains should be excluded when subsoil infiltration rates are suitable. Additional hydromodification control can be provided by increasing surface storage volume or subsurface drainage layer storage depth.

Maintenance Considerations *(see* Appendix D *for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of bioretention	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded.
Inlet inspection		Internal erosion or excessive sediment, trash, and/or debris accumulation	Check for sediment accumulation to ensure that flow into the bioretention is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within bioretention area, mulch around outlet, internal erosion	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized.
Pruning	1–2 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2–12 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Frequency depends on location and desired aesthetic appeal and type of vegetation.
Outlet inspection	1 time/year	Erosion at outlet	Remove any accumulated mulch or sediment.
Mulch removal and replacement	1 time/2–3 years	2/3 of mulch has decomposed	Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches
Remove and replace dead plants	1 time/year	Dead plants	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Temporary Watering	1 time/2–3 days for first 1–2 months	Until establishment and during severely-droughty weather	Watering after the initial year might be required.
Fertilization	1 time initially	Upon planting	One-time spot fertilization for first year vegetation.

Bioretention

Description

Bioretention areas are small-scale, vegetated depressions designed to provide stormwater storage and filtration through engineered media. Using detention, sedimentation, filtration and adsorption, bioretention enhances the removal of contaminants from stormwater by both plants and soils.

Bioretention can also incorporate pretreatment (i.e., vegetated filter strips, vegetated swales or settling forebays), allowing increased sedimentation and capture of debris from heavily trafficked areas. Finally, bioretention can be used in-line with traditional stormwater conveyance systems.

Treatment Efficiency	
Runoff Volume	High (unlined)/Low (lined)
Sediment	High
Nutrients	Medium
Pathogens	High
Metals	High
Oil & Grease	High
Organics	High

TETRA TECH

THE NOBLEST MOTIVE IS THE PUBLIC GOOD · COUNTY OF SAN DIEGO · MDCCCL

Siting and Suitability

Bioretention swales are highly versatile stormwater IMPs that effectively reduce pollutants. With a narrow width, bioretention swales can be integrated into site plans with various configurations and components. Ideal sites for bioretention swales include the right-of-way of linear transportation corridors and along borders or medians of parking lots. In heavily trafficked areas, curb cuts can be used to delineate boundaries. Bioretention swales can be combined with other basic and stormwater runoff BMPs to form a treatment train, reducing the required size of a single IMP unit. See Section 3 for details.

Drainage Area: Less than 2 acres and fully stabilized.

Head Requirements: Bioretention swale typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

Slopes: Slopes draining to bioretention swale should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and check dams should be used to provide longitudinal bed slopes of 2.5% (average slope should not exceed 4% from inlet to outlet).

Setbacks: Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

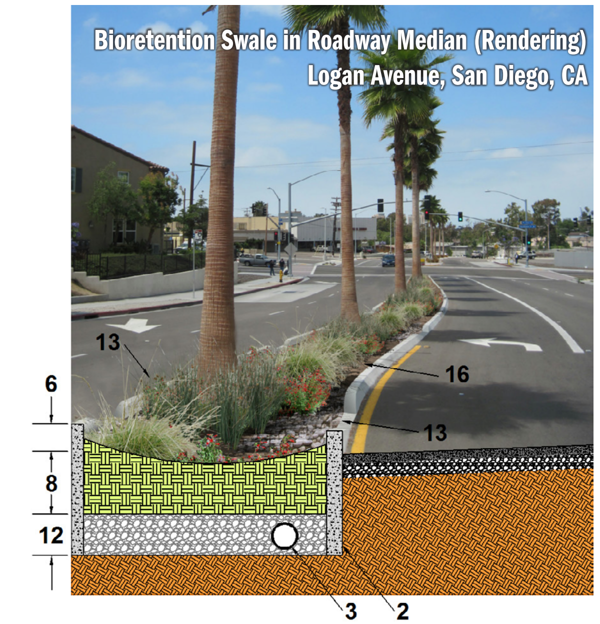
Water Table & Bedrock: At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

Soil Type: Bioretention swale can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

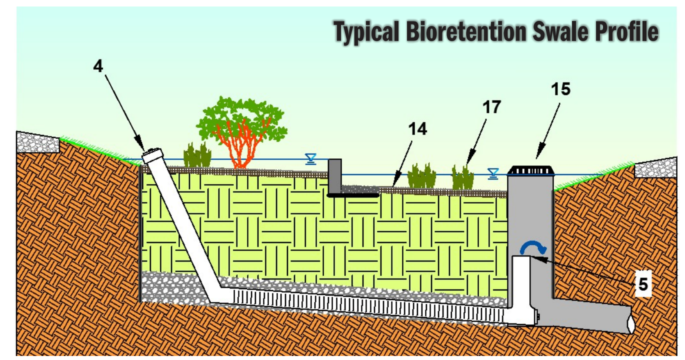
Areas of Concern: Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

Design Considerations & Specifications *(see* Appendices A & G *for details)*

		Design Component	General Specification
IMP Function	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized.
	4	Cleanouts/ Observation Wells	Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe.
	5	Internal Water Storage (IWS)	If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention to promote plant survival and treatment. Top of IWS should be greater than 18 inches below surface.
	6	Temporary Ponding Depth	Use check dams to provide 6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
	7	Drawdown Time	Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs.
Soil Media	8	Soil Media Depth	2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
	9	Soil Media Composition	65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume.
	10	Media Permeability	5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction)
	11	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight.
	12	Drainage Layer	Separate media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone.
Routing	13	Inlet/Pretreatment	Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows.
	14	Slope and Grade Control	If necessary, use check dams to maintain maximum 2.5% bed slope. Check dams should extend sufficiently deep to prevent piping (undercutting) below the check dam.
	15	Outlet Configuration	Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows.
Landscape	16	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
	17	Vegetation	Native, deep rooting, drought tolerant plants.
	18	Multi-Use Benefits	Provide educational signage, artwork, or wildlife amenities.



This rendering demonstrates the application of bioretention swales as green street retrofits. Runoff enters the bioretention swale through curb cuts and is filtered vertically through the soil media. Lateral hydraulic restriction layers protect adjacent infrastructure from lateral seepage while allowing infiltration from the bottom of the bioretention swale. The underdrain is offset to avoid roots of existing vegetation.



This schematic shows the major design elements of a bioretention swale. IWS is incorporated for enhanced infiltration and water quality treatment by upturning the underdrain in the outlet structure. Check dams ensure capture of the water quality volume and slow surface flow during larger storms.

Maintenance Considerations *(see* Appendix D *for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of bioretention swale	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded.
Inlet inspection		Internal erosion or excessive sediment, trash, and/or debris accumulation	Check for sediment accumulation to ensure that flow into the bioretention swale is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within bioretention swale area, mulch around outlet, internal erosion	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized.
Pruning	1–2 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2–12 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Frequency depends on location and desired aesthetic appeal and type of vegetation.
Outlet inspection	1 time/year	Erosion at outlet	Remove any accumulated mulch or sediment.
Mulch removal and replacement	1 time/2–3 years	2/3 of mulch has decomposed	Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches
Remove and replace dead plants	1 time/year	Dead plants	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Temporary Watering	1 time/2–3 days for first 1–2 months	Until establishment and during severely-droughty weather	Watering after the initial year might be required.
Fertilization	1 time initially	Upon planting	One-time spot fertilization for first year vegetation.

Bioretention Swale

Description

Bioretention swales are shallow, open channels that are designed to reduce runoff volume through infiltration. Additionally, bioretention swales remove pollutants such as trash and debris by filtering water through vegetation within the channel. Swales can serve as conveyance for stormwater and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a bioretention swale is infiltration and water quality enhancement rather than conveyance. In addition to reducing the mass of pollutants in runoff, properly maintained bioretention swales can enhance the aesthetics of a site.

Treatment Efficiency			
Runoff Volume	High (unlined)/ Low (lined)	Bacteria	High
Sediment	High	Nutrients	Medium
Trash/ debris	High	Heavy Metals	High
Organics	High	Oil & Grease	High

TETRA TECH

THE NOBLEST MOTIVE IS THE PUBLIC GOOD · COUNTY OF SAN DIEGO · MDCCCL

Permeable Pavement

Description

Permeable pavement allows for percolation of stormwater through subsurface aggregate and offers an alternative to conventional concrete and asphalt paving. Typically, stormwater that drains through the permeable surface is allowed to infiltrate underlying soils and excess runoff drains through perforated underdrain pipes. Permeable pavement can be designed as a self-treating or self-retaining area.

Treatment Efficiency	
Runoff Volume	High (unlined)/Low (lined)
Sediment	High
Nutrients	Low
Pathogens	Medium
Metals	High
Oil & Grease	Medium
Organics	Low

Siting and Suitability

The use of permeable pavement is encouraged for sites such as parking lots, driveways, pedestrian plazas, rights-of-way, and other lightly traveled areas. Numerous types and forms of permeable pavers exist and offer a range of utility, strength, and permeability. Permeable pavement must be designed to support the maximum anticipated traffic load but should not be used in highly trafficked areas. For designs that include infiltration, surrounding soils must allow for adequate infiltration. Precautions must be taken to protect soils from compaction during construction. See Section 3 for details.

Available Space: Permeable pavement is typically designed to treat storm water that falls on the pavement surface area and runon from other impervious surfaces. It is most commonly used at commercial, institutional, and residential locations in area that are traditionally impervious. Permeable pavement should not be used in high-traffic areas.

Underground Utilities: Complete a utilities inventory to ensure that site development will not interfere with or affect utilities.

Existing Buildings: Assess building effects on the site. Permeable pavement must be set away from building foundations at least 10 feet and 50 feet from steep slopes and 100 feet from water supply wells.

Water Table and Bedrock: Permeable pavement is applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 10 feet or greater.

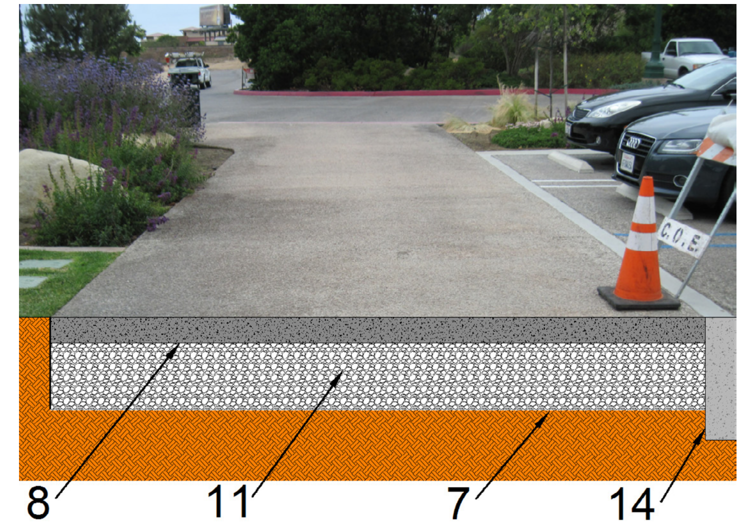
Soil Type: Examine site compaction and soil characteristics. Minimize compaction during construction; do not place the bed bottom on compacted fill. Determine site-specific permeability; it is ideal to have well-drained soils.

Areas of Concern: Permeable pavement that includes infiltration in design is not recommended for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membrane can be used to contain flow within areas of concern.

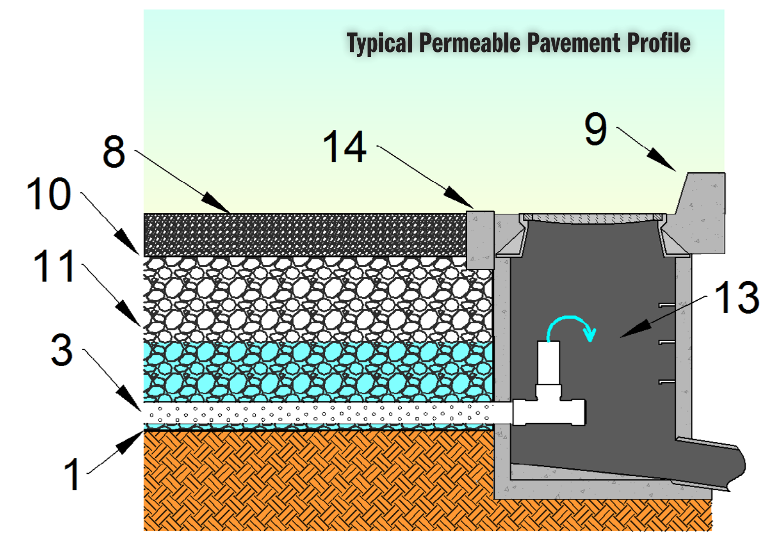
Design Considerations & Specifications *(see Appendix A for details)*

		Design Component	General Specification
IMP Function	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
IMP Function	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
IMP Function	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized.
IMP Function	4	Observation Wells	Provide capped observation wells to monitor drawdown.
IMP Function	5	Internal Water Storage (IWS)	If using underdrain in infiltrating systems, the underdrain outlet can be elevated to create a sump to enhance infiltration and treatment.
IMP Function	6	Drawdown Time	If using fully-lined system, provide orifice at underdrain outlet sized to release water quality volume over 2–5 days.
IMP Function	7	Subgrade Slope and Geotextile	Subgrade slope should be 0.5% or flatter. Baffles should be used to ensure water quality volume is retained. Geotextile should be used along perimeter of cut to prevent soil from entering the aggregate voids.
Profile	8	Surface Course	Pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP) are the preferred types of permeable pavement because detailed industry standards and certified installers are available.
Profile	9	Temporary Ponding Depth	Surface ponding should be provided (by curb and gutter) to capture the design storm in the event that the permeable pavement surface clogs.
Profile	10	Bedding Course (for PICP)	Use a 2-inch bedding course of ASTM No. 8 stone.
Profile	11	Reservoir Layer	Base layer should be washed ASTM No. 57 stone (washed ASTM No. 2 may be used as a subbase layer for additional storage).
Profile	12	Structural Design	A pavement structural analysis should be completed by a qualified and licensed professional.
Routing	13	Large Storm Routing	For poured in place systems (pervious concrete or porous asphalt): system can overflow internally or on the surface. For modular/paver-type systems (PICP): internal bypass is required to prevent upflow and transport of bedding course.
Other	14	Edge Restraints and Dividers	Provide a concrete divider strip between any permeable and impermeable surfaces and around the perimeter of PICP installations.
Other	15	Signage	Signage should prohibit activities that cause premature clogging and indicate to pedestrians and maintenance staff that the surface is intended to be permeable.
Other	16	Multi-Use Benefits	Provide educational signage, enhanced pavement colors, or stormwater reuse systems.

Pervious Concrete Cross Section
Cottonwood Creek Park, Encinitas, CA



Permeable pavements can be used to treat and reduce stormwater runoff in parking lots, roadway parking lanes, and pedestrian plazas. A reservoir layer below the permeable surface detains stormwater as it infiltrates or is slowly release through underdrain pipes.



This schematic represents a typical permeable pavement profile with internal water storage to enhance capture and infiltration of the design storm volume. An orifice can be provided at the invert of the underdrain to slowly dewater captured runoff in non-infiltrating systems.

Maintenance Considerations *(see Appendix D for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly during routine property maintenance	Sediment accumulation on adjacent impervious surfaces or in voids/joints of permeable pavement	Stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be graded to drain away from permeable pavement.
Miscellaneous upkeep	Weekly or biweekly during routine property maintenance	Trash, leaves, weeds, or other debris accumulated on permeable pavement surface	Immediately remove debris to prevent migration into permeable pavement voids. Identify source of debris and remedy problem to avoid future deposition.
Preventative vacuum/ regenerative air street sweeping	Twice a year in higher sediment areas	N/A	Pavement should be swept with a vacuum power or regenerative air street sweeper at least twice per year to maintain infiltration rates.
Replace fill materials	As needed	For paver systems, whenever void space between joints becomes apparent or after vacuum sweeping	Replace bedding fill material to keep fill level with the paver surface.
Restorative vacuum/ regenerative air street sweeping	As needed	Surface infiltration test indicates poor performance or water is ponding on pavement surface during rainfall	Pavement should be swept with a vacuum power or regenerative air street sweeper to restore infiltration rates.

TETRA TECH

THE NOBLEST MOTIVE IS THE PUBLIC GOOD · COUNTY OF SAN DIEGO · MDCCCL

Rock Infiltration Swale

Description

Rock infiltration swales are shallow, open channels that are designed to reduce runoff volume through infiltration. Rock infiltration swales are identical to bioretention swales except the surface is typically covered by cobble rather than mulch and vegetation. Rock infiltration swales can serve as conveyance for stormwater and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a rock infiltration swale is infiltration and water quality enhancement rather than conveyance. In addition to reducing the mass of pollutants in runoff, properly maintained rock infiltration swales can enhance the aesthetics of a site.

Treatment Efficiency			
Runoff Volume	High (unlined)/ Low (lined)	Bacteria	High
Sediment	High	Nutrients	Medium
Trash/ debris	High	Heavy Metals	High
Organics	High	Oil & Grease	High

Siting and Suitability

Rock infiltration swales are highly versatile stormwater IMPs that effectively reduce pollutants. With a narrow width, rock infiltration swales can be integrated into site plans with various configurations and components. Ideal sites for rock infiltration swales include the right-of-way of linear transportation corridors and along borders or medians of parking lots. In heavily trafficked areas, curb cuts can be used to delineate boundaries. Rock infiltration swales can be combined with other basic and stormwater runoff BMPs to form a treatment train, reducing the required size of a single IMP unit. See Section 3 for details.

Drainage Area: Less than 2 acres and fully stabilized.

Head Requirements: Rock infiltration swale typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

Slopes: Slopes draining to rock infiltration swale should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and check dams should be used to provide longitudinal bed slopes of 2.5% (average slope should not exceed 4% from inlet to outlet).

Setbacks: Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

Water Table & Bedrock: At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

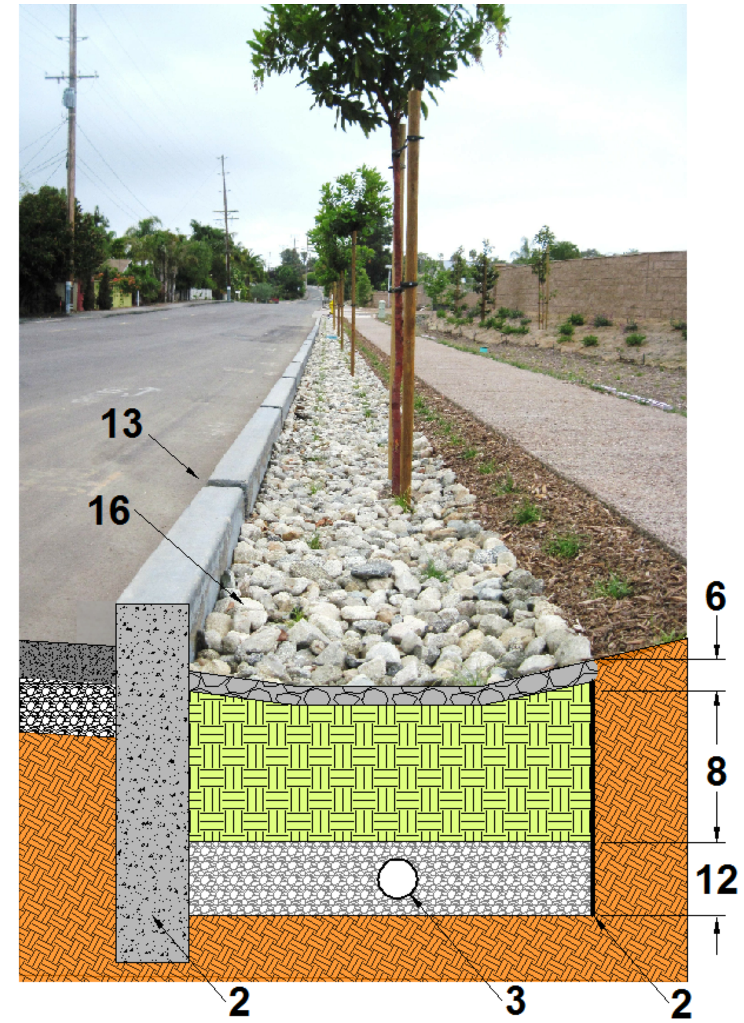
Soil Type: Rock infiltration swale can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

Areas of Concern: Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

Design Considerations & Specifications *(see Appendices A & G for details)*

		Design Component	General Specification
IMP Function	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized.
	4	Cleanouts/ Observation Wells	Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe.
	5	Internal Water Storage (IWS)	If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention treatment. Top of IWS should be greater than 18 inches below surface.
	6	Temporary Ponding Depth	Use check dams to provide 6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
	7	Drawdown Time	Surface drawdown: 12-96 hrs, Subsurface dewatering: 48 hrs.
Soil Media	8	Soil Media Depth	2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
	9	Soil Media Composition	65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume.
	10	Media Permeability	5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction).
	11	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight.
	12	Drainage Layer	Separate media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone.
Routing	13	Inlet/Pretreatment	Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows.
	14	Slope and Grade Control	If necessary, use check dams to maintain maximum 2.5% bed slope. Check dams should extend sufficiently deep to prevent piping (undercutting) below the check dam.
	15	Outlet Configuration	Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows.
Landscape	16	Surface	Armor surface with cobble. If planted (optional), install drought-tolerant, low-maintenance trees and shrubs.
	17	Multi-Use Benefits	Provide educational signage, artwork, or wildlife amenities.

Rock Infiltration Swale Cross Section, Encinitas, CA



This schematic shows the major components of a rock infiltration swale. The rock infiltration swale in the photograph intercepts roadway runoff through curb cuts and filters it through subsurface soil media.

Maintenance Considerations *(see Appendix D for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of rock infiltration swale	Permanently stabilize any exposed soil and remove any accumulated sediment in a manner that does not cause an illegal discharge. Adjacent pervious areas may need to be regraded.
Inlet inspection		Internal erosion or excessive sediment, trash, and/or debris accumulation	Check for sediment accumulation to ensure that flow into the rock infiltration swale is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within rock infiltration swale area, mulch around outlet, internal erosion	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized.
Outlet inspection	1 time/year	Erosion at outlet	Remove any accumulated mulch or sediment.
Temporary Watering	1 time/2–3 days for first 1–2 months	Until establishment and during severely-droughty weather	Watering after the initial year might be required.
Fertilization	1 time initially	Upon planting	One-time spot fertilization for first year vegetation.

TETRA TECH

Flow-Through Planters

Description

Flow-through planters are vegetated IMP units that capture, temporarily store, and filter storm water runoff. The vegetation, ponding areas, and soil media in the flow-through planters remove contaminants and retain storm water flows from small drainage areas before directing the treated storm water to an underdrain system. Typically, Flow-through planters are completely contained systems; for this reason, they can be used in areas where geotechnical constraints prevent or limit infiltration or in areas of concern where infiltration should be avoided. Flow-through planters offer considerable flexibility and can be incorporated into small spaces, enhancing natural aesthetics of the landscape.

Treatment Efficiency			
Runoff Volume	Low	Metals	High
Sediment	High	Oil & Grease	High
Nutrients	Medium	Organics	High
Pathogens	High		

Siting and Suitability

Flow-through planters require relatively little space and can be easily adapted for urban retrofits such as building and rooftop runoff catchments or into new street and sidewalk designs. Because flow-through planters are typically fully-contained systems, available space presents the most significant limitation. To ensure healthy vegetation in the planter box, proper plant and media selection are important considerations for accommodating the drought, ponding fluctuations, and brief periods of saturated soil conditions. See Section 3 for details.

Drainage Area: To be less than 0.35 acres and fully stabilized.

Underground Utilities: Complete a utilities inventory to ensure that site development will not interfere with or affect the utilities.

Existing Buildings: Assess building effects (runoff, solar shadow) on the site. When completely contained, building setbacks are less of a concern.

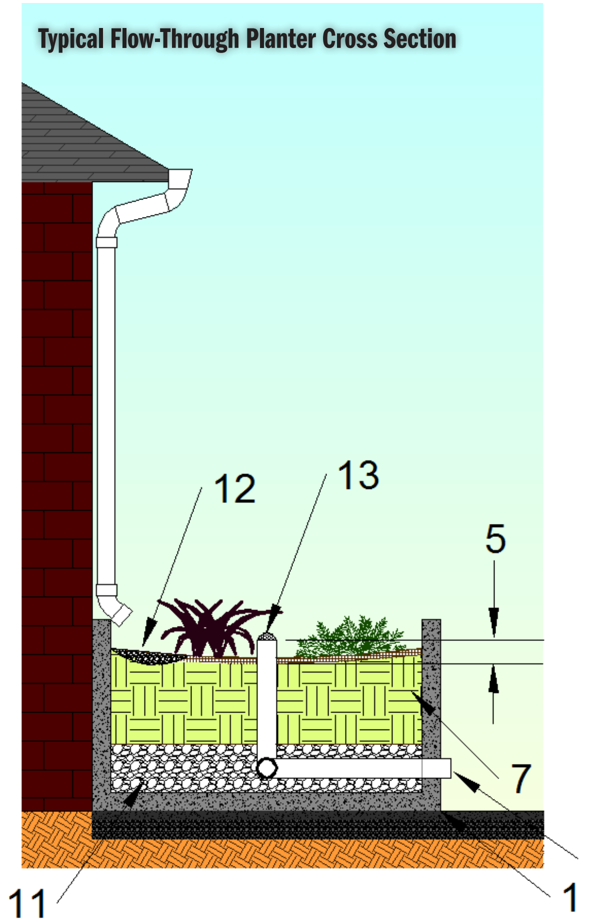
Water Table: Seasonal high water table should be located below the bottom of the planter.

Soil Type: Soils within the drainage area must be stabilized. If flow-through planters are fully contained, local soils must provide structural support.

Areas of Concern: Fully-contained flow-through planters can be used in areas with known soil contamination or in *hot spots*.

Design Considerations & Specifications *(see Appendices A & G for details)*

		Design Component/ Consideration	General Specification
IMP Function	1	Impermeable liner	Planter boxes are typically contained within a concrete vault.
	2	Underdrain (required)	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized.
	3	Cleanouts/ Observation Wells	Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe.
	4	Internal Water Storage (IWS)	With careful plant selection, the outlet can be slightly elevated to create a sump for additional moisture retention to promote plant survival and enhanced treatment. Top of IWS should be greater than 18 inches below surface.
	5	Temporary Ponding Depth	Provide 6–18 inches surface ponding (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
	6	Drawdown Time	Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs.
Soil Media	7	Soil Media Depth	2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
	8	Soil Media Composition	65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume.
	9	Media Permeability	5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction).
	10	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight.
	11	Drainage Layer	Separate soil media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. Additional aggregate storage depth can be provided for hydromodification control.
Routing	12	Inlet/ Pretreatment	Provide stabilized inlets and energy dissipation. Install rock armored forebay, gravel splash pad, or upturn incoming pipes.
	13	Outlet Configuration	Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows.
Landscape	14	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
	15	Vegetation	Native, deep rooting, drought tolerant plants.
	16	Multi-Use Benefits	Provide educational signage, artwork, or wildlife habitat.



This diagram shows the design elements of a flow-through planter installed for water quality control. Flow-through planters can be used in highly urbanized settings or areas where infiltration is restricted. Additional surface storage or subsurface aggregate storage can be provided for hydromodification control.

Maintenance Considerations *(see Appendix D for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of bioretention swale	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded.
Inlet inspection		Internal erosion or excessive sediment, trash, and/ or debris accumulation	Check for sediment accumulation to ensure that flow into the bioretention swale is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within bioretention swale area, mulch around outlet, internal erosion	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized.
Pruning	1–2 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2–12 times/year	Overgrown vegetation that interferes with access, lines of sight, or safety	Frequency depends on location and desired aesthetic appeal and type of vegetation.
Outlet inspection	1 time/year	Erosion at outlet	Remove any accumulated mulch or sediment.
Mulch removal and replacement	1 time/2–3 years	2/3 of mulch has decomposed	Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches
Remove and replace dead plants	1 time/year	Dead plants	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Temporary Watering	1 time/2–3 days for first 1–2 months	Until establishment and during severely-droughty weather	Watering after the initial year might be required.
Fertilization	1 time initially	Upon planting	One-time spot fertilization for first year vegetation.

TETRA TECH

Siting and Suitability

Vegetated roofs are typically constructed on flat or gently sloped rooftops of a wide variety of shapes and sizes. Where installed on new construction, building structural design should consider the additional load of the vegetated roof. Where installed on existing buildings the structure should be evaluated by a structural engineer to determine suitability. Vegetated roofs can be implemented on a wide range of building types and settings and can integrate with other roof infrastructure such as HVAC components, walkways, and solar panels. See Section 3 for details.

Drainage Area: Varies widely from a few square feet to several acres.

Head Requirements: Not applicable

Slopes: Vegetated roofs can be installed on roof surfaces that are flat or are sloped.

Setbacks: Not applicable

Structural Requirements: a structural engineer should evaluate the structure to ensure that it is capable of supporting the vegetated roof.

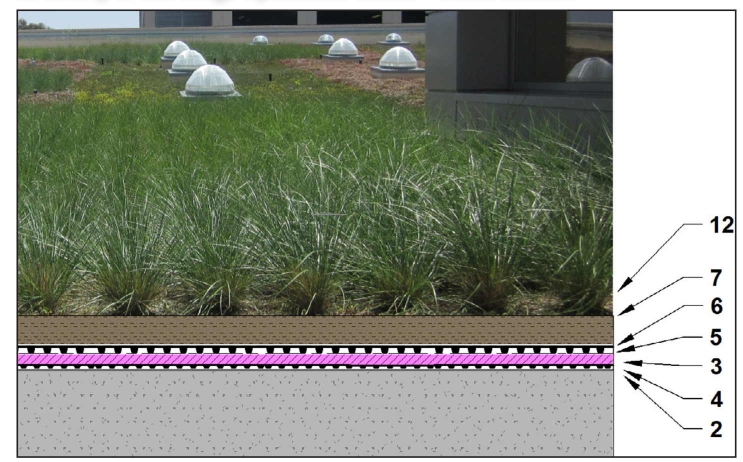
Areas of Concern: In areas of significant wind loads design considerations may be necessary to ensure security of media or a vegetated roof may not be suitable.

Design Considerations & Specifications *(see* Appendix A *for details)*

		Design Component	General Specification
IMP Function	1	Roof Slope	Vegetated roofs may be constructed on slopes from 1% to 30%. Where slopes approach 30% media retention practices such as baffles or geo-grids should be incorporated into the design.
IMP Function	2	Waterproof Liner	All vegetated roof systems should incorporate a waterproof liner to protect the roof deck and underlying structure from leaks.
IMP Function	3	Insulation (optional)	Insulation may be placed either above or below the waterproof liner to enhance the energy efficiency of the building and to provide additional protection of the roof deck.
IMP Function	4	Root Barrier	Root barrier is placed directly above the waterproof liner, or insulation as appropriate, to prevent plant roots from impacting the integrity of the liner
IMP Function	5	Drainage Layer	Aggregate: Minimum of 2 inches of clean washed synthetic or inorganic aggregate material such as no 8 stone or suitable alternatives. Manufactured: A wide range of prefabricated drainage layers are available which incorporate drainage and storage or rainfall. Minimum storage capacity should be 0.8 inches.
IMP Function	6	Permeable Filter Fabric	A semipermeable filter fabric is placed between the drainage layer and growth media to prevent migration of the media into the drainage layer.
Growth Media	7	Media Depth	Minimum 4 inches of growth media.
Growth Media	8	Media Composition	80–90% lightweight inorganic materials such as expanded slates, shales, or pumice. No more than 20% organic materials with a low potential for leaching nutrients.
Other Considerations	9	Roof Drains and Scuppers	Setback vegetated roof media and drainage layers a minimum of 12 inches from all roof drains and scupper and fill these areas with washed no. 57 stone to a depth equal to or greater than the depth of the vegetated roof components.
Other Considerations	10	Other Infrastructure	Setback vegetated roof 24 inches from other rooftop infrastructure such as vents, HVAC components, etc. Setback areas may be filled with washed no. 57 gravel or suitable alternative.
Other Considerations	11	Access	Adequate access to the roof must be provided to allow routine maintenance.
Landscape	12	Vegetation	Primarily drought tolerant species which can thrive in a rooftop environment without supplemental irrigation; see Plant List (Appendix E).
Landscape	13	Multi-Use Benefits	Include features to enhance habitat, aesthetics, recreation, and public education as desired.

The extensive vegetated roof on this public library features modular units containing lightweight media and various drought-tolerant vegetation.

Extensive Vegetated Roof
at County of San Diego Operations Center - Cross Section



Typical components of an extensive green roof. The cross section of intensive green roofs will be deeper and vary from site to site based on desired functions and structural capacity of the underlying structure.

Maintenance Considerations *(see* Appendix D *for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Media Inspection	2 times/year	Internal erosion of media from runoff or wind scour, exposed underlayment components	Replace eroded media and vegetation. Adopt additional erosion prevention practices as appropriate.
Liner Inspection	1 time/year	Liner is exposed or tenants have experienced leaks	Evaluate liner for cause of leaks. Repair or replace as necessary.
Outlet Inspection	2 times/year	Accumulation of litter and debris around the roof drain or scupper or standing water in adjacent areas.	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging. If sediment has accumulated in the gravel drain buffers remove and replaces the gravel.
Vegetation Inspection	1 time/year	Dead plants or excessive open areas on vegetated roof	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Invasive Vegetation	2 times/year	Presence of unwanted or undesirable species	Remove undesired vegetation. Evaluate vegetated roof for signs of excessive water retention.
Temporary Watering	1 time/2–3 days for first 1–2 months	Until establishment and during severely-droughty weather	Watering after the initial year might be required.

Vegetated Roofs

Description

Vegetated roofs are vegetated surfaces generally installed on flat or gently sloped rooftops. Sometimes called green roofs, they consist of drought tolerant vegetation grown in a thin layer of media underlain by liner and drainage components. Vegetated roofs reduce stormwater runoff volume and improve water quality by intercepting rainfall which is either filtered by the media, evaporated from the roof surface or utilized by the vegetation. Vegetated roofs can be installed on a wide range of building types and may provide additional functions such as extending roof-life and reducing energy requirements of the building. Research has shown that vegetated roofs also may improve property values of adjacent buildings and provide air quality benefits. In addition to these functions vegetated roofs can serve as passive recreation areas and provide wildlife habitat. Vegetated roofs are considered self-treating areas and drainage requires no further treatment control.

Treatment Efficiency			
Runoff Volume	High	Bacteria	Low
TSS	Medium	Nutrients	Low
Trash/debris	Medium	Heavy Metals	High

TETRA TECH

THE NOBLEST MOTIVE IS THE PUBLIC GOOD · COUNTY OF SAN DIEGO · MDCCCL

Sand Filters

Description

Sand filters are filtering IMPs that can be installed on the surface or subsurface. They remove pollutants by filtering stormwater vertically through a sand media and can also be designed for infiltration. Although they function similar to bioretention, sand filters lack the pollutant removal mechanisms provided by the biological activity and fine clay particles found in bioretention media.

Treatment Efficiency	
Runoff Volume	Low
Sediment	High
Nutrients	Low
Pathogens	Medium
Metals	Low
Oil & Grease	Medium
Organics	Medium

TETRA TECH

Siting and Suitability

Sand filters require less space than many LID IMPs and are typically used in areas with restricted space such as parking lots or other highly impervious areas. Sizing should be based on the desired water quality treatment volume and should take into account all runoff at ultimate build-out, including off-site drainage. The design phase should also identify where pretreatment will be needed. Aboveground units should be designed with a vegetated filter strip or forebay as a pretreatment element, and belowground units should incorporate a forebay sediment chamber. See Section 3 for details.

Underground Utilities: A complete utilities inventory should be done to ensure that site development will not interfere with or affect the utilities.

Existing Buildings: If used underground, ensure that the sand filter will not interfere with existing foundations.

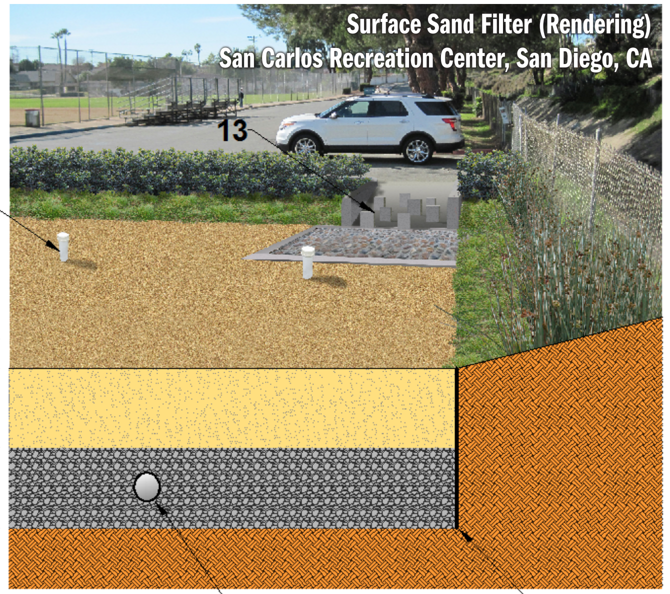
Water Table and Bedrock: Sand filters are applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 10 ft or greater.

Soil Type: If infiltration is planned to existing soils, examine site compaction and soil characteristics. Determine site-specific permeability. It is ideal to have well-drained soils. If native soils show less than 0.5 in/hr infiltration rate, underdrains should be included.

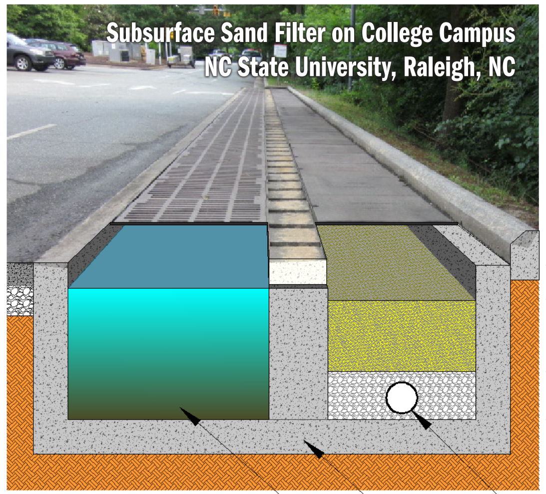
Areas of Concern: Sand filters, if lined, can be used for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membranes must be used to contain infiltration within areas of concern.

Design Considerations & Specifications *(see Appendix A for details)*

		Design Component	General Specification
IMP Function	1	IMP Type	Surface sand filters: installed in shallow depressions on surface. Require pretreatment by vegetated swales, filter strip, or forebay. Subsurface sand filters: can be installed along the edges of roads and parking lots to conserve space. Must include a sedimentation chamber for pretreatment.
	2	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
	3	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
	4	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized.
	5	Cleanouts/ Observation Wells	Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe.
	6	Internal Water Storage (IWS)	If using underdrain in infiltrating systems, the underdrain outlet can be elevated to create a sump for enhanced infiltration and treatment. Top of IWS should be greater than 10 inches below surface.
	7	Temporary Ponding Depth	No greater than 8 feet (shallower depth should be used in residential areas or near schools and parks).
	8	Drawdown Time	Surface drawdown: 12-96 hrs. Subsurface dewatering: 48 hrs.
Soil Media	9	Soil Media Depth	1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
	10	Gradation	Washed concrete sand (ASTM C-33) free of fines, stones, and other debris.
	11	Chemical Analysis	Total phosphorus < 15 ppm.
	12	Drainage Layer	Separate soil media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone.
Routing	13	Inlet/ Pretreatment	Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows to surface sand filters. For subsurface sand filters, a sedimentation chamber is provided (should be dewatered between storm events).
	14	Outlet Configuration	Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows.
Other	15	Multi-Use Benefits	Provide features to enhance aesthetics and public education.



A surface sand filter intercepts and filters runoff from a parking lot. Underdrains discharge to the adjacent creek.



A subsurface sand filter intercepts sheet flow from a parking lot through grate inlets. Runoff is pretreated in a sedimentation chamber to remove coarse sediment and debris, then flows through slot weirs into the sand filter chamber. Underdrain discharge and overflow are routed to an adjacent catch basin structure.

Maintenance Considerations *(see Appendix D for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of sand filter.	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regarded.
Inlet inspection	Once after first major rain of the season, then every 2 to 3 months depending on observed sediment and debris loads	Debris or sediment has blocked inlets.	Remove any accumulated material.
Sedimentation chamber/forebay inspection	Every two months	Sediment has reached 6-inches-deep (install a fixed vertical sediment depth marker) or litter and debris has clogged weirs between sedimentation chamber and sand filter chamber (for subsurface filters).	Remove accumulated material from sedimentation chamber. Remove and replace top 2 to 3 inches of sand filter if necessary.
Sand filter surface infiltration inspection	After major storm events or biannually	Surface ponding draws down in greater than 48 hours.	Remove and replace top 2 to 3 inches of sand filter, or as needed to restore infiltration capacity. Inspect watershed for sediment sources.
Outlet inspection	Once after first major rain of the season, then monthly	Erosion or sediment deposition at outlet.	Check for erosion at the outlet and remove any accumulated sediment.
Miscellaneous upkeep	12 times/year		Tasks include trash collection, spot weeding, soil media replacement, and removal of visual contamination.

Cisterns

Description

Cisterns are storage vessels that can collect and store rooftop runoff from a downspout for later use. Sized according to rooftop area and desired volume, cisterns can be used to collect both residential and commercial building runoff. By temporarily storing the runoff, less runoff enters the storm water drainage system, thereby reducing the amount of pollutants discharged to surface waters. Additionally, cisterns and their smaller counterpart referred to as rain barrels are typically used in a treatment train system where collected runoff is slowly released into another IMP or landscaped area for infiltration. Because of the peak-flow reduction and storage for potential beneficial uses, subsequent treatment train IMPs can be reduced in size. Cisterns can collect and hold water for commercial uses, most often for non-potable uses such as irrigation or toilet flushing.

Treatment Efficiency	
Runoff Volume	Varies based on cistern size and drawdown mechanisms
Water Quality	Water quality improvements depend on downstream practices—high pollutant removal can be achieved if paired with an infiltrating or filtering practice

Siting and Suitability

Cisterns should be placed near a roof downspout, but can also be located remotely if a "wet conveyance" configuration is used. The structural capacity of soils should be investigated to determine whether a footer is needed. Cisterns are available commercially in numerous sizes, shapes, and materials. The configuration will be determined by available space, intended reuse strategy, and aesthetic preference. An overflow mechanism is important to prevent water from backing up onto rooftops—overflow should be conveyed in a safe direction away from building foundations. See Section 3 for details.

Drainage Area: Rooftop area.

Existing Buildings: Ideally, cistern overflows should be set away from building foundations at least 5 feet.

Water Table: The seasonal high water table should be located below the bottom of the cistern, particularly underground cisterns, to prevent buoyant forces from affecting the cistern.

Soil Type: Ensure that the cistern is securely mounted on stable soils. If structural capacity of the site is in question, complete a geotechnical report to determine the structural capacity of soils.

Areas of Concern: Overflow volume or outflow volume should not be directed to areas where infiltration is not desired. Such areas may include *hot spots*, where soils can be contaminated.

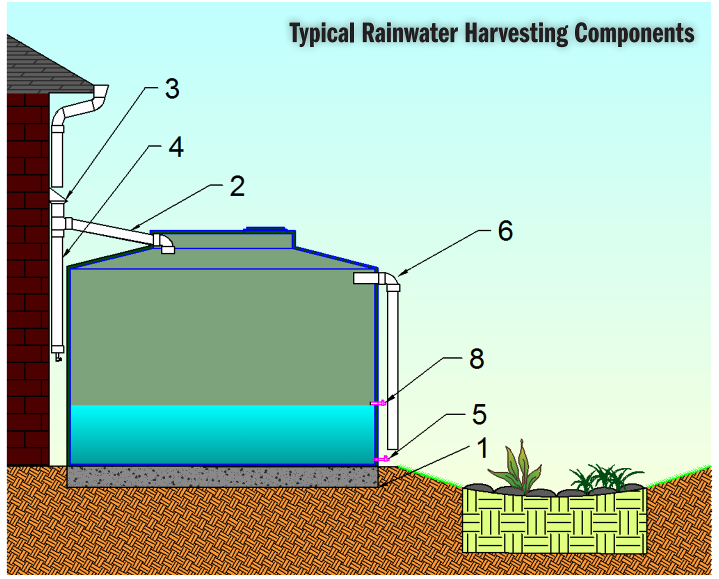
Design Considerations & Specifications (*see* Appendix A *for details*)

		Design Component	General Specification
Configuration and Function	1	Cistern material and foundation	Tanks should typically be opaque to prevent algal growth. A foundation of gravel should be provided if the weight of the cistern at capacity is less than 2000 pounds, otherwise a concrete foundation should be provided.
	2	Conveyance configuration	Runoff should be conveyed to the cistern such that no backwater onto roofs occurs during the 100-yr event. Two types of inlet configurations are available: · Dry conveyance: conduit freely drains to cistern with no water storage in pipe · Wet conveyance: a bend in the conduit retains water between rainfall events (allows cistern to be placed further from buildings)
	3	Inlet filter	A self-cleaning inlet filter should be provided to strain out large debris such as leaves. Some systems incorporate built-in bypass mechanisms to divert high flows.
	4	First flush diverter	A passive first flush diverter should be incorporated in areas with high pollutant loads to capture the first washoff of sediment, debris, and pollen during a rainfall event. First flush diverters are typically manually dewatered between events.
	5	Low-flow outlet	An outlet should be designed to dewater the water quality storage volume to a vegetated area in no less than 2 days. The elevation of the outlet depends on the volume of water stored for alternative purposes.
	6	Overflow or bypass	Emergency overflow (set slightly below the inlet elevation) or bypass must be provided to route water safely out of the cistern when it reaches full capacity.
Reuse and Safety	7	Signage	Signage indicating: "Caution: Reclaimed Water, Do Not Drink" (preferably in English and Spanish) must be provided anywhere cistern water is piped or outlets.
	8	Pipe color and locking features	All pipes conveying harvested rainwater should be purple in color and be labeled as reclaimed or recycled water. All valves should feature locking features.
	9	Routing water for use	Regardless of gravity or pumped flow, adequate measures must be taken to prevent contamination of drinking water supplies.
	10	Makeup water supply	A makeup water supply can be provided to refill the cistern to a desired capacity when harvested water has a dedicated use.
	11	Vector control	All inlets and outlets to the cistern must be covered with a 1-mm or smaller mesh to prevent mosquito entry/egress.
Other	12	Multi-use benefits	Harvested rainwater should be used to offset potable water uses, such as irrigation, toilet flushing, car washing, etc. Additionally, educational signage and aesthetically-pleasing facades should be specified.

Residential Cistern

Arid Solutions, Inc.

Smaller cisterns or rain barrels can be used to capture and reuse residential rooftop runoff for irrigation and other non-potable uses.



This diagram illustrates the major design elements of a rainwater harvesting system. In this configuration, detention storage is provided above the low flow outlet and water for reuse is stored in the lower half of the cistern. Note that the cistern is paired with a bioretention area to achieve both hydromodification and water quality control.

Maintenance Considerations (*see* Appendix D *for detailed checklist*)

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Gutter and rooftop inspection	Biannually and before heavy rains	Inlet clogged with debris	Clean gutters and roof of debris that have accumulated, check for leaks
Remove accumulated debris	Monthly	Inlet clogged with debris	Clean debris screen to allow unobstructed stormwater flow into the cistern
Structure inspection	Biannually	Cistern leaning or soils slumping/eroding	Check cistern for stability, anchor system if necessary
Structure inspection	Annually	Leaks	Check pipe, valve connections, and backflow preventers for leaks
Add ballast	Before any major wind-related storms	Tank is less than half-full	Add water to half full
Miscellaneous upkeep	Annually		Make sure cistern manhole is accessible, operational, and secure

TETRA TECH

Vegetated Swales

Description

Swales are shallow, open channels that are designed remove pollutants such as sediment by physically straining and filtering water through vegetation or cobble within the channel. Additionally, swales can serve as conveyance for storm water and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a swale is filtration and water quality enhancement rather than conveyance. Some designs also include infiltration through subsurface soil media, or underlying soils to reduce peak runoff volume during storms.

Treatment Efficiency			
Runoff Volume	Low	Bacteria	Low
Sediment	High	Nutrients	Low
Trash/debris	High	Heavy Metals	Medium
Organics	Medium	Oil & Grease	Medium

TETRA TECH

Siting and Suitability

Site evaluation must first determine the volume of water to be conveyed through the swale. To accommodate the volume, design considerations must incorporate three components: the longitudinal slope, resistance to flow, and cross-sectional area. Incorporating vegetated filter strips along the top of the channel banks and using sheet flow for entry can enhance treatment in swales. Avoid slopes and soil conditions that limit infiltration as they could lead to excessive ponding. See Section 3 for details.

Drainage Area: Less than 2 acres.

Available Space: The footprint of swales is dependent on drainage area, typically sized as 10 to 20 percent of the upstream drainage. If space allows, pretreatment can be incorporated into design.

Underground Utilities: A complete utilities inventory should be done to ensure that site development will not interfere with or affect utilities.

Existing Buildings: Assess building effects (runoff, solar shadow) on the site. Swales must be setback from building foundations at least 10 feet.

Water Table: Swales are applicable where depth to water table is more than 2 feet to limit the potential of undesired ponding.

Soil Type: Examine site compaction and soil characteristics. Determine site-specific permeability; it is ideal to have well-drained soils for volume reduction and treatment in swales.

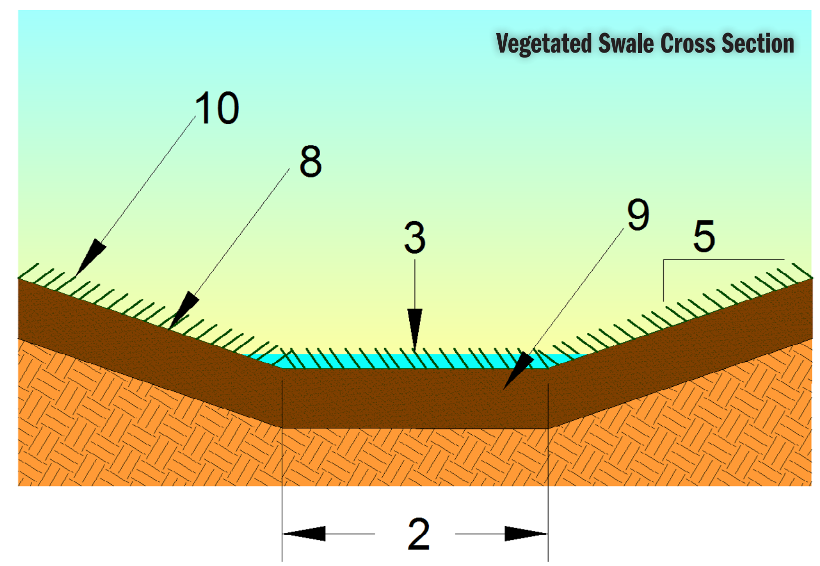
Areas of Concern: Swales should not be used to receive storm water runoff from storm water *hot spots*, unless adequate pretreatment is provided upstream.

Design Considerations & Specifications *(see Appendix A for details)*

	Design Component		General Specification
IMP Dimensions	1	Footprint and flowpath	Determine allowable swale dimensions per site constraints. Maximize flow path to optimize treatment.
	2	Swale bottom width	2 ft to 8 ft width. If wider than 8 ft, channel dividers may be necessary to prevent meandering and low-flow channel formation.
	3	Flow depth	Water quality flow: flow depth during the water quality treatment event should not exceed two-thirds the height of the vegetation for optimum treatment. 100-yr flow: flow depth should be fully contained within the swale so as not to flood adjacent property or infrastructure.
	4	Longitudinal slope	1% to 6% overall slope (1% to 2% optimum). Slopes greater than 2.5% should incorporate grade control (see below). Slopes flatter than 0.5% may result in nuisance ponding. Flow should not exceed 3 feet/second in grassed swales.
	5	Side slopes	3:1 (H:V) or flatter to prevent bank erosion.
IMP Design Features	6	Channel dividers	If bottom width exceeds 8 ft, channel dividers may be necessary to prevent meandering and low-flow channel formation.
	7	Grade and erosion control	Grade control provided by 6–18 inch check dams to maintain <2.5% longitudinal invert slope. For particularly flashy catchments, turf reinforcement mats may be necessary to prevent erosion.
	8	Pretreatment	Where practicable provide vegetated filter strip (sheet flow) or cobble energy dissipater (concentrated flow) for pretreatment.
	9	Soil amendments	Soils can be amended with organic matter or bioretention media to improve volume reduction.
	10	Vegetation	Turf grasses (not bunch grasses) should be maintained on the surface to prevent erosion and improve treatment.

Vegetated Swale at Public Park, San Diego County, CA

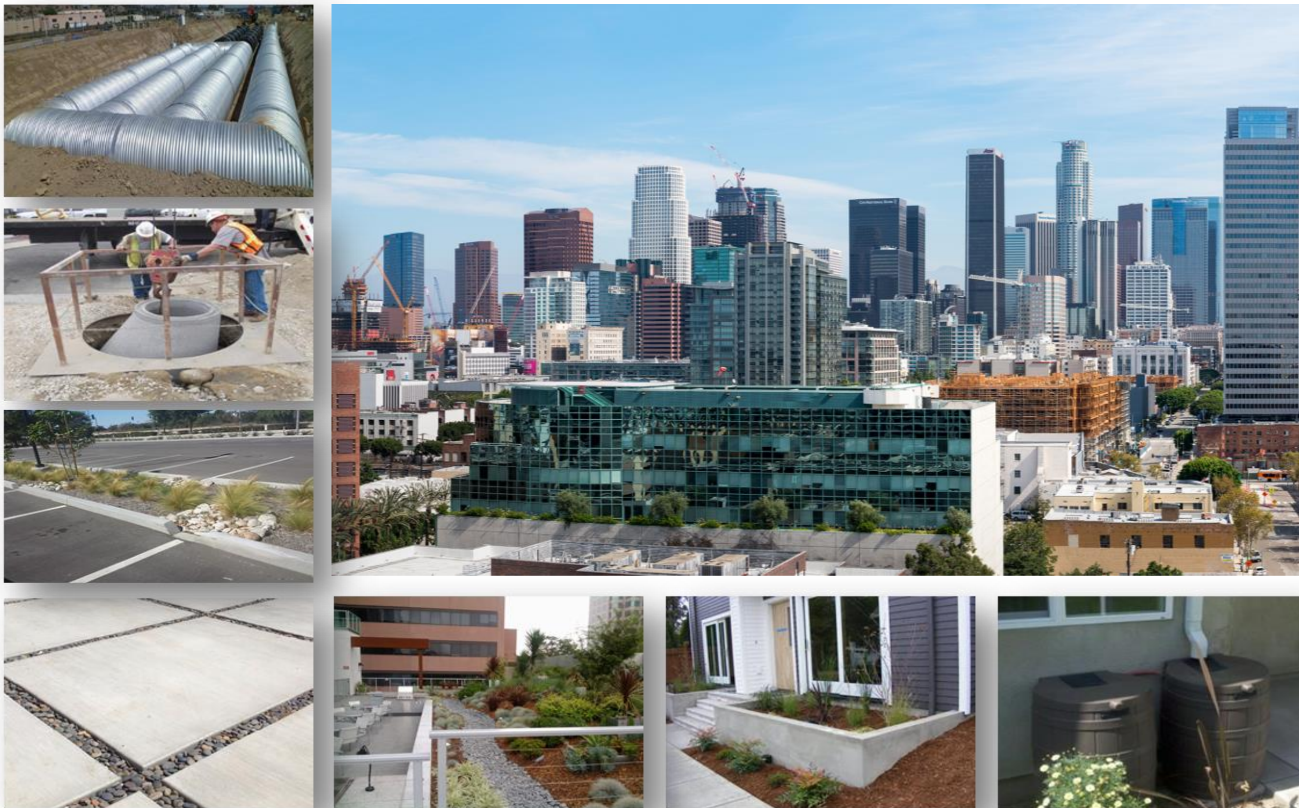
A vegetated swale conveys and treats runoff from a public park. Proper design, maintenance of dense vegetation, and accurate fine grading ensure optimum treatment and minimize the risks of erosion or standing water.



This schematic labels the typical design components of swales.

Maintenance Considerations *(see Appendix D for detailed checklist)*

Task	Frequency	Maintenance Notes
Inlet Inspection	Twice annually	Check for sediment accumulation and erosion within the swale.
Mowing	2-12 times per year	Frequency depends upon location and desired aesthetic appeal.
Watering	1 time per 2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year may be required.
Fertilization	1 time initially	One time spot fertilization for “first year” vegetation.
Remove and replace dead plants	1 time per year	Within first year 10 percent of plants may die. Survival rates increase with time.
Check dams	One prior to the wet season and monthly during the wet season	Check for sediment accumulation and erosion around or underneath the dam materials.
Miscellaneous upkeep	12 times per year	Tasks include trash collection and spot weeding.



PLANNING AND LAND DEVELOPMENT HANDBOOK FOR LOW IMPACT DEVELOPMENT (LID)

PART B
PLANNING ACTIVITES
5TH EDITION

May 9, 2016

SECTION 4: BMP PRIORITIZATION AND SELECTION

4.1 PRIORITIZATION OF BMP SELECTION

BMPs shall be designed to manage and capture stormwater runoff. Infiltration systems are the first priority type of BMP improvements as they provide for percolation and infiltration of the stormwater into the ground, which not only reduces the volume of stormwater runoff entering the MS4, but in some cases, can contribute to groundwater recharge. If stormwater infiltration is not possible based on one or more of the project site conditions listed below, the developer shall utilize the next priority BMP.

The order of priority specified below shall apply to all projects categorized as "all other developments" in accordance with Section 3.2.2. Each type of BMP shall be implemented to the maximum extent feasible when determining the appropriate BMPs for a project.

1. Infiltration Systems
2. Stormwater Capture and Use
3. High Efficiency Biofiltration/Bioretention Systems
4. Combination of Any of the Above

For purposes of compliance with the LID requirements, and without changing the priority order of design preferences as mentioned in this section, all runoff from the water quality design storm event, as determined in Section 3.2.2 above, that has been treated through an onsite high removal efficiency biofiltration system shall be credited as equivalent to 100% infiltration regardless of the runoff leaving the site from the onsite high removal efficiency biofiltration system and that runoff volume shall not be subject to the offsite mitigation requirements.

If partial or complete onsite compliance of any type is technically infeasible, the project Site and LID Plan shall be required to maximize onsite compliance. Under this option a mechanical / hydrodynamic unit may be used. Any remaining runoff that cannot feasibly be managed onsite must be mitigated under the offsite mitigation option.

4.2 INFILTRATION FEASIBILITY SCREENING

The implementation of infiltration BMPs may be deemed infeasible at a project site due to existing site conditions. To assist in the determination of compliance feasibility, a categorical screening of specific site information shall be carried out to assess site conditions.

The first category of screening shall consist of specific site conditions which, if present at the site, would deem the specified BMP-type "feasible". The second category of screening shall consist of specific site conditions which, if present at the site, would deem the BMP-type "potentially feasible". Project locations passing this screening category may still be able to utilize the screened compliance measure, though the implementation of such a measure may require supplementary actions. The third category of screening shall consist of site conditions which, if present at the site, would deem a specified BMP-type "infeasible". This type of screening can generally be carried out in the pre-planning stage of a project. These categorical screenings must be verified by a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional geotechnical engineer or geologist and approved by LADBS. Refer to the County of Los Angeles Department of Public Works Geotechnical and Materials Engineering Division for testing methods that can be used to determine the insitu infiltration rates[1].

To assist in the determination of site feasibility for infiltration BMPs, Table 4.1 has been created.

1 http://ladpw.org/gmed/permits/docs/policies/GS200.1.pdf

	Category 1 Screening (Feasible)	**Category 2 Screening (Potentially Feasible)**	**Category 3 Screening (Infeasible)**
Description	1. Underlying Groundwater ☐ Depth of bottom of infiltration facility to observed groundwater is > 10 ft 2. Site Soils ☐ Infiltration rate (K_{sat}) is > 0.5 in/hr ☐ Geotechnical hazards are not a potential near the site 3. Site Surroundings ☐ Buildings or structures are at least 25 ft away from the potential infiltration BMP ☐ Site is not located within the designated hillside grading area. ☐ No continuous presence of dry weather flows	1. Underlying Groundwater ☐ Depth from bottom of infiltration facility to observed groundwater is ≤ 10 ft ☐ Unconfined aquifer is present with beneficial uses that may be impaired by infiltration. Full treatment required if this is the case ☐ Groundwater is known to be polluted. Infiltration must be determined to be beneficial 2. Site Soils ☐ Infiltration rate is ≤ 0.5 in/hr but potential connectivity to higher K_{sat} soils is feasible ☐ Geotechnical hazards such as liquefaction are a potential near the site 3. Site Surroundings ☐ Buildings or structures are within 10 to 25 ft of the potential infiltration BMP ☐ High-risk areas such as service/gas stations, truck stops, and heavy industrial sites. Full treatment is required if this is the case, or high-risk areas must be separate from stormwater runoff mingling	1. Underlying Groundwater ☐ Depth from bottom of infiltration facility to observed groundwater is ≤ 5 ft ☐ Sites with soil and/or groundwater contamination** 2. Site Soils ☐ Infiltration rate is ≤ 0.3 in/hr and connectivity to higher K_{sat} soils is infeasible ☐ Building sites designated “Landslide” or “Hillside Grading” areas as specified by the Department of City Planning’s Zone Information and Map Access System (ZIMAS) ☐ Geotechnical hazards such as liquefaction, collapsible soils, or expansive soils exist 3. Site Surroundings ☐ Site is located on a fill site ☐ Site is located on or within 50 feet upgradient of a steep slope (20% or greater) and has not been approved by a professional geotechnical engineer or geologist
Instructions	If all of the above boxes are checked, they shall be confirmed by a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional geotechnical engineer or geologist, verifying that infiltration BMPs are feasible at the site*. Otherwise, proceed to Category 2 screening.	If all of the above boxes are checked, or if corresponding boxes in Category 1 are checked in combination with the above boxes, a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional geotechnical engineer or geologist shall be carried out to approve infiltration measures*. Otherwise, proceed to Category 3 screening.	If any of the above boxes are checked, a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional geotechnical engineer or geologist shall be submitted to prove infiltration practices are not feasible. *

Table 4.1: Infiltration Feasibility Screening

* Geotechnical Reports shall be approved by LADBS Grading Division. See Geotechnical Report Requirements herein.

** The presence of soil and/or groundwater contamination and/or the presence of existing or removed underground storage tanks shall be documented by CEQA or NEPA environmental reports, approved geotechnical reports, permits on file with the City, or a review of the State of California’s Geotracker website.

Assessing Site Infiltration Feasibility

Assessing a site's potential for implementation of Low Impact Development Best Management Practices (LID BMPs) and infiltration BMPs requires both the review of existing information and the collection of site-specific measurements. Available information regarding site layout and slope, soil type, geotechnical conditions, and local groundwater conditions should be reviewed as discussed below. In addition, soil and infiltration testing is required to be conducted to determine if stormwater infiltration is feasible and to determine the appropriate design parameters for the infiltration BMP.

<u>Geotechnical Considerations and Report Requirements:</u>

As determined by the City of Los Angeles, Department of Building and Safety, Grading Division, a geotechnical report will be required for projects that will incorporate infiltration as part of the drainage system. Geotechnical reports shall be signed by a professional Geotechnical or Civil Engineer licensed in the State of California and/or a Certified Engineering Geologist.

Refer to the current Building & Safety information bulletin, "Guidelines for Stormwater Infiltration" for additional information, Appendix H.

<u>Site Conditions</u>

Slope:

The site's topography should be assessed to evaluate surface drainage, topographic high and low points, and to identify the presence of steep slopes that qualify as "Hillside Grading Areas" or "Landslide" locations, all of which have an impact on what type of infiltration BMPs will be most beneficial for a given project site. Stormwater infiltration is more effective on level or gently sloping sites. On hillsides, infiltrated runoff may seep a short distance down slope, which could cause slope instability depending on the soil or geologic conditions, or result in nuisance seepage. Figure E-1 in Appendix E provides general guidance of the City with slopes greater than 15%. Refer to LADBS Parcel Profile Report to see if project is located within one of these areas.

Soil Type and Geology:

The site's soil types and geologic conditions should be determined to evaluate the site's ability to infiltrate stormwater and to identify suitable, as well as unsuitable locations for locating infiltration-based BMPs. Areas designated as "liquefaction" should not be considered for infiltration. Refer to LADBS Parcel Profile Report to see if project is located within one of these areas.

In addition, available geologic or geotechnical reports on local geology should be reviewed to identify relevant features such as depth to bedrock, rock type, lithology, faults, and hydrostratigraphic or confining units. These geologic investigations may also identify shallow water tables and past groundwater issues that are important for BMP design (see below). Figure E-5 in Appendix E provides general guidance identifying parts of the City that have well-draining soil conditions.

Groundwater Considerations:

The depth to groundwater beneath the project during the wet season may preclude infiltration. A minimum of five feet of separation to the seasonal (December through April) high ground water level and mounded groundwater level is required. For projects located in the Upper Los Angeles River Area, ten feet of separation is required.

Infiltration on sites with contaminated soils or groundwater that could be mobilized or exacerbated by infiltration is not allowed, unless a site-specific analysis determines the infiltration would be beneficial. A site-specific analysis may be conducted where groundwater pollutant mobilization is a concern to allow for infiltration-based BMPs. Areas with known groundwater impacts include sites listed by the RWQCB's Leaking Underground Storage Tanks (LUST) program and Site Cleanup Program (SCP). The California State Water Resources Control Board maintains a database of registered contaminated sites through their 'Geotracker' Program. Registered contaminated sites can be identified in the project vicinity when the site address is typed into the "map cleanup sites" field. Mobilization of groundwater contaminants may also be of concern where contamination from natural sources is prevalent (e.g., marine sediments, selenium rich groundwater, to the extent that data is available). Figure E-3 in Appendix E provides general guidance identifying parts of the City that may be in areas of concern.

Upper Los Angeles River Watermaster Requirements:

Infiltration projects located in the Upper Los Angeles River Area (ULARA) must comply with the requirements of the ULARA Watermaster[2]. Boundaries, requirements and approval process of the ULARWM are shown in Appendix I.

Managing Offsite Drainage:

Locations and sources of offsite run-on to the site must be identified early in the design process. Offsite drainage must be considered when determining appropriate BMPs for the site so that the drainage can be managed. By identifying the locations and sources of offsite drainage, the volume of water running onto the site may be estimated and factored into the siting and sizing of onsite BMPs. Vegetated swales or storm drains may be used to intercept,

---

2 http://www.ularawatermaster.com/

divert, and convey offsite drainage through or around a site to prevent flooding or erosion that might otherwise occur.

4.3 CAPTURE AND USE FEASIBILITY SCREENING

Capture and use, commonly referred to as rainwater harvesting, collects and stores stormwater for later use, thereby offsetting potable water demand and reducing pollutant loading to the storm drain system, therefore sufficient landscaped area with appropriate water demand is needed for the captured runoff to be directed to. Partial capture and use can also be achieved as part of a treatment train by directing the overflow to a bioretention system to provide additional volume reduction and water quality treatment in instances where the quantity of runoff from a storm event exceeds the volume of the collection tank.

In the City of Los Angeles, the use of collected stormwater will primarily be limited to irrigation of landscaped surfaces. However, as new guidelines and guidance becomes available the potential for other uses of collected stormwater will be considered. Capture and use BMPs that are designed with the intent to use captured stormwater for indoor or consumptive purposes will be reviewed on a case-by-case basis to ensure that all treatment, plumbing, and Building and Safety codes are met.

Assessing Site Capture and Use Feasibility

As with infiltration BMPs, assessing a site's potential for implementation of capture and use BMPs requires both the review of existing information and the collection of site-specific measurements. Available information regarding the site's landscaped area should be reviewed as discussed below. In addition, human health concerns should be prioritized, particularly with regards to vector control issues arising from the addition of standing water on site.

Landscaped Area Assessment

To determine a site's feasibility for capture and use BMPs, the Estimated Total Water Usage (ETWU) for irrigation from October 1 – April 30 must be greater than or equal to the volume of water produced by the stormwater quality design storm event (i.e. $ETWU_{7\text{ - month}} \geq Vm$).

Los Angeles County Department of Public Health Requirements

Projects that are implementing rainfall or urban runoff capture and distribution systems must obtain approval from the County of Los Angeles, Department of Public Health. See Appendix J for the Policy and Operation Manual.

Vector Control Considerations

A vector is any insect, arthropod, rodent, or other animal that is capable of harboring or transmitting a causative agent of human disease. In the City of Los Angeles, the most significant vector population related to stormwater is mosquitoes.

Vector sources occur where conditions provide habitat suitable for breeding, particularly any source of standing water. This means that stormwater BMPs, especially those of the capture and use type, can be breeding grounds for mosquitoes and other vectors resulting in adverse public health effects related to vectors and disease transmission. Because of this, efforts shall be made to design capture and use BMPs that do not facilitate the breeding of vectors. Vectors should be considered during the preparation of stormwater management and maintenance plans and during preconstruction planning to avoid creating possible public health hazards.

Oversized capture and use BMPs designed to hold captured stormwater for longer than 72 hour periods will require additional treatment such as filtration or disinfection to protect the collection tanks from fouling, to prevent the breeding of vectors, and/or to improve the quality of water for reuse applications. These BMPs must have appropriate vector control measures incorporated into the design of the system to exclude vector access and breeding (i.e., observation access for vector inspection and treatment). They should be approved by the County of Los Angeles Department of Public Health. These scenarios will be reviewed on a case-by-case basis.

If vector breeding is taking place at a site as a result of contained stormwater or inadequately maintained BMPs, the Greater Los Angeles County Vector Control District has the ability to fine site owners for violating the California Health and Safety Code (Section 2060 – 2067).

4.4 INFILTRATION BMPS

Infiltration refers to the physcial process of percolation, or downward seepage, of water through a soil's pore space. As water infiltrates, the natural filtration, adsorption, and biological decomposition properties of soils, plant roots, and micro-organisms work to remove pollutants prior to the water recharging the underlying groundwater. Infiltration BMPs include infiltration basins, infiltration trenches, infiltration galleries, bioretention without an underdrain, dry wells, and permeable pavement. Infiltration can provide multiple benefits, including pollutant removal, peak flow control, groundwater recharge, and flood control. However, conditions that can limit the use of infiltration include soil properties, proximity to building foundations and other infrastructure, geotechnical hazards (e.g., liquefaction, landslides), and potential adverse impacts on groundwater quality (e.g industrial pollutant source areas, contaminated soils, groundwater plumes)[3]. To ensure that infiltration would be physcially feasible and desireable (i.e., not have adverse impacts), a categorical screening of site feasibility criteria must be completed prior to the use of infiltration BMPs following the guidelines presented in Section 4.2.

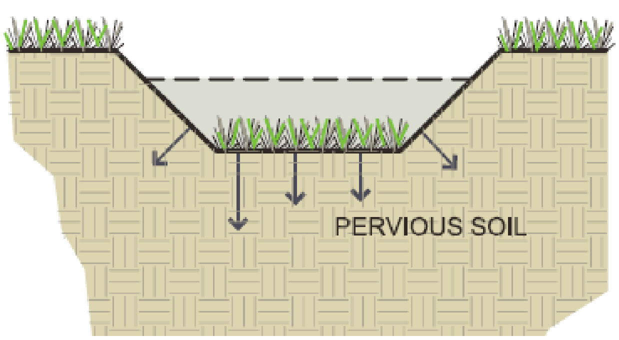
4.4.1 Infiltration BMP Types

__Surface Infiltration BMPs__

These BMPs rely on infiltration in a predominantly vertical (downward) direction and depend primarily on soil characteristics in the upper soil layers. These infiltration BMPs include:

Infiltration Basins

An infiltration basin consists of an earthen basin constructed in naturally pervious soils with a flat bottom typically vegetated with dry-land grasses or irrigated turf grass. An infiltration basin functions by retaining the design runoff volume in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time.



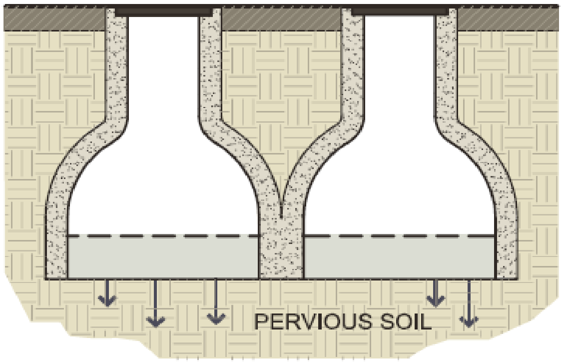
Infiltration Trenches

Infiltration trenches, which are similar to basins, are long, narrow, gravel-filled trenches, often vegetated, that infiltrate stormwater runoff from small drainage areas. Infiltration trenches may include a shallow depression at the surface, but the majority of runoff is stored in the void space within the gravel and infiltrates through the sides and bottom of the trench.

---

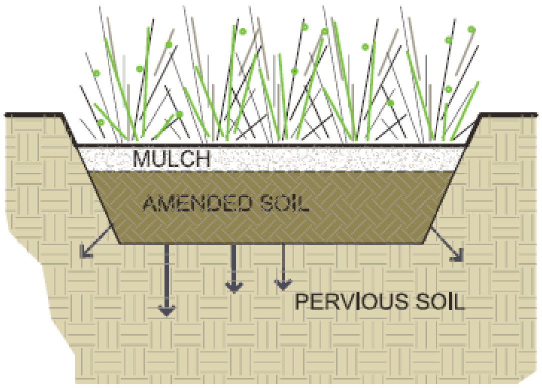
3 Depending on the design of the infiltration practice, Federal Underground Injection Control (UIC) Rules (40 CFR 144) may apply, which may further restrict the use of infiltration facilities in some locations.

Infiltration Galleries



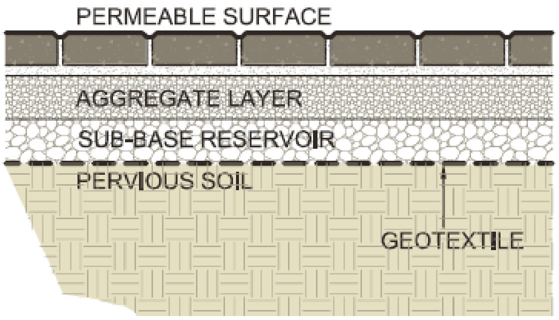
Infiltration galleries are open-bottom, subsurface vaults that store and infiltrate stormwater. A number of vendors offer prefabricated, modular infiltration galleries that provide subsurface storage and allow for infiltration. Infiltration galleries come in a variety of material types, shapes and sizes.

Bioretention



Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, plantings, and, optionally, a subsurface gravel reservoir layer.

Permeable Pavements



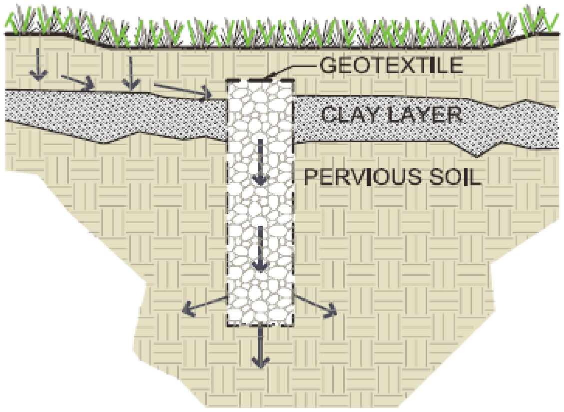
Permeable (or pervious) pavements contain small voids that allow water to pass through to a stone base. They come in a variety of forms; they may be a modular paving system (concrete pavers, modular grass or gravel grids) or poured-in-place pavement (porous concrete, permeable asphalt). All permeable pavements with a stone reservoir base treat stormwater and remove sediments and metals to some degree by allowing stormwater to percolate through the pavement and enter the soil below.

Multi-Directional Infiltration BMPs

These BMPs take advantage of the hydraulic conductivities (K_{sat}) of multiple soil strata and infiltration in multiple directions. They may be especially useful at locations where low K_{sat} values are present near the surface and soils with higher permeabilities exist beneath. A Multi-Directional Infiltration BMP may be implemented to infiltrate water at these lower soil layers, thus allowing infiltration to occur at sites that otherwise would be infeasible. These infiltration BMPs typically have smaller footprints and include, but are not limited to:

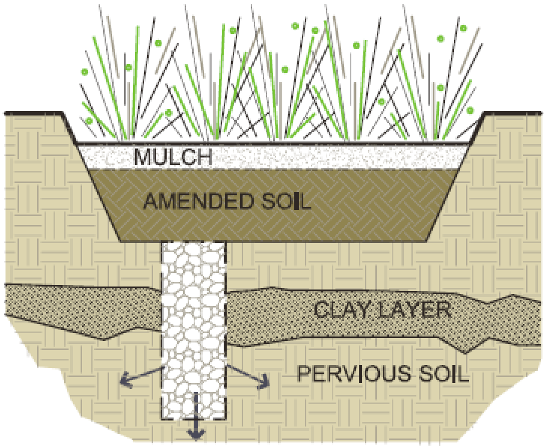
Dry Wells

A dry well is defined as an excavated, bored, drilled, or driven shaft or hole whose depth is greater than its width. Drywells are similar to infiltration trenches in their design and function, as they are designed to temporarily store and infiltrate runoff, primarily from rooftops or other impervious areas with low pollutant loading. A dry well may be either a drilled borehole filled with aggregate or a prefabricated storage chamber or pipe segment.



Hybrid Bioretention/Dry Wells

A bioretention facility with dry wells is useful in areas with low surface-level hydraulic conductivities that would normally deem a bioretention BMP infeasible but have higher levels of permeability in deeper strata. By incorporating drywells underneath the bioretention facility, water is able to be infiltrated at deeper soil layers that are suitable for infiltration, if present. This hybrid BMP combines the aesthetic and filtration qualities of a bioretention facility with the enhanced infiltration capabilities of a dry well.



4.4.2 Siting Requirements and Opportunity Criteria

Drainage areas implementing infiltration BMPs must pass the Category 1 or Category 2 Screening in accordance with the siting requirements set forth in Table 4.1. This screening process must be approved by a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional geotechnical engineer or geologist.

Additionally, drainage areas that will result in high sediment loading rates to the infiltration facility shall require pretreatment to reduce sediment loads and avoid system clogging. Examples of appropriate pretreatment may include: sedimentation/settling basins, baffle boxes, hydrodynamic separators, media filters, vegetated swales, or filter strips.

4.5 CAPTURE AND USE BMPS

Underground Cistern
Taylor Yard

Capture and Use refers to a specific type of BMP that operates by capturing stormwater runoff and holding it for efficient use at a later time. On a commercial or industrial scale, capture and use BMPs are typically synonomous with cisterns, which can be implemented both above and below ground. Cisterns are sized to store a specified volume of water with no surface discharge until this volume is exceeded. The primary use of captured runoff is for subsurface drip irrigation purposes. The temporary storage of roof runoff reduces the runoff volume from a property and may reduce the peak runoff velocity for small, frequently occurring storms. In addition, by reducing the amount of stormwater runoff that flows overland into a stormwater conveyance system, less pollutants are transported through the conveyance system into local streams and the ocean. The onsite use of the harvested water for non-potable domestic purposes conserves City-supplied potable water and, where directed to unpaved surfaces, can recharge groundwater in local aquifers.

4.5.1 Siting Requirements and Opportunity Criteria

Drainage areas implementing capture and use BMPs must pass the feasibility screening in accordance with the siting requirements set forth in Section 4.3. This screening process must be approved by a site-specific geotechnical investigation report and/or hydrologic analysis conducted and certified by a State of California registered professional civil engineer, geotechnical engineer, geologist, or other qualified professional.

Capture and use BMPs designed for these extended holding times will require additional treatment such as filtration or disinfection to protect the collection tanks from fouling, to prevent the breeding of vectors, and/or to improve the quality of water for reuse applications. These scenarios will be reviewed on a case-by-case basis.

4.5.2 Irrigation / Dispersial of Captured Stormwater

A developer is required to hold harvested stormwater for the purpose of irrigation during dry periods. Calculations in line with the California Department of Water Resources Model Water Efficent Landscape Ordiance AB 1881 (also refer to City of Los Angles Irrigation Guidelines[6]) shall be provided. Captured stormwater should be used to offset the potable irrigation demand that would occur during the rain season (Oct 1 – Apr 31, 7 months). If the volume of captured

6 City of Los Angles Irrigation Guidelines: http://cityplanning.lacity.org/Forms_Procedures/2405.pdf

stormwater exceeds the Estimated Total Water Use for the rain season ($ETWU_7$),excess stormwater shall, at a minimum establish a schedule to release captured stormwater over landscaping.

4.5.3 Design Criteria and Requirements

Capture & Use

- Unless specifically stated, the following criteria and requirements listed below are required for the implementation of all capture and use BMPs. Provisions not met must be approved by the City of Los Angeles.
- Fertilizers, pesticides, or herbicides on landscaped areas shall be minmized.
- Above-ground cisterns are secured in place and designed to meet seismic requiremnts for tanks.
- Overflow outlet is provided upstream of the tank inlet and is designed to disperse overflow onsite. Dispersial and overflow must be through an approved landscape areas where erosion or suspension of sediment is minimized, or through a high flow biotreatment BMP. Overflow from the tank into the storm drain system is not allowed.
- For landscape applications, a subsurface drip irrigation system, a pop up, or other approved irrigation system, has been aproved and installed to adequately discharge the captured water[7].
- If a pumping system is used, a reliable pump capable of delivering 100% of the design capacity is provided. Pump is accessible for maintenance. Pump has been selected to operate within 20% of its best operating efficiency. A high/low-pressure pump shut off system is installed in the pump discharge piping in case of line clogging or breaking.
- If an automated harvesting control system is used, it is complete with a rainfall or soil moisture sensor. The automated system has been programmed to not allow for continuous application on any area for more than 2-hours.
- Dispersion is directed so as not to knowingly cause geotechnical hazards related to slope stability or triggering expansive (clayey) soil movement.
- Cisterns do not allow UV light penetration to prevent algae growth.
- Cistern placement allows easy access for regular maintenance. If cistern is undergrond, manhole shall be accessible, operational, and secure.

---

7 If alternative distribution systems (such as spray irrigation) are approved, the City will establish guidelines to implement these new systems.

- Refer to County of Los Angeles , Department of Health Services for additional guidelines and requiremnets (Appendix J).
- Provide observation access for vector inspection and treatment.

4.5.4 Operations and Maintenance

- Cistern components, including spigots, downspouts, and inlets will be inspected 4 times annually to ensure proper functionality. Parts will be repaired or replaced as needed.
- Cisterns and their components will be cleaned as necessary to prevent algae growth and the breeding of vectors.
- Dispersion areas will be maintained to remove trash and debris, loose vegetation, and rehabilitate any areas of bare soil.
- Effective energy dissipation and uniform flow spreading methods will be employed to prevent erosion and facilitate dispersion.
- Cisterns will be emptied as necessary to prevent vector breeding, unless exclusion devices are implemented to prevent vector access. If vector breeding is taking place at a site as a result of contained stormwater or inadequately maintained BMPs, the Greater Los Angeles County Vector Control District has the ability to fine site owners for violating the California Health and Safety Code (Section 2060 – 2067).

4.6 HIGH EFFICENCY BIOFILTRATION BMPS

Projects that have demonstrated they cannot manage 100% of the water quality design volume onsite through infiltration and/or capture and use BMPs may manage the remaining volume through the use of a high removal efficiency biofiltration/biotreatment BMP. A high removal efficiency biofiltration/biotreatment BMP shall be sized to adequately capture 1.5 times the volume not managed through infiltration and/or capture and use.

Bioretention (Planter Boxes)
Watermarke Tower

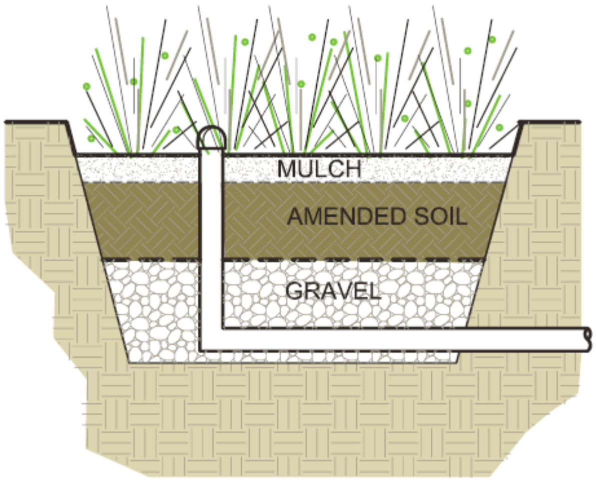
Biofiltration BMPs are landscaped facilities that capture and treat stormwater runoff through a variety of physical and biological treatment processes. Facilities normally consist of a ponding area, mulch layer, planting soils, plants, and in some cases, an underdrain. Runoff that passes through a biofiltration system is treated by the natural adsorption and filtration characteristics of the plants, soils, and microbes with which the water contacts. Biofiltration BMPs include vegetated swales, filter strips, planter boxes, high flow biotreatment units, bioinfiltration facilities, and bioretention facilities with underdrains. Biofiltration can provide multiple benefits, including pollutant removal, peak flow control, and low amounts of volume reduction through infiltration and evapotranspiration.

4.6.1 Biofiltration BMP Types

Biofiltration BMPs rely on various hydraulic residence times and flow-through rates for effective treatment. As a result, a variety of BMPs are available.

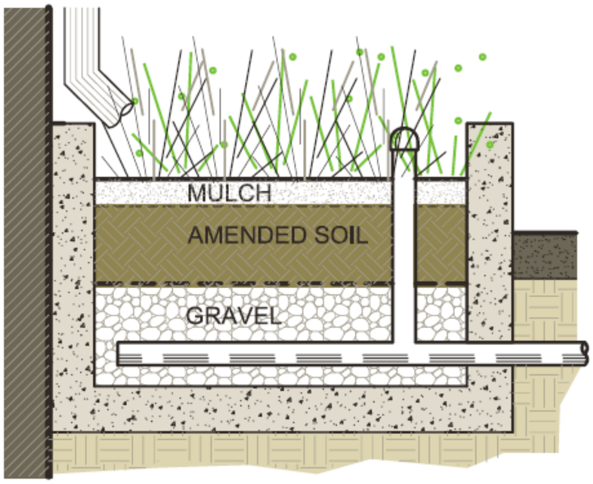
Bioretention with Underdrain

Bioretention facilities are landscaped shallow depressions that capture and filter stormwater runoff. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Because they are not contained within an impermeable structure, they may allow for infiltration. For sites not passing the infiltration feasibility screening for reasons other than low infiltration rates (such as soil contamination, expansive soils, etc.), an impermeable liner may be needed to prevent incidental infiltration.



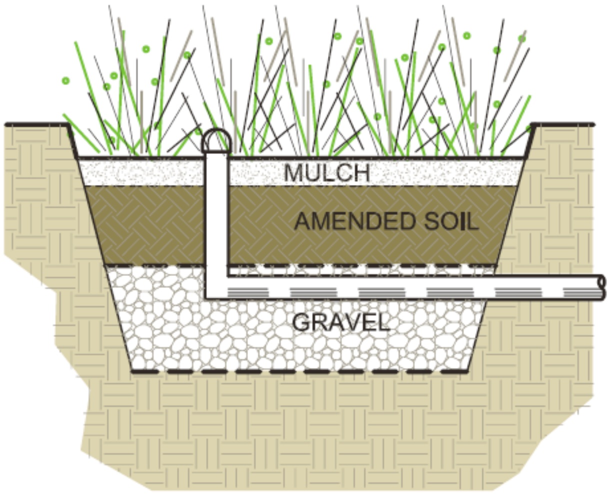
Planter Boxes

Planter boxes are bioretention treatment control measures that are completely contained within an impermeable structure with an underdrain (they do not infiltrate). They are similar to bioretention facilities with underdrains except they are situated at or above ground and are bound by impermeable walls. Planter boxes may be placed adjacent to or near buildings, other structures, or sidewalks.

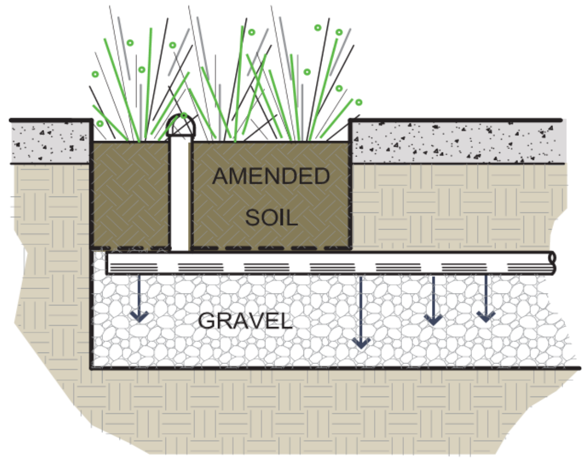


Bioinfiltration

Bioinfiltration facilities are designed for partial infiltration of runoff and partial biotreatment. These facilities are similar to bioretention devices with underdrains but they include a raised underdrain above a gravel sump designed to facilitate infiltration and nitrification/denitrification. These facilities can be used in areas where there are little to no hazards associated with infiltration, but infiltration screening does not allow for infiltration BMPs due to low infiltration rates or high depths of fill.

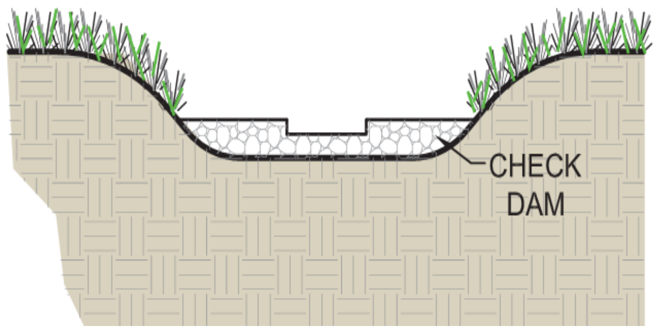


High-Flow Biotreatment with Raised Underdrain



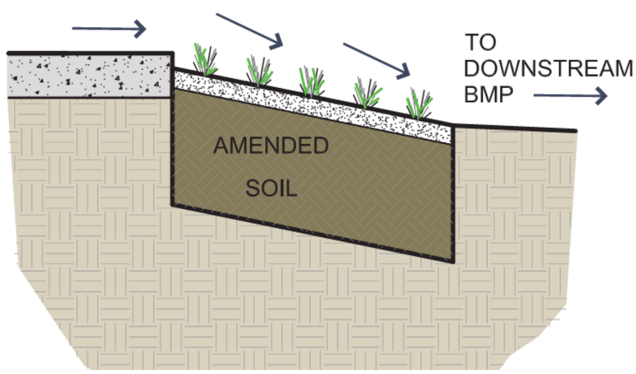
High-flow biotreatment devices are proprietary treatment BMPs that incorporate plants, soil, and microbes engineered to provide treatment at higher flow rates and with smaller footprints than their non-proprietary counterparts. Like bioinfiltration devices, they should incorporate a raised underdrain above a gravel sump to facilitate incidental infiltration where feasible. They must be shown to have pollutant removal efficiencies equal to or greater than the removal efficiencies of their non-proprietary counterparts. Proof of this performance must be provided by adequate third party field testing.

Vegetated Swales



Vegetated swales are open, shallow channels with dense, low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff to downstream discharge points. An effective vegetated swale achieves uniform sheet flow through the densely vegetated area for a period of several minutes. The vegetation in the swale can vary depending on its location and is the choice of the designer. Most swales are grass-lined.

Filter Strips (to be used as part of a treatment train)



Filter strips are vegetated areas designed to treat sheet flow runoff from adjacent impervious surfaces such as parking lots and roadways, or intensive landscaped areas such as golf courses. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform flow. Filter strips are primarily used to pretreat runoff before it flows to an infiltration BMP or another biofiltration BMP.

4.6.2 Siting Requirements and Opportunity Criteria

Sites with plans to implement high removal efficiency biofiltration/biotreatment systems for the management of stormwater must first be screened for infiltration and capture and use BMP feasibility. Biofiltration should be implemented to treat all runoff onsite to the maximum extent feasible at sites incapable of implementing infiltration and/or capture and use BMPs as a result of the feasibility screening process set forth in this handbook.

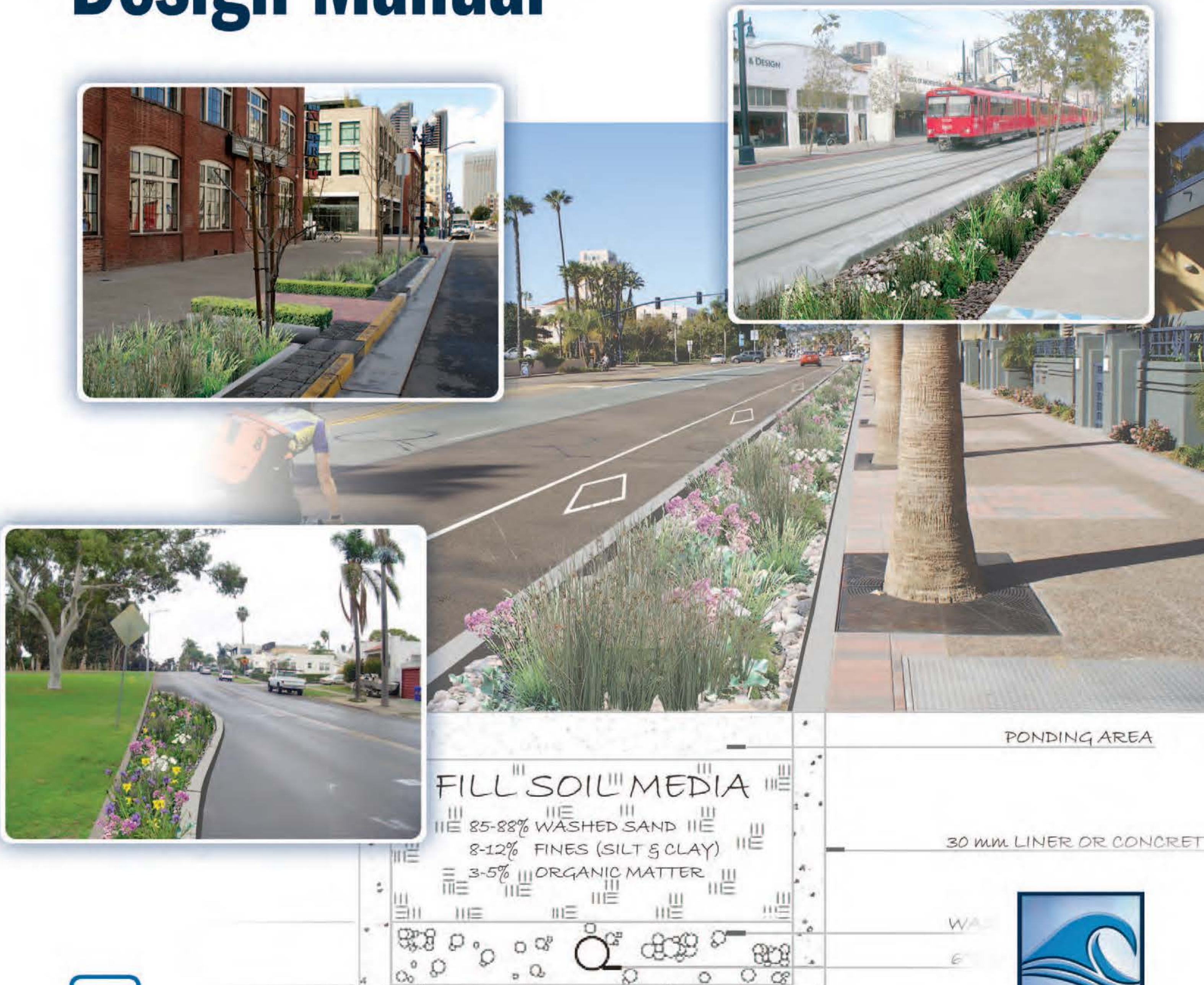
Sites implementing biofiltration BMPs must have sufficient area available to ensure that BMPs produce adequate contact time for filtration to occur. For biofiltration BMPs with underdrains, sufficient vertical relief must exist to permit vertical percolation through the soil media to the underdrain below. For biofiltration BMPs with incidental infiltration, it must be demonstrated that there are no hazards associated with infiltration (i.e. infiltration screening does not allow for infiltration BMPs due to low infiltration rates or high depths of fill).

4.6.3 Calculating Size Requirements for Biofiltration BMPs

Biofiltration BMPs should be designed according to the requirements listed in Table 4.3 and outlined in the section below.

CITY OF SAN DIEGO STORM WATER

San Diego Low Impact Development Design Manual



TETRA TECH

think BLUE SAN DIEGO

Document No. PITS070111-01

July 2011

Appendix B. BMP Design Guidance

Contents

Figures

about

GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

www.ghd.com