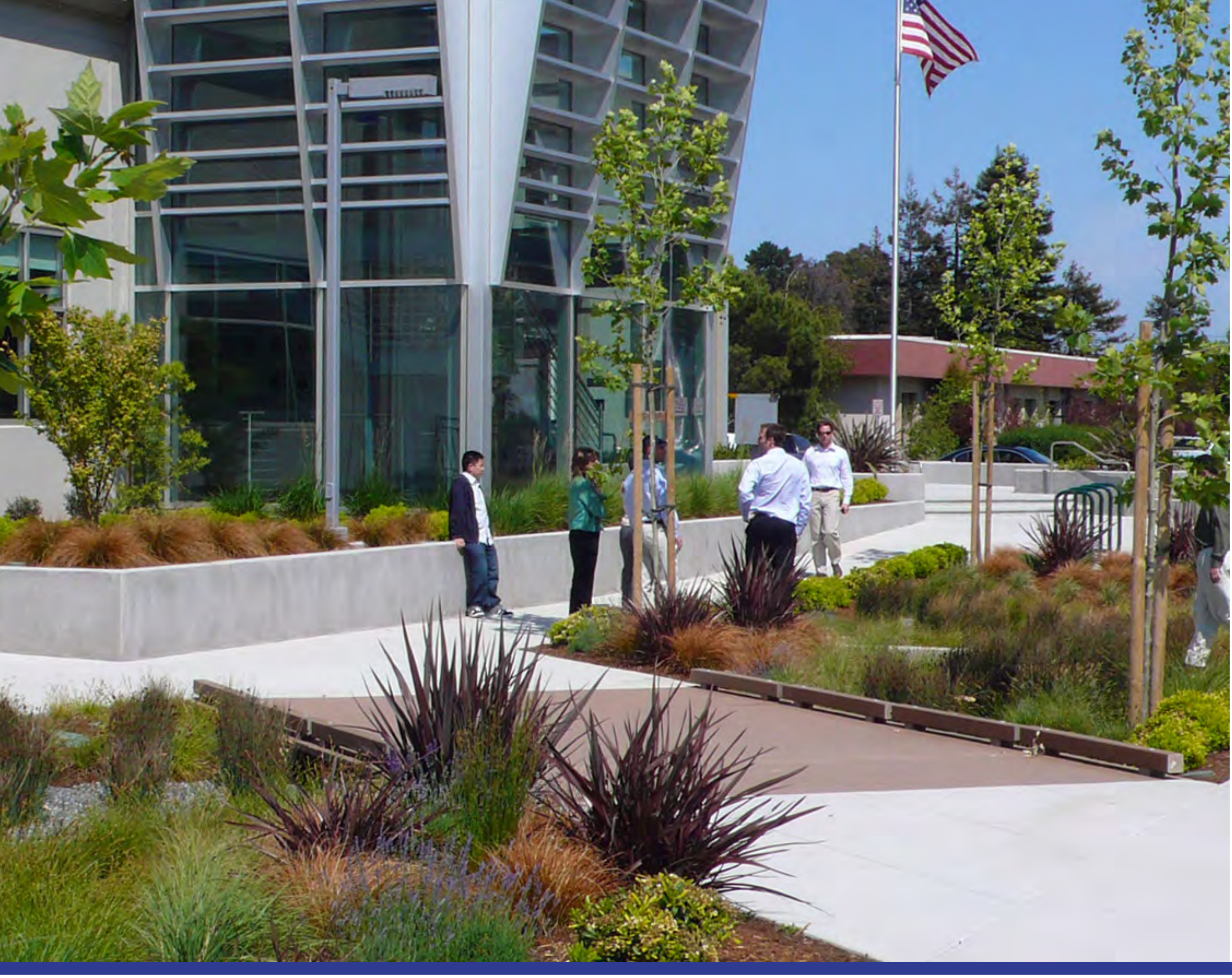
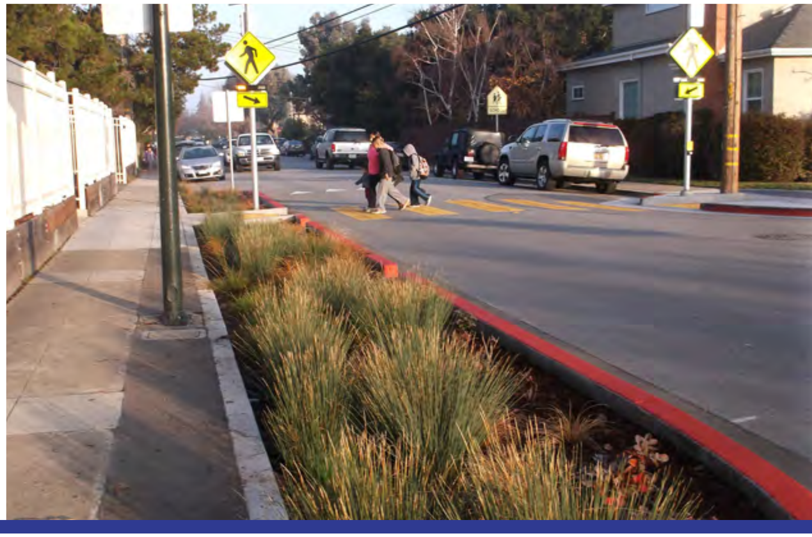




Green Infrastructure Design Guide

Third Edition | 2024

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program
Clean Water. Healthy Community.

San Mateo County, California

Table of Contents

NOTE: This document contains interactive elements to help make navigation between subject areas easier. Simply click on the chapter you wish to view on the overhead navigation bar or click through the provided table of contents or indices. Return to this complete table of contents by clicking the arrow symbol on the left edge of the overhead navigation bar. If printing this document, the overhead navigation bar will disappear in the paper version.

Table of Contents

◄ *California poppies blanket a stormwater curb extension along Hillside Boulevard in South San Francisco.*
Photo Credit: Urban Rain|Design

The Donnelly Avenue Green Street and Parking Lot Project in Burlingame, California. ▶
Photo Credit: Urban Rain|Design

Acknowledgements

The Green Infrastructure Design Guide provides inspiration and a shared commitment for the thoughtful implementation of green infrastructure and sustainable streets within San Mateo County. We acknowledge the vision, collaboration, and dedication of the San Mateo Countywide Program, it's member agencies, the Green Infrastructure Committee, and the consultant team in the development of this Guide.

San Mateo Countywide Water Pollution Prevention Program

Reid Bogert, Program Director

Green Infrastructure Committee Representatives

Muneer Ahmed
John Allan
Leticia Alvarez
Corey Alvin
Natalie Asai
Michael Barber
Keegan Black
Dennis Bosch
Maziar Bozorginia
Sibely Calles
Kelly Carroll, CSG Consultants
Julie Casagrande
Ray Chan
Ted Chapman
Andrea Chow
Leo Chow
Michelle Daher
Nestor Delgado
Brian Dong
Raymond Donguines
Brad Donohue
Adena Friedman
Michael Fu
Mike Futrell
Kevin Gardiner
Ofelia Guner
Marty Hanneman
Deborah Hirst
David Huynh
Ken Johnson
Jonathan Kwan
Joe LaClair
Christopher Lamm
Mark Lander, CSG Consultants
Grace Le
Danielle Lee
Jennifer Lee
Camille Leung
Clarence Li
Jacinta Liang
Breann Liebermann
Grant Ligon
Khee Lim
Vivian Ma
Rob Mallick
Anwarbeg Mirza
Brad Misner
Azalea Mitch

Dong Nguyen
James O'Connell
Afshin Oskoui
Robert Ovadia
Ruemel Panglao
Lisa Porras
Martin Quan
Hae Won Ritchie
Kathryn Robertson
Sean Rose
Sarah Scheidt
Katherine Sheehan, CSG Consultants
Vicki Sherman
Michael Smith
Kim Springer
Marlene Subhashini
Jimmy Tan
Hillary Tung
Andrew Wemmer
Robin J. Lee, Schaaf and Wheeler
David Wong
Sandy Wong
Robert Wood
Gilbert Yan
Andrew Yang
Howard Young
Matt Fabry, former Program Director

Current Guide Consultant

EOA, Inc.
Jill Bicknell, P.E.
Peter Schultze-Allen, CPSWQ, RQP
Quan Lu, EIT

Past Consultant Team

Community Design + Architecture (CD+A)
Urban Rain Design, Inc.
Quadriga Landscape Architecture & Planning

This update is dedicated in memory and appreciation of the contributions of Kevin Robert Perry from Urban Rain Design.

CITY OF HALF MOON BAY

Chapter 1

Introduction

Pervious pavers and stormwater planters aid in treating runoff at the Half Moon Bay Library.

1.0 Introduction
Overview

EOA

The City/County Association of Governments of San Mateo County (C/CAG), a joint powers agency whose members are the County of San Mateo and the 20 incorporated cities and towns, administers the San Mateo Countywide Water Pollution Prevention Program (Countywide Program) to assist its member agencies with meeting requirements to reduce pollution in stormwater runoff. These requirements are contained in the San Francisco Bay Regional Water Quality Control Board's (Regional Board) Municipal Regional Permit (MRP) and include specific provisions for addressing key pollutants of concern, namely mercury, PCBs (polychlorinated biphenyls), sediment, and trash. The MRP also requires jurisdictions to transition from gray, or piped, infrastructure storm drainage systems to green, or landscape-based, systems that capture, treat, and infiltrate runoff — Green Infrastructure.

The MRP defines green infrastructure as: *Infrastructure that uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water.*[1]

The Countywide Program created the San Mateo Countywide Green Infrastructure Design Guide (guide) to aid jurisdictions in gradually transitioning from gray to green infrastructure over time. This guide, which includes design guidance, standards and typical details for green infrastructure implementation in public and private projects, is a core component of implementing local Green Infrastructure Plans. In the previous MRP the Regional Board described the purpose of Green Infrastructure Plans as:

> *Over the long term, the [Green Infrastructure] Plan is intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green – that is, a more resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other green infrastructure practices to clean stormwater runoff.*

◀ *Green infrastructure measures can complement complete streets elements such as this mid-block stormwater curb extension used along a Safe Routes to School path.*

1 San Francisco Bay Regional Water Quality Control Board, Municipal Regional NPDES Permit (MRP 3.0), adopted in 2022 and amended in 2023, comprises Order Nos. R2-2022-0018 and R2-2023-0019. GI is defined on page 251 of the 2022 permit.

The Plan shall also identify means and methods to prioritize particular areas and projects within each Permittee's jurisdiction, at appropriate geographic and time scales, for implementation of green infrastructure projects. Further, it shall include means and methods to track the area within each Permittee's jurisdiction that is treated by green infrastructure controls and the amount of directly connected impervious area.[2]

More information on Green Infrastructure Plans is provided in other sections of this chapter, along with other regulatory frameworks and local plans and programs that are advancing sustainable stormwater management in San Mateo County. In the following chapters, this guide provides helpful design guidance and strategies for building green infrastructure in streets, buildings, sites, and parking lots. Though all green infrastructure projects should be designed, built, and maintained to adequately capture, store, and treat stormwater, some projects that meet certain criteria have strict requirements for site designs and stormwater control measures. These projects, referred to as regulated projects, must adhere to the specific requirements of the MRP and guidance, standards, and details for these projects are provided separately in the companion **C.3 Regulated Projects Guide**.

Beyond supporting the transition from "gray" to "green," this guide also addresses key challenges and opportunities for building green infrastructure, especially in the public right of way. **Sections 4, 5,** and **6** in **Chapter 3 Design Strategies and Guidelines** provide design guidance and strategies for sustainable streets, which this guide defines as projects that integrate green street infrastructure with complete streets treatments. This integrated approach provides additional benefits and opportunities for more cost-effective capital improvement projects when local agencies plan street reconstruction for transit, bicycle, and/or pedestrian improvements or other transportation investments. The Countywide Program encourages this sustainable stormwater management approach that goes beyond water quality improvement goals.

This guide is intended to be a "one-stop shop" for agencies, builders, and project sponsors covering a broad range of aspects in the design, construction, and maintenance of green infrastructure in San Mateo County. The structure of the chapters is meant to increase the user interface of these tools and guidance.

2 San Francisco Bay Regional Water Quality Control Board, Municipal Regional NPDES Permit (MRP 3.0), adopted in 2022 and amended in 2023, comprises Order Nos. R2-2022-0018 and R2-2023-0019. GI is defined on page 251 of the 2022 permit.

1.0 Introduction

How to Use the Green Infrastructure Design Guide

CD+A

▲ *Multiple types of green infrastructure - slotted metal grating and stormwater planters that step with a weir - come together and create an attractive and effective building entry point.*

CITY OF FOSTER CITY

▲ *Green infrastructure can match the aesthetics of standard landscape while providing numerous ecological, environmental, and economic benefits.*

The Green Infrastructure Design Guide provides guidance regarding the design, implementation, and on-going operations and maintenance of green infrastructure throughout communities in San Mateo County. This guide is a "living document" and will be periodically updated to reflect new information, findings, and experience. This guide is intended to aid the public, decision makers, designers, and maintenance workers with information to inform their understanding of green infrastructure and its importance in supporting community goals and to ensure green infrastructure facilities are implemented and maintained well.
This document provides information that is more design-focused and less technical-focused than the **C.3 Regulated Projects Guide**. In addition, this guide supports the MRP's requirement of developing, identifying, and describing design guidance and considerations to integrate green infrastructure with complete streets projects; something that many people currently do not have much experience with or knowledge of. The two documents, Green Infrastructure Design Guide and the **C.3 Regulated Projects Guide**, make up what is referred to as the "GreenSuite". Together, the GreenSuite provides a range of strategies and other elements applicable to the full spectrum of planning, design, construction, and operations and maintenance of green infrastructure. The User will need to determine what type of project is being designed to include green infrastructure – is it public or private; a regulated project or not; is it a site, parking lot, street, or other improvement – and review the chapters and appendices within the GreenSuite that cover the project type and conditions.

The GreenSuite does not provide information on measures that manage and protect stormwater during construction activities. Information related to construction phase BMPs can be found at www.flowstobay.org/construction.

Organization of the San Mateo County GreenSuite

Green Infrastructure Design Guide

1. **Introduction:** Explains overall purpose and elements of this guide, the existing regulatory framework, and the main functions and design considerations of green infrastructure.
2. **Green Infrastructure Measures and Opportunities:** Provides a general description of 13 green infrastructure measures and design guidance that is applicable in many locations. Benefits; potential constraints; opportunities for; why use measures in a building, site, street, or parking lot; and special considerations are also discussed.
3. **Design Strategies and Guidelines: Describes strategies and guidance applicable to San Mateo County** and other locations. Separate sections describe what is applicable and possible for managing stormwater with green infrastructure at building, site, parking lot, or street locations. More specific guidance is provided for implementation of green infrastructure in streets (green streets), as well as introducing complete street elements and how together these create Sustainable Streets. It also includes two sections that provide illustrative examples in prototypical locations throughout San Mateo County of green infrastructure installations. These include photographs and discussion of built examples and "before and after" illustrations of installations.
4. **Key Design and Construction Considerations:** A range of design and construction considerations that need to be addressed in all green infrastructure designs or in particular situations, such as protecting existing improvements, designing for poor soils, or choosing appropriate plant materials.
5. **Key Implementation Strategies:** Discusses a range of implementations strategies, including reducing project costs, changing municipal policies and codes, and others.
6. **Operations and Maintenance:** Provides information related to the operation and maintenance of green infrastructure and other treatment measures.

A. **Appendices, Glossary, and References:** Includes technical appendices for definitions of words and phrases; lists additional references and resources; typical sustainable streets design details and specifications, including additional information on biotreatment soil media (BSM), pervious pavements, and plant palette; sample maintenance plan forms; and the Countywide Program's green infrastructure funding options report.

C.3 Regulated Projects Guide

The **C.3 Regulated Projects Guide** explains Regional Board regulations and provides technical guidance for sizing and design of treatment measures for public and private projects that are required to meet regulated projects water quality requirements.

CD+A

▲ *Bridging structures allow for direct pedestrian access across linear green infrastructure measures.*

URBAN RAIN DESIGN

▲ *Stormwater facilities slow the flow of stormwater runoff through the interaction of the water with plants and soil.*

CHAPTER 1

1.1 Sustainable Stormwater Design Basics

Principles of Green Infrastructure Stormwater Design

CD+A

This section introduces the concept of sustainable stormwater design including the principles, benefits, and related sustainable practices and techniques that include the use of green infrastructure measures.

For much of the last century, stormwater drainage systems have been engineered to quickly collect runoff in underground pipes and carry it away using an "out of sight, out of mind" approach. This design philosophy treats rainfall runoff as a waste, and many people are unaware of the stormwater flowing in pipes underneath city streets when it rains.

Sustainable stormwater design treats rainfall runoff as a valuable resource. It is based on modifying urban, suburban, and rural development patterns and designs to preserve and mimic natural hydrological functions. Furthermore, sustainable stormwater design achieves the multiple goals of being cost effective, improving water quality, and supporting other community goals for the environment of their neighborhoods and districts. Mimicking the natural hydrological function of healthy ecosystems in built human landscapes can dramatically reduce pollution, decrease runoff volume, reduce runoff temperature[3], protect aquatic habitat, and create more interesting places to live. In addition, stormwater runoff can be captured and reused to aid in reducing potable water needs such as for irrigation or toilet flushing, and recharging groundwater aquifers. As detailed in **Chapter 3 Design Strategies and Guidelines**, sustainable streets projects offer additional complete streets benefits, making streets greener, safer, and accessible to all users.

3 Rise in runoff temperatures can affect a water bodies' ecological health, and flora and fauna by decreasing oxygen levels; impacting temperature for habitable areas and viability of egg development; increasing growth of fungus and bacteria; amongst many other concerns. Impervious areas heated by the sun increase the temperature of stormwater runoff that ponds or flows over them. See Water properties: Temperature; USGS website; https://water.usgs.gov/edu/temperature.html.

Stormwater Management Goals

Green infrastructure design should achieve three primary stormwater management goals: water quality improvement, flow reduction, and volume reduction. These interrelated goals help foster a balanced development condition that manages stormwater in a way that is closer to pre-development conditions, see sidebar on following pages.

Improve Water Quality

Green infrastructure facilities can filter and remove excess sediments and other pollutants from runoff. By allowing water to interact with plants and soil, water quality improvements are achieved through a variety of natural, physical and chemical processes. Even if soils are not conducive to infiltration, or if there is a high-water table, water quality is still enhanced through green infrastructure via pollutant settling, absorption into the soil, and uptake by plants.

Reduce Water Flow

Green infrastructure facilities can slow the velocity of runoff by detaining stormwater in the landscape. Flow rate reduction can often be achieved by integrating design strategies such as pervious paving, bioretention planters, rain gardens, green roofs, and other green infrastructure measures that provide stormwater detention. By detaining and delaying runoff, peak flow rates are attenuated, and downstream creeks are protected from erosive flows. Conveying runoff through a system of naturalized surface features mimics the natural hydrological cycle and minimizes the need for underground drainage infrastructure.

Reduce Water Volume

Whenever possible, green infrastructure facilities should collect and absorb stormwater to reduce the overall volume of runoff. Retention facilities offer long-term stormwater collection and storage for reuse or groundwater recharge. Plants contribute to retention capacity by intercepting rainfall, taking up water from the soil, and assisting infiltration by maintaining soil porosity. Where native soil conditions support infiltration, green infrastructure can remove pollutants prior to the stormwater infiltrating into native soils.


CD+A

▲ *Sediment, trash, and oils regularly collect in the street and flow into storm drain systems or water bodies.*


NEVUE NGAN ASSOCIATES

▲ *Green infrastructure measures aid in collecting and filtering out pollutants before the stormwater enters the storm drain system or natural water bodies.*

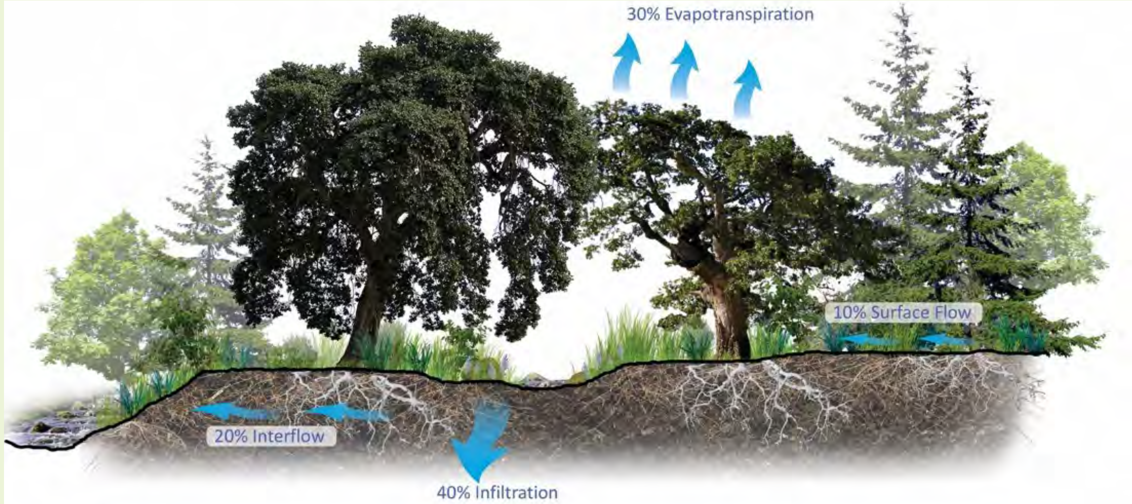
1.1 Sustainable Stormwater Design Basics

Principles of Green Infrastructure Stormwater Design

Achieving a Balanced Development Condition with Healthier Stormwater Processes

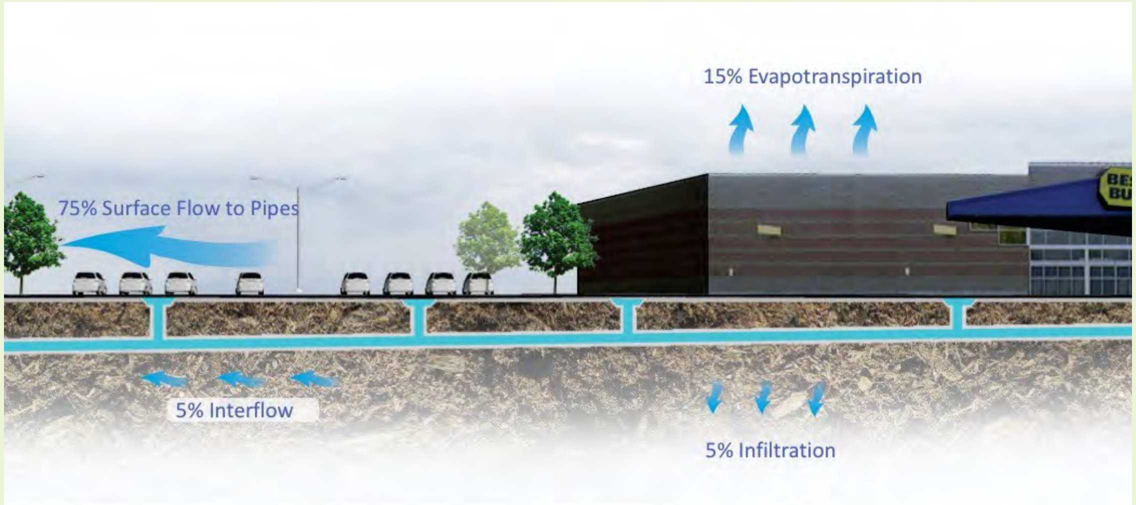
Pre-Development Condition

A healthy, undisturbed landscape acts like a sponge by capturing, absorbing, and slowing the flow of water from the moment a raindrop lands on the ground. Urban development, though, has dramatically impacted natural hydrologic systems by reducing the landscape's absorptive capacity and introducing pollutants.



Built Development Condition

When the natural landscape is urbanized, impervious surface is created that prevents water from being absorbed at the source. Sediments and pollutants from streets, parking lots, buildings, yards, and other sources are washed into pipes and water bodies. Stormwater flowing over pavement and roof surfaces typically increases in temperature. Stormwater runoff increases as more and more impervious surface is created. The high volume and velocity of stormwater runoff emptying into creeks and streams may cause flooding and erosion, damaging natural habitat. Urban stormwater runoff also includes pollutants that are gathered or absorbed from streets, buildings, and other sources; reduction of pollutants in stormwater runoff into water bodies, particularly San Francisco Bay, is a major goal of the MRP.



Balanced Development Condition

Infrastructure can be designed to minimize its impact on natural drainage systems. The buildings, streets, and parking lots of our built human environment can help maintain the balance of natural drainage systems by capturing, slowing, and absorbing stormwater, as well as filtering the pollutants and reducing heat that urban development introduces. Green infrastructure such as green streets, green parking lots, and green roofs helps to reduce surface flows, increase the time it takes stormwater runoff to flow downstream, and distributes the volume of water entering into creeks over a longer period of time, thereby decreasing flooding and reducing the erosive forces of the water.

1.1 Sustainable Stormwater Design Basics

Benefits of Green Infrastructure

NEVUE NGAN ASSOCIATES

▲ *When it rains on our streets, pollutants are washed directly into pipes and then into creeks, the Bay, or the Pacific Ocean.*

KEVIN ROBERT PERRY

▲ *Vegetation and soil within green infrastructure help to filter out sediment and other pollutants before it enters the storm drain system.*

As described in the Stormwater Management Goals section above, green infrastructure measures are primarily designed to provide stormwater sustainability benefits from buildings, sites, streets, and parking lots and are designed with a landscape and/or paving system that captures, slows, filters, and potentially recharges groundwater supplies from stormwater. These features reduce stormwater runoff and improve water quality before discharging to local creeks and other water bodies. Green infrastructure can provide other benefits, including enhancing community character and placemaking, supporting economic vitality, and reducing impervious areas.

Sustainable stormwater design offers wide-ranging benefits over other facilities and treatment measures designed in conventional ways. When integrated with complete streets and within development projects, they create additional urban greening and support walking, biking, and transit use, which in-turn support economic, health, environmental, and community benefits. This section offers a brief overview of the evidence of these benefits.

Environmental

Vegetation in green infrastructure can increase biodiversity and provide the opportunity to connect urban open spaces and wildlife habitats through a "green" network. The use of green infrastructure can change the perception of stormwater from a waste product to an important resource that sustains trees and other plant life that enriches the everyday environment. The rain harvesting, bioretention, and infiltration functions of green infrastructure, when combined with proper plant selection, can reduce overall irrigation demand for potable water. In addition, vegetated and pervious surfaces promote water absorption, treatment, and retention, which can create cleaner, more sustainable water supplies and prevent soil erosion.

Green infrastructure strategies aid in climate adaptation and resiliency by reducing localized flooding; increasing water storage, reuse, and potential recharge; and reducing erosion and temperature of stormwater runoff and the general urban environment. Providing vegetation in landscaped green infrastructure aids in reducing urban heat island effects from human development, which helps to improve air quality, reduce energy used by buildings for cooling and heating, and decrease surface temperatures in cities. See the urban heat island sidebar for further information on the benefits of healthy street trees.

Green roofs and trees are effective in reducing the amount of energy needed to heat and cool buildings by providing insulation to the upper levels of buildings or providing shade and solar access to interior spaces within buildings. Vegetated walls and roofs can also remove pollutants from the air. This provides improved air quality and various health benefits to those who are exposed to poor air quality. Evapotranspiration of water through the plants has the added benefit of reducing the temperature of the roof and surrounding air.[4]

CITY OF SAN CARLOS

▲ *This rain garden with trees also aids to manage localized flooding, reduce urban heat island effects, and to add embellishment to a parking lot.*

UNKNOWN

▲ *Green infrastructure along building façades work to capture runoff on site, stabilize the internal temperature of the building, and reduce the heat island effect.*

4 Using Green Roofs to Reduce Heat Islands; EPA website; www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands: This website summarizes and provides sources and resources regarding the many benefits of green roofs including the reduction of heat island effect; energy use; and air pollution and greenhouse gas emission; in addition to improved rainfall and/or stormwater management and treatment; habitat value; and human health and comfort.

1.1 Sustainable Stormwater Design Basics

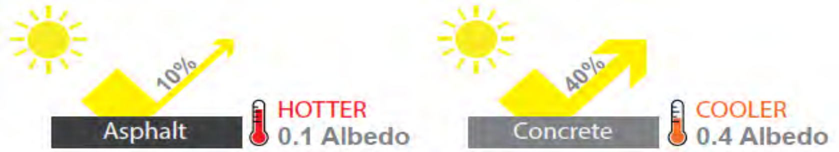
Benefits of Green Infrastructure

Street Trees can Reduce Heat in Cities

What is Albedo?

Albedo, or solar reflectance, measures a surface material's ability to reflect energy from sun rays on a scale of 0 to 1. An albedo value of 0.0 indicates that the surface absorbs all solar radiation, and a 1.0 albedo value represents total reflectivity. The more solar radiation a material absorbs, the hotter it will become. Much of our urban environment, such as paving and roofing, have relatively low albedo and absorb high levels of solar radiation during the day. As the solar radiation is dissipated from these materials it heats the surrounding air, often resulting in higher night time temperatures as well.

These two blocks of 17th Street in Downtown Oakland have nearly identical areas of asphalt and concrete paving. However, the block to the right has a significantly higher albedo average because the street trees along it provide a buffer from the sun's rays to the pavement.



17th Street between Webster and Harrison

Image Credit: Google

- TOTAL ASPHALT: 12,000 SQ FT — OPEN TO SKY: 11,770 SQ FT — 98%
- TOTAL CONCRETE: 6,000 SQ FT — OPEN TO SKY: 5,770 SQ FT — 92%
- TOTAL TREE CANOPY COVER: 460 SQ FT

AVERAGE ALBEDO OF STREET : 0.21

17th Street between Webster and Franklin

Image Credit: Google

- TOTAL ASPHALT: 12,000 SQ FT — OPEN TO SKY: 3,848 SQ FT — 32%
- TOTAL CONCRETE: 6,000 SQ FT — OPEN TO SKY: 1,830 SQ FT — 30%
- TOTAL TREE CANOPY COVER: 12,322 SQ FT

AVERAGE ALBEDO OF STREET : 0.54

Economic Vitality

Green infrastructure can result in a range of local economic vitality benefits, from higher property sales and rental value to increased consumer spending in commercial districts. Commercial properties with well-designed green stormwater infrastructure can benefit from higher property values, more retail sales, energy savings, reduced life-cycle and maintenance costs, reduced flood damage, lower water bills, reduced crime, and improved health and job satisfaction for office employees. Green infrastructure and other green building practices are increasingly becoming a quality benchmark for the private sector because they illustrate an owner's, and their tenant's, commitment to healthier and sustainable communities and placemaking, while creating measurable value added for property owners and tenants alike.[5] Studies show that views and access to landscape results in improved worker productivity, increasing the potential that patrons will linger longer on retail main streets, and an increase in value for nearby homes.[6] Green infrastructure installed on or near properties has been found to improve the ability to rent properties, including having higher occupancy rates and shorter periods between leases.[7] In addition, green roofs have been shown to contribute to a rental premium on residential units.[8] The aesthetic improvements and reduced flooding associated with green infrastructure projects have been proven to increase nearby property values.[9]

CD+A

▲ *Green infrastructure included in commercial retrofits treat runoff at its source and beautifies the public storefront and streetscape, creating a more inviting atmosphere for tenants and patrons.*

CD+A

▲ *Streetscape improvements create more enjoyable spaces and boost economic vitality.*

5 The Green Edge: How Commercial Property Investment in Green Infrastructure Creates Value; Janet Clements, Alexis St. Juliana, and Paul Davis, Natural Resources Defense Council, NRDC Report; December 2013; page 4

6 The Experience of Nature: A Psychological Perspective; Rachel Kaplan and Stephen Kaplan; Cambridge UP; 1989: indicates that worker productivity is improved when trees and landscaped areas are visible from their workspace. The Determinants of Neighborhood Transformation in Philadelphia – Identification and Analysis: the New Kensington Pilot Study; S. Wachter; The Wharton School, University of Pennsylvania; 2004 and What is a Tree Worth? Green-City Strategies, Signaling and Housing Prices; S. Wachter and G. Wong; Real Estate Economics 36(2); 2008: studies concluded property values increased 2-10% with new street tree plantings. Trees in the city: Valuing street trees in Portland, Oregon; G. Donovan and B. Butry; Landscape and Urban Planning 94(2); 2010: reports street trees increase home sales prices by nearly $9,000 and slightly decreases the time homes are on the market. The Effect of Low-Impact-Development on Property Values; Ward et al; WEF Publication; 2008: concluded a 3.5-5% property value increase associated with tree plantings in King County, Washington.

7 Economic Benefits of Runoff Controls. Office of Wetlands, Oceans and Watersheds. US EPA 1995.

8 New York City Property Values: What Is the Impact of Green Roofs on Rental Pricing? Letters in Spatial and Resource Sciences 4 (1): 21–30. Ichihara, K., and J.P. Cohen. 2011.

9 The Economics of Low-Impact Development: A Literature Review; Ed MacMullan and Sarah Reich, ECONorthwest; prepared for Waterkeeper Alliance; 2007: indicates that property values increased 6% from adjacency to retrofitted green streets in Seattle. A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds: Final Report; Stratus Consulting, Inc.; Prepared for the Office of Watersheds, City of Philadelphia; 2009: study showed property values increased up to 7% in areas with LID, street trees, and other landscape.

1.1 Sustainable Stormwater Design Basics

Benefits of Green Infrastructure

CD+A

▲ *Green infrastructure facilities can be integrated with paving and restriping plans, allowing for cost efficiencies in project planning and construction.*

CD+A

▲ *Stormwater curb extensions can aid in traffic calming by visually narrowing the street and slowing vehicle traffic, while also allowing stormwater runoff to infiltrate into pervious pavement and tree well filters.*

Complete Streets and Green Infrastructure Coordination

Green infrastructure can be combined with many design features that are used in complete streets. For example, corner curb extensions are used to slow vehicle turning movements and shorten crossing distance for pedestrians, and curb extensions can be designed to include landscape area that can easily take in stormwater from flows along the gutter. Landscape and bioretention planters can provide a buffer between people walking and moving vehicles, creating a more comfortable walking experience.

While including green infrastructure in streets, development, and urban open spaces does not always eliminate the need for gray infrastructure, green infrastructure can be more cost-effective, especially in areas that currently flood due to an undersized storm sewer system or there being no storm sewer at all. Green infrastructure is typically built in a distributed and decentralized manner, which lends to expansion over time as space and funds become available. Large-scale gray infrastructure projects are often upgraded or newly constructed in larger increments, requiring major capital funding at one time. It is important for jurisdictions to have regular multi-disciplinary staff meetings to coordinate and discuss green infrastructure opportunities and implementation. See *Green Infrastructure Planning and Implementation Coordination* sidebar, next page, for more information.

The addition of green infrastructure can further lengthen the life span of existing public improvements, such as roads, streets, and pipes, by reducing the amount of stormwater runoff entering these systems, which can eventually degrade these systems.

Green infrastructure elements also aid in the capture and removal of trash and debris. Trash and debris capture are a significant public works operating cost. Green infrastructure can be a first line of defense in collecting debris and trash from entering catch basins and inlets, and natural waterways. Removal of trash can then become part of the normal maintenance of the green infrastructure.

Public Health

Complete street and green street elements such as corner curb extensions and narrowing roadways create safer and more comfortable places to walk and cycle, encourage people to be more physically active, and improve air quality with less vehicles on the street. Plants and soil components of green infrastructure, and landscape in general, aid in capturing contaminants such as PCBs, mercury, heavy metals, and other pollutants from water and air that impact the health of people and wildlife. Each of these can lead to positive secondary outcomes including lower obesity rates, reduced rates of chronic disease infections, and increased life expectancy.[10]

Green infrastructure, trees, and landscape have also been shown to improve physical and mental health. The addition of street trees and vegetation in green infrastructure may also improve social interaction and encourage a greater sense of community belonging.[11] Hospital patients with views of nature were found to experience less severe pain, shorter hospitalization stays, less anxiety, and higher hospital and room satisfaction.[12] Dementia care facilities that have gardens have been shown to contribute to reductions in medication use and in the number and severity of falls.[13]

10 Children Living in Areas with More Street Trees Have Lower Prevalence of Asthma; Lovasi, G.S., and others; 2008: reports that the rate of asthma fell by 25% for every extra 340 trees per kilometer, and that residents in areas with the highest levels of greenery are three times as likely to be physically active and 40% less likely to be overweight or obese than residents living in least green settings. How Neighborhoods Can Reduce the Risk of Obesity; Rand Corporation website; https://www.rand.org/pubs/research_briefs/RB9267/index1.html. This website provides various cases studies and sources regarding how access to parks and playgrounds, and other factors affect and can reduce obesity. Additional public health and other benefits and related case studies are available at https://www.epa.gov/green-infrastructure/benefits-green-infrastructure .

11 Nature-based Recreation, Mood Change, and Stress Restoration; Michael Se Hull; Leisure Sciences; 1995: indicates that visiting parks lowered anxiety and sadness. Nearby Nature a Buffer of Life Stress among Rural Children; Nancy M. Wells and Gary W. Evans; Environment and Behavior 35.3; 2003: reports that elementary school children's stress is reduced with contact with nature. The Value of Trees to a Community; Roger S. Ulrich; Arbor Day Foundation; June 2011: found that exercising in natural environments contributes to improved mental wellbeing and positive engagement. In addition, Social Benefits of Civic Nature; K.L. Wolf; Master Gardener; Winter 2008: reports that studies of inner-city neighborhoods indicate that shared green spaces, and especially those with trees, are associated with residents having higher levels of supportive patterns of interaction.

12 View through a window may influence recovery from surgery. Ulrich, R.S., Science 224, 1984. 27, 420.

13 Scheduled medications and falls in dementia patients utilizing a wander garden. Detweiler, M.B., P.F. Murphy, K.Y. Kim, L.C. Myers, & A. Ashai. American Journal of Alzheimer's Disease and Other Dementias 24, 2009, 322-332.

Green Infrastructure Planning and Implementation Coordination

Local Green Infrastructure Plans will aid jurisdictions in planning for, permitting, implementing, and tracking green infrastructure opportunities and projects. It is important for the different departments and divisions in jurisdictions to regularly coordinate on items and issues such as existing and future capital improvement and development projects, funding opportunities, and planning and policy updates and documents. Coordination across departments, such as public works, transportation, planning, maintenance, parks and open space, public health, and urban forestry, can keep everyone abreast of potential green infrastructure opportunities and how to efficiently implement and maintain them. Staff should meet regularly to identify and discuss street reconstruction projects, upcoming grant opportunities, and maintenance issues.


NEVUE NGAN ASSOCIATES

▲ *Rain gardens can hold and treat larger volumes of runoff.*

1.1 Sustainable Stormwater Design Basics

Sustainable Stormwater Measures

CD+A

Disconnected downspouts reduce runoff from entering the storm drain.

CD+A

Pervious pavement and stormwater planters provide an attractive environment throughout the year.

A range of measures can be used for stormwater management and treatment. There are site design measures that reduce the land disturbance and minimize the amount of impervious surface directly connected to the storm drain system. There are also source control measures or "good house-keeping practices" to prevent stormwater pollution, such as maintaining trash enclosures, street sweeping and maintaining inlets and catch-basins. Finally, there are stormwater treatment measures or "structural controls" that are designed to capture, store, and/or treat urban runoff. These include bioretention, street trees, and pervious paving, to name a few. The primary focus of this guide is to provide design guidance and strategies for these types of structural stormwater measures.

To simplify the analysis of green infrastructure opportunities in San Mateo County, the Countywide Program has developed a three-tier typology of sustainable stormwater measures, including Green Streets, Site-based Low Impact Development (LID), and Regional Capture Projects. This typology was developed in the **San Mateo Countywide Stormwater Resource Plan** (completed in 2017) to prioritize and visualize green infrastructure opportunities in feasible public rights of way and publicly owned parcels in the county. Below are examples of existing or conceptual projects across the three categories in San Mateo County.

Case Studies: Regulated and Non-Regulated Projects and Treatment Measures

Green Street

The City of Burlingame was awarded a Metropolitan Transportation Commission One Bay Area Grant to implement the Carolan Avenue Complete Street project to calm traffic by converting a 4-lane roadway with sharrows into a 2-lane road with center turn lane and buffered bike lanes. The City also provided funds towards the project costs. Stormwater curb extensions with ADA ramp and crosswalk improvements are provided at intersections to improve pedestrian safety crossing the streets. While the project was determined to not be a regulated project, the city voluntarily included the nine stormwater curb extensions to manage and treat stormwater runoff. Due to the limitations of the project and the available space for the green infrastructure, the resulting stormwater facilities do not treat all of the runoff from the drainage area. Runoff that is not captured by the stormwater curb extensions flows into overflow structures within them or out of the facility and into new or existing drop inlets downstream. The stormwater curb extensions use biotreatment soil media and the depth of the biotreatment soil media (BSM) is greater around the trees to accommodate the larger root ball size of the tree and to provide more soil for the tree's roots and improved health. This approach to green street design is appropriate in more dense and urbanized areas of San Mateo County. See **Section 4.12** for guidance on the design and allowable reduced sizing of green infrastructure in constrained rights of way of non-regulated street projects that cannot met the treatment facility sizing requirements for regulated projects.

MATT FABRY

1.1 Sustainable Stormwater Design

Sustainable Stormwater Measures

CD+A

Regulated Building and Site Project

Lyngso Garden Materials, at 345 Shoreway Road in San Carlos, California, uses curb cuts and rain gardens adjacent to parking lots and disconnected building downspouts directing roof rainwater into raised bioretention planters to collect and treat runoff, as well as perform water harvesting to use the rain for irrigation. Building and site projects that are less dense typically use these types of bioinfiltration or bioretention areas in parking lots and around buildings.

CD+A

Regional Project

To-date, one regional scale multi-benefit stormwater capture project has been constructed in San Mateo County at Orange Memorial Park in the City of South San Francisco. This first-of-its kind project was funded through a Cooperative Implementation Agreement with Caltrans for design and construction. The City of South San Francisco now operates the regional stormwater retention project in collaboration with the San Mateo County Flood and Sea Level Rise Resilience District. The project includes a gravity diversion from the Colma Creek channel, where the water is piped to a subsurface cistern and infiltration chamber beneath the newly replaced athletic fields to capture, store/reuse, and infiltrate stormwater that drains from portions of South San Francisco, Colma, Daly City, Pacifica and Unincorporated San Mateo County. The project removes sediment and trash for the portion of flow that returns to the channel, recharges groundwater, provides treated stormwater for landscaping in the park and adjacent trails and supports the community with a revitalized park. This project also aids in alleviating flooding in the lower reaches of Colma Creek.

CITY OF SOUTH SAN FRANCISCO/ DESIGNER: LOTUS WATER

SAN MATEO COUNTY STORMWATER RESOURCE PLAN

1.2 Existing Regulatory Framework & Related Policies and Programs

Existing Regulatory Framework

Municipal Regional Stormwater Permit (MRP)

This section provides additional detail regarding the San Francisco Bay Regional Water Quality Control Board's Municipal Regional Stormwater Permit (MRP) regulatory requirements for implementation of green infrastructure. This is the 'primer' section for those who are less familiar with the MRP and explains the requirements to comply with the provisions of the MRP.

The MRP governs the treatment and discharge of stormwater and other waters from cities and towns into natural waterways. Provision C.3 of the MRP provides requirements related to New Development and Redevelopment projects, and implementation of Green Infrastructure Plans. Provision C.3 measures are directly related and linked to MRP provisions C.11 Mercury Controls and C.12 Polychlorinated Biphenyls (PCBs Controls). Together, these three MRP provisions are designed to achieve mandated reductions in pollutants of concern impacting the Bay (i.e., mercury and PCBs). More information about pollutants of concern and other contaminant reductions and controls can be obtained from the MRP.[14]

C.3 Provisions for New and Redevelopment

The development or redevelopment of property represents an opportunity to incorporate green infrastructure measures that can reduce water quality impacts over the life of a project. The MRP includes requirements for incorporating green infrastructure treatment and site design measures into new development and redevelopment projects. These requirements are known as Provision C.3 requirements.

Provision C.3.c establishes thresholds at which new development and redevelopment projects must comply with Provision C.3, although the municipal stormwater permit also requires agencies to encourage all projects subject to local development review to include adequate source control and site design measures that minimize stormwater pollutant discharges. Regardless of a project's need to comply with Provision C.3, municipalities apply standard stormwater conditions of approval for projects that receive development permits. These conditions of approval require appropriate site design, source control measures, and,

◀ *Bioretention planter and pervious pavers treat stormwater runoff for multi-family project.*

14 San Francisco Bay Regional Water Quality Control Board, Municipal Regional NPDES Permit (MRP 3.0), adopted in 2022 and amended in 2023, comprises Order Nos. R2-2022-0018 and R2-2023-0019.

in some cases, treatment measures and hydromodification control measures. Note that Provision C.3.j.i defines the requirements for Green Infrastructure Plans, including prioritized green infrastructure in public projects. For clarity in the GreenSuite documents, green infrastructure that is developed to satisfy Provision C.3.c are referred to as "regulated projects".

As noted earlier, the updated C.3 Stormwater Technical Guidance document is now referred to as the **C.3 Regulated Projects Guide** and, along with this guide, forms the GreenSuite.

Green Infrastructure Plans

As adopted by each co-permittee, Green Infrastructure Plans provide a process and accounting system for communities to transition from more engineered stormwater and impervious solutions to one that is greener, with more sustainable and natural solutions.

The following is a summary of the components of Green Infrastructure Plans as defined in the previous MRP's Provision C.3.j.i.(2); refer to MRP 2.0 for the full description.

(a) Create and implement a mechanism for prioritizing and mapping all potential and planned green infrastructure projects anticipated to be implemented by 2020, 2030, and 2040; identify opportunities to treat runoff from streets and private parcels in retrofitted public streets (i.e.; green or sustainable streets); incorporate projects into long-term planning and capital improvement processes; and identify criteria for prioritization of these green infrastructure projects.

(b) Provide outputs from (a), above, to include: maps of green infrastructure opportunities to treat runoff from streets and private parcels in retrofitted public streets, and prioritization criteria for these green infrastructure projects.

(c) Define targets for the amount of impervious surface of all projects to be retrofitted over the 2020, 2030, and 2040 time frame periods.

(d) Create and implement a process for tracking and mapping completed green infrastructure projects.

(e) Develop streetscape and project design and construction guidelines that implement green and complete street concepts and functions.

(f) Develop standard specifications, typical design details, and related information for design and construction of green infrastructure in street and other projects.

CD+A

▲ *Certain street projects, such as this new street, are required to meet C.3 provisions of the MRP.*

PAUL HATHAWAY

▲ *The use of pervious pavement helps to reduce impervious areas.*

1.2 Existing Regulatory Framework & Related Policies and Programs


CD+A

▲ *Green infrastructure associated with new and re-development is one of a host of measures to improve water quality.*

CD+A

▲ *Signage alerts the public to the benefits of and protection for rain gardens.*

(g) Define requirements to meet the treatment and hydromodification sizing requirements of the MRP and describe an alternative approach for specific issues or scenarios when projects cannot be defined to meet the sizing requirements. [Refer to **Section 4.12** for guidance on alternative, or reduced, sizing and design of green infrastructure facilities of non-regulated street projects within constrained rights of way.]

(h) Provide a summary of planning documents that have been updated or modified to incorporate green infrastructure improvements, prior to the end of the permit term (December 31, 2020).

(i) Provide a workplan identifying how green infrastructure measures will be appropriately included in future plans.

(j) Create a workplan for completion of prioritized green infrastructure projects.

(k) Provide an evaluation of funding options to support and implement prioritized projects.

Green Infrastructure Plans were adopted and submitted to the Regional Board as part of each jurisdiction's 2019 Annual Report.

Reasonable Assurance Analysis

A Reasonable Assurance Analysis (RAA) is required by the MRP to demonstrate quantitatively that mercury and PCBs load reductions can reasonably be achieved by 2040 with the implementation of green infrastructure within the Bay Area permit-area generally and San Mateo County specifically. The model developed for the **San Mateo Countywide RAA** model establishes the relationships between the overall amount of green infrastructure implementation and the quantity of runoff volume and the overall amount of green infrastructure needed to achieve incremental reductions of mercury and PCB loadings through stormwater capture, infiltration, and/or treatment in San Mateo County watersheds. The RAA establishes a robust quantitative linkage between runoff volumes managed with green infrastructure and mercury and PCB loads to demonstrate phased reductions to meet total maximum daily load (TMDL) wasteload allocations set by the MRP at 2020, 2030, and 2040. The **San Mateo Countywide Stormwater Resource Plan (SRP)** developed by C/CAG identified suitable locations for three types of stormwater capture projects through a desktop analysis using screening criteria to identify project opportunity. That assessment of spatial opportunity will be used in conjunction with physical and process parameters to represent regional stormwater capture projects, green street, and LID in the RAA model. See **Section 1.3 Local Green Infrastructure Policies and Programs** for further information on the SRP. Further definition of green street opportunities, and prioritization of these opportunities, will be developed in the **Countywide Sustainable Streets Master Plan** that C/CAG is preparing.

The RAA focuses on determining the extent of green infrastructure needed at the sub-watershed level, and summarized by jurisdiction, needed to meet the MRP load reduction targets for mercury and PCBs, though the water quality benefits of green infrastructure exceed those associated with these two pollutants. The cost-optimization of the RAA results allows individual agencies in San Mateo County to determine at the sub-watershed or jurisdictional scale, the most efficient “recipe” of sustainable stormwater control measures to achieve the required load reductions by 2040.

Related Policies and Programs

San Mateo Countywide Water Pollution Prevention Program

The Countywide Program’s member agencies derive their authority to regulate stormwater quality and hydrograph modification impacts primarily from their stormwater ordinances. These regulations may be enhanced as member agencies adopt their Green Infrastructure Plans. Related municipal code sections, planning documents, resolutions, policies and standard procedures are also important regulatory sources; and revisions to these documents are called for in the MRP. Each municipal stormwater ordinance may have unique elements, but they provide the municipalities the authority to implement the MRP, including the requirements of Provision C.3 as described above.

The Countywide Program has a range of documents available for reference and use for member agencies and interested parties related to the C.3 New and Redevelopment provisions. These documents can be found at www.flowstobay.org/newdevelopment. In support of the Green Infrastructure Plan preparation, various model documents were developed by the Countywide Program, including the GreenSuite. It is recognized that individual jurisdiction modification of GreenSuite components, especially the typical details and specifications for sustainable streets projects, may be necessary to address local conditions and community context.

CD+A

▲ *Green infrastructure can be implemented on most urban and rural streets to help meet and exceed goals for water quality and pollutant levels.*

CITY OF FOSTER CITY

▲ *Streets and parking lots cover a large percentage of the built environment. Pervious pavements such as these permeable pavers can aid in providing drivable and walkable surfaces that treat and infiltrate runoff.*

1.3 Local Green Infrastructure Policies & Programs

Member agency planning, guidance, and other documents are required by the MRP to be reviewed and revised to integrate policy, standards, and guidance that will support efficient planning, design, construction, and maintenance for green infrastructure within member agencies' jurisdictions. The process of updating relevant planning, guidance and policy documents is a good opportunity to also consider addressing the broader goals and benefits of implementing green infrastructure. These include: sea level rise, flood control, healthy and safe communities, integrated multimodal transportation, sustainability, climate adaptation and resiliency, urban forestry and urban greening, water conservation, and open space management.

Green Infrastructure Plans

As noted earlier, Green Infrastructure Plans are local planning documents that the MRP requires jurisdictions to prepare and adopt. Green Infrastructure Plans determine, define, and support local green infrastructure goals, policies, and guidance to meet target stormwater pollutant load reductions for mercury and PCBs, and to create a process for prioritizing integration of green infrastructure into capital improvement projects. A crucial aspect of Green Infrastructure Plans is the consistent and thorough integration of green infrastructure benefits, elements, policies, and guidance across all relevant jurisdictional planning and design documents.

Countywide Stormwater Resource Plan

The SRP, and the RAA (see **Section 1.2 Existing Regulatory Framework and Related Policies and Programs** discussed above), develop long term policies, identify green infrastructure opportunities throughout the county, and determine the extent of green infrastructure needed to meet mandated pollutant reduction targets. The San Mateo Countywide SRP provides a quantitative and transferable methodology for identifying and prioritizing opportunities to manage stormwater runoff using a watershed-based approach to attain a host of regional and community benefits, including reduced flooding, pollution control, and improved neighborhood character. The SRP also begins to define an adaptive management system that allows individual member agencies to adapt the countywide approach to community-specific priorities and opportunities that may change over time, and to identify opportunities to coordinate with other agencies to implement regional opportunities that benefit multiple agencies. To learn more about the SRP, please refer to www.flowstobay.org/data-resources/plans/srp/. The SRP is also an essential document for San Mateo countywide agencies, as it allows them to submit for state grant funding to implement stormwater management projects such as green and complete streets and regional water quality projects.

◄ *This stormwater planter captures and treats runoff from both the sidewalk and adjacent parking lot.*

San Mateo County Sustainable Streets Master Plan

C/CAG created the Sustainable Streets Master Plan in collaboration with Caltrans under a Climate Adaptation Planning Grant Program. This long-term planning effort builds on years of watershed modeling and stakeholder input, and takes a closer look at how and where to build sustainable streets in San Mateo County that integrate stormwater management with local priorities, like bike and pedestrian mobility, transit improvements, climate change adaptation, and more. The plan also includes a down-scaled climate change analysis to better understand the potential future precipitation related impacts from climate change and how green stormwater infrastructure can help adapt to changing conditions. For more information, see www.flowstobay.org/data-resources/plans/sustainable-streets-master-plan/.

General Plans, Specific Plans, Precise Plans, Municipal Codes, and Development Standards to Define Local and Subarea Plans, Policies, and Guidance

Planning and guidance documents can describe the benefits of and require green infrastructure elements in public and private projects, as well as provide consistent design and maintenance standards and guidelines on where and how to implement green infrastructure. The MRP requires that revisions to these documents be made, as necessary, for them to require and support appropriate implementation of green infrastructure improvements to meet the goals of the MRP. Plan chapters that may be expected to include references to green infrastructure include Mobility or Circulation, Health, Urban Design, Infrastructure, Open Space and Conservation, and Sustainability. Development standards should include detailing and specifications for the construction of green infrastructure elements, plant palettes, soil mix, mulch types, and other elements of constructing and maintaining green infrastructure. See the *East Palo Alto General Plan Update* sidebar for a summary of green infrastructure and related stormwater management goals and policies from that document. These are good examples of what can be included in planning documents to support green infrastructure implementation through policy updates.

East Palo Alto General Plan Case Study of Green Infrastructure Supportive Goals and Policies

The *East Palo Alto General Plan* was adopted in October 2016 and includes a stormwater goal with related green infrastructure and other policies. These can provide a starting place for other communities in developing their own goals and policies; see page 9-7 of the City's *General Plan 2035* (www.cityofepa.org/econdev/page/general-plan-2035-east-palo-alto).


CITY OF DALY CITY

▲ *Rain gardens are one of many options to manage localized stormwater runoff that also improves neighborhood character.*

CD+A

▲ *Stormwater planters can be used in a variety of land use contexts and street types.*

1.3 Local Green Infrastructure Policies & Programs

CD+A

▲ *Green infrastructure measures can provide habitat for pollinators and other wildlife.*

CD+A

▲ *Green infrastructure along a bike lane.*

Goal ISF-1. Manage stormwater safely, efficiently, and sustainably.

Intent: To reduce dangers from flooding, protect community safety and property, and provide well-maintained infrastructure to the community while reducing the negative environmental impacts of storm run-off on creeks and the Bay.

Policy 1.5 Collaborative stormwater management: Encourage collaborative, integrated stormwater management between multiple property owners and sites.

Policy 1.6 Green infrastructure in public rights-of-way: Encourage green streets with in-street bioretention and other forms of stormwater retention and infiltration in streets and public rights-of-way.

Policy 1.7 Regional and local collaboration: Collaborate with Palo Alto, Menlo Park, the San Francisquito Creek Joint Powers Authority and other jurisdictions and agencies in the watershed to reduce and remove contaminants from stormwater runoff.

Policy 1.9 Stormwater and flooding: Integrate stormwater management efforts with flood control efforts, seeking synergies and innovative strategies for stormwater treatment to reduce flood risks and volumes.

Climate Change Action Plans and Other Resiliency Planning Documents

Climate resiliency and adaptation documents are opportunities to discuss how green infrastructure can address and mitigate climate change. Policies, action items, and other measures should relate to specific green infrastructure considerations. For example, climate action plans may have policies encouraging the planting of street or stormwater trees to remove carbon from the atmosphere, and provide benefits of reducing urban heat island effects, while reducing flow and improving water quality

Climate Change Action Plans and Other Resiliency Planning Documents

Climate resiliency and adaptation documents are opportunities to discuss how green infrastructure can address and mitigate climate change. Policies, action items, and other measures should relate to specific green infrastructure considerations. For example, climate action plans may have policies encouraging the planting of street or stormwater trees to remove carbon from the atmosphere, and provide benefits of reducing urban heat island effects, while reducing flow and improving water quality (see **Section 1.1 Benefits of Green Infrastructure** for a discussion of urban heat island effects). These policies should also address both climate resiliency and stormwater management goals and include a reference to the community's Green Infrastructure Plan.

Stormwater Management Plans, Flood Prevention Plans, and Hazard Mitigation Plans

Plans and policies addressing flooding and management of stormwater can highlight the function, use, and adaptability of green stormwater infrastructure to help manage stormwater runoff and aid in the reduction of flooding and erosion, increased water table elevations, higher storm and tidal surges, and related hazards. These plans should refer to community's GI Plans and support implementation of green infrastructure, because it is part of a holistic approach in limiting the impacts of flooding and other issues and reduce over straining storm drain systems at critical points.

Green and Complete Street Plans and Other Similar Documents

Green and complete street plans and other pedestrian and bicycle facility plans are important documents to guide the integration and implementation of green infrastructure elements in new and retrofit street projects, including within the roadway or behind the curb but within the right of way. Integrating green infrastructure with complete streets projects is critical for maximizing the potential for implementation of the green street opportunities identified in the SRP and RAA because many of these opportunities have already been identified through local bicycle and pedestrian plans. Green infrastructure measures can be added seamlessly to features such as corner curb extensions and tree well filters. (See City of San Mateo *Sustainable Streets Plan and Guidelines* sidebar for discussion of that community's integrated complete and green streets plan and guidelines).

CITY OF SAN CARLOS

▲ *Public uses such as parks are good locations for capturing and treating runoff. This rain garden also provides a landscaped buffer to the basketball courts.*

CD+A

▲ *Opportunities to integrate multimodal and other improvements into the planning and design of green infrastructure projects should be considered and included.*

1.3 Local Green Infrastructure Policies & Programs

▲ *Detail pages from the San Mateo Sustainable Streets Plan and Guidelines.*

City of San Mateo Sustainable Streets Plan and Guidelines

The *Sustainable Streets Plan and Guidelines* combine policies and guidance on both complete streets and green streets into an integrated program and lays out the path to “a transportation system that is sustainable, safe, and healthy and supports a sense of community and active living, where walking, bicycling, and transit are integral parts of daily life.”

The *Sustainable Streets Plan* promotes the direct integration of green infrastructure – and other general landscape improvements – into the street design process to take full advantage of landscape and hardscape elements that can capture, slow, and treat stormwater runoff. This approach generates additional benefits with respect to placemaking in the public realm, enhancement of the overall pedestrian experience and economic and community vitality as well as environmental benefits. A range of green streets elements are identified that are appropriate for the street right-of-way, allowing the street designer to select individual or combinations of general landscape and green infrastructure functions and benefits most appropriate to the local conditions. These include stormwater management needs, soil and hydrological conditions, urban design context, and multimodal transportation needs. Examples of design characteristics discussed in the guidelines include the detailing of hardscape elements such as planter walls or pavement design and materials, and plant selection, as well as the potential need for underdrains in a given location.

Go to https://bit.ly/2QrNMDl to download the *Sustainable Streets Plan and Guidelines document.*

Green Infrastructure Functions, Design Considerations, and Strategies 1.4

Green Infrastructure Functions

The selection and use of green infrastructure treatment and site design measures should reflect the type of treatment needed, what is possible at each specific site in terms of physical and environmental opportunities and constraints, and additional goals of the community and project. Green infrastructure elements provide a diversity of functions to manage and treat stormwater runoff and rainwater and can serve individually or as part of a treatment train. Stormwater treatment and design measures most applicable to the conditions found in San Mateo County are identified and described in this section to aid in understanding their function and usage.

Green infrastructure provides a variety of functions, including infiltration, bioretention, pollutant removal, interception, and detention – note that more detailed and technical definitions are provided in **Appendix 1, Glossary**. Together, these functions help reduce, manage, and treat stormwater runoff.

Bioretention is the process of reducing peak runoff rates and volumes, as well as providing stormwater treatment through green infrastructure.

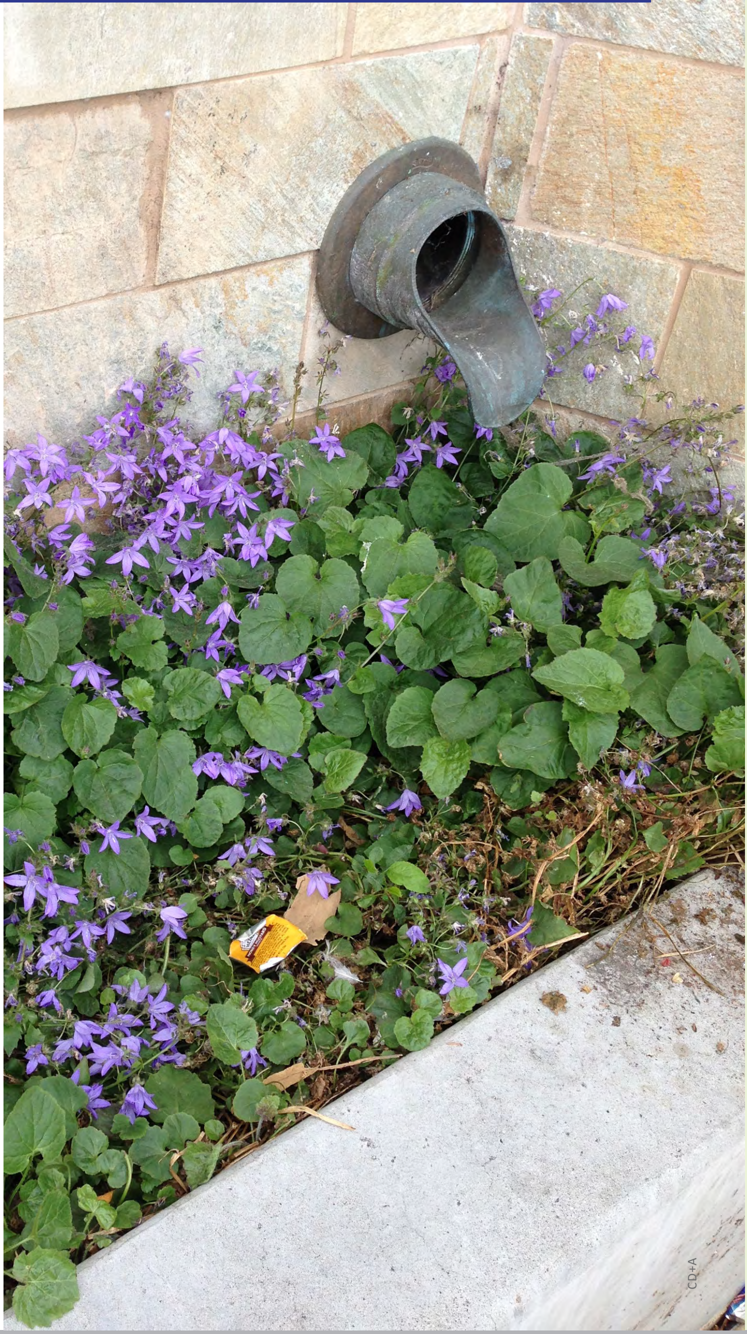
Detention is the process of providing treatment through the temporary storage of stormwater runoff that permits sediments to settle before the water is discharged; can also reduce peak flows into the stormwater system.

Infiltration is the process of slowing, filtering, and soaking stormwater runoff into native soil.

Interception is where trees and other elements collect and capture rainfall prior to rainfall contacting an impervious surface and becoming stormwater runoff.

Pollutants such as trash, debris, sediment, chemicals, and other elements can be *removed or reduced* from runoff. Green infrastructure can aid in trapping, reducing, treating, or uptaking pollutants.

For more information, see **Table 2-1** in **Chapter 2 Green Infrastructure Measures and Opportunities** which references the various green infrastructure function(s) relative to a specific green infrastructure measure.



Rainwater runoff from rooftops can be directed to planters for treatment.

1.4 Green Infrastructure Functions, Design Considerations, and Strategies

CD+A

▲ *Green infrastructure can provide naturalistic amenity within communities and open space systems.*

CD+A

▲ *Plants aid in capturing trash and debris before it enters the storm drain system.*

Site Specific Design Considerations for Green Infrastructure in San Mateo County

Due to the variations in the available space, soil, hydrology, land use, climate, slope gradient, elevation, and other conditions found in specific locations, a "one size fits all" approach is not possible in the planning, design, implementation, and maintenance of green infrastructure. For locations in San Mateo County, prevalent site-specific conditions include high-ground water, often found near the San Francisco Bay; soils with a high clay content and limited infiltration potential; and the broad range of land use characteristics including rural, suburban, and urban conditions. Following is a summary of some of these considerations, as well as strategies to address these conditions. Additional strategies are presented elsewhere in this guide.

Soil Conditions and Hydrology

Soil conditions and hydrology vary considerably in San Mateo County. In some cases, infiltration may be difficult due to steep hillsides, high water table, or non-permeable soils. Various methods for designing green infrastructure facilities in these difficult conditions do exist, however, including stepping structures with the slope of the land, wrapping the facility with an impervious barrier, building the green infrastructure above the native soil, or over-excavating the clayey or contaminated soils and using subdrains.

Trash Removal

The MRP requires the removal of trash prior to entering stormwater systems and natural waterways. While there is no substitute for preventing trash from ending up on city streets and sites, green infrastructure stormwater elements can serve as localized collectors. Trash that would otherwise end up in San Mateo County's waterways can be regularly removed, recycled, or discarded in an environmentally appropriate way through a regular maintenance schedule of the green infrastructure, see **Chapter 6 Operations and Maintenance**. In addition, educational signage can discourage littering and encourage passerbys to pick up trash when found.

Utility Conflicts

For street retrofit and other projects with utility easements, underground and surface mounted utilities such as pipes and street lights can create a conflict with the location and design of green infrastructure elements. In such instances, different types or locations of green infrastructure features will need to be considered and designed, as well as the use of special detailing to work around or enable existing utilities to protrude into and through the green infrastructure feature. This condition is especially common in denser and developed areas.

Constrained Areas

In areas that are constrained by one or more issues such as narrow street rights of way, small parcels with high levels of building coverage, areas with utility conflicts, or urban conditions that require large areas of pavement for transportation, the use of modular suspended pavement systems or pervious pavements can contribute to green infrastructure implementation. Increasing the depth of the facility may be feasible in some cases or using alternative accounting measures. Also refer to **Section 4.12** for alternative sizing and design guidance for green infrastructure projects in constrained non-regulated street projects. This guidance allows for green infrastructure measures to use a smaller sizing factor and be counted towards the treatment of impervious area and reduction in pollutants.

Land Use

Different levels of development density and intensity, as well as the type of land use, can affect the type, location, and distribution of green stormwater infrastructure. Where developments are denser, there is less room to provide surface level green infrastructure on the site. This situation may require other types of treatment options, such as subsurface facilities, raised bioretention planters, shared public/private facilities within the street or on offsite parcels, and green roofs.

Sediment Removal

Because PCBs and other pollutants attach themselves to sediment and tend not to dissolve into water easily, it is becoming increasingly important to trap and remove sediment prior to it entering municipal stormwater and natural drainage systems. Forebays, sediment basins, or other techniques should be integrated into the design of green infrastructure elements and maintained on a regular basis to limit the buildup of sediment in green infrastructure and ensure these systems operate as designed.

▲ *Pervious pavements can provide firm footing in constrained areas.*

▲ *The locations of new and existing utilities need to be assessed before locating and designing green infrastructure.*

Chapter 2

Green Infrastructure Measures and Opportunities

◄ *This rain garden at The Cove at Oyster Point collects stormwater from both building and parking lot surfaces.* Photo Credit: Urban Rain|Design

2.0 Green Infrastructure Measures and Opportunities

Introduction

The Toolbox of Green Infrastructure Measures

This chapter provides design guidance for green infrastructure design measures that are most applicable to conditions found in San Mateo County. **Table 2.1** lists all the green infrastructure measures included in this Guide, in the order that guidance is provided in this chapter. For each green infrastructure measure, **Table 2.1** provides a recommended installation location and guidance for using it to fulfill Regulated Projects requirements. Finally, the table indicates what green infrastructure functions are typically provided by the various treatment measures and if this is a primary or secondary function of the green infrastructure measure.

Determining Opportunities for Green Infrastructure

Site Design Strategies

Before choosing and designing a stormwater facility, there are certain site design strategies that should be first explored to maximize a site's full potential to incorporate green infrastructure. Evaluate the site based on site conditions and context, as well as community goals, to identify potential types and locations where green infrastructure treatment and site design measures can be implemented. Refer to the jurisdictional agency's prioritization map for placement of potential green infrastructure where the project is located. Maximize permeable areas as feasible. Site conditions to pay particular attention to include:

- Hydrology of the site, including flooding, sea-level rise, water table depth, drainage patterns on-site and from adjacent areas.
- Soil conditions, such as percolation rates, compaction levels, and hazardous materials.
- Site topography, natural features, existing plant material.
- Locations of below and above ground utilities and other built structures.

Site context is also important in determining the type of green infrastructure measures to use for a specific project. Some considerations can include, but are not limited to:

- Is the site area in an urban, suburban, or semi-rural location in the community? This can affect the land area that may be available for the green infrastructure and its landscape character.
- If there are uses adjacent to or within the project itself, or other conditions occur that will result in higher levels of pedestrian activity, this can affect the hardiness of the landscape and design details of the green infrastructure.   The green infrastructure are may be constrained, and solutions such as pervious pavement and/or modular suspended pavement systems may be more appropriate.
- High demands on the use of limited sidewalk area or open space within a project, such as high pedestrian volumes or very limited space, can restrict the ability to provide adequate area for a healthy landscape. Design solutions in constrained sidewalk conditions include the use of pervious pavement and/or modular suspended pavement systems with tree planter areas to provide for green infrastructure under paved surfaces.
- Consider the function, size, and type of green infrastructure measure(s) appropriate for the site and project.
- Assess how other community benefits and goals can be incorporated into the design of the project.
- Consider the private or public entity's ability to operate and maintain green infrastructure, refer to the **Chapter 6 – Operations and Maintenance**.

The last step is to select the type of green infrastructure measure(s) based on considerations listed above.


CD+A

▲ *The redevelopment of the adjacent multi-family project provided an opportunity for this green infrastructure measure to treat runoff from both public and private areas.*

CD+A

▲ *Multimodal improvements such as this bike boulevard project provide opportunities for the integration of green infrastructure.*

2.0 Green Infrastructure Measures and Opportunities

Introduction

A Visual Guide of Green Infrastructure Measures

Stormwater Planters

Stormwater Curb Extensions

Rain gardens

Green Gutters

Tree Well Filters

Stormwater Trees

Trees in the Landscape

Infiltration Systems

Pervious Pavement

Green Roofs

Green Walls

Rainwater Harvesting

Vegetated Swales

Table 2.1 Green Infrastructure Measure Applicability

Green Infrastructure Measures	Guidance Location	Suitable Green Infrastructure Location				C.3 Regulated Project Type		Primary and Secondary Functions				
		Site	Parking Lot	Building	Street	Stand-alone Treatment	Element of Treatment Train	Infiltration[1]	Bio-Retention	Pollutant Removal	Interception	Detention
Stormwater Planter[2]	2.1, 3.5	●	●		●	●		■ / □	■	■	□[3]	■ / □
Stormwater Curb Extension	2.2, 3.5		●		●	●		■ / □	■	■	□[3]	■ / □
Rain gardens	2.3, 3.5	●	●		●	●		■ / □	■	■	□[3]	■ / □
Green Gutter	2.4, 3.5	●	●		●			■ / □	□	□		
Tree Well Filter	2.5, 3.5	●	●		●	●		■ / □	■	■	■	■ / □
Stormwater Tree	2.6, 3.5	●	●		●			■ / □	□		■	
Trees in the Landscape[4]	2.7, 3.5	●	●	●	●					□	■	
Infiltration Systems	2.8, 3.5	●	●		●	●	●		□	■		■ / □
Pervious Pavement	2.9, 3.5	●	●		●	●	●	■ / □		■		■ / □
Green Roof	2.10	●		●		●[5]			■	■	■	
Green Wall	2.11			●					□	□	■	
Rainwater Harvesting[6]	2.12	●	●	●		●						■
Vegetated Swale	2.13, 3.5	●	●		●		●	■ / □		□	■ / □	

Endnotes

1. Where site-specific percolation tests confirm that an infiltration rate of 0.5/hour is realistic, see **C.3 Regulated Projects Guide** for further discussion.
2. Alternative Term: "Bioretention Swale" – linear rain gardens, not the same as "Vegetated Swale".
3. Primary Function if trees are included in design.
4. Pertains to trees as site design measures for regulated and non-regulated projects.
5. If built to specifications approved by Regional Water Board.
6. Includes cisterns, rain barrels, and other measures and strategies for maximizing use of rain water for non-potable uses such as toilet flushing or landscape irrigation.

Legend

- ● Applicable Green Infrastructure Measure
- ■ Primary Function
- □ Secondary Function
- ■ / □ Primary or Secondary Function Depending on Site Conditions and Design

2.1 Green Infrastructure Measures and Opportunities

Stormwater Planters

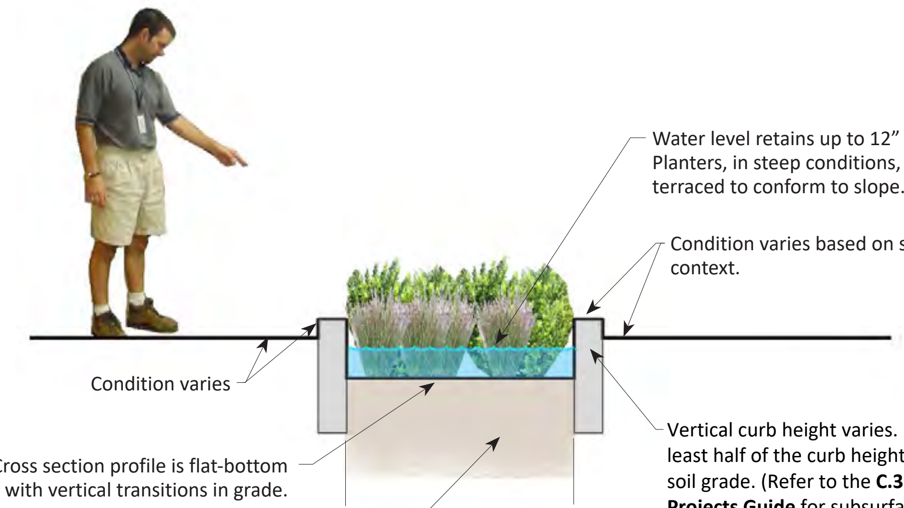
DEFINITION: Infiltration, bioretention, and flow-through stormwater planters are contained landscape areas designed to capture, treat, and retain stormwater runoff.

Stormwater planters are narrow, flat or nearly flat-bottomed, often rectangular, landscape areas used to treat stormwater runoff. Their most distinguishing feature is that the side slopes typically used in other treatment measures are replaced with vertical side walls. This allows for more storage volume in less space where site conditions are constrained. There are three types of planters used for stormwater management: infiltration, bioretention, and flow-through planters. All three types of stormwater planters are visually similar with differences being underground and in the details of design. Infiltration planters are designed to treat stormwater runoff and infiltrate it into native soil. Bioretention planters have an underdrain at the bottom of specialized engineered soil to capture excess water, but can still allow for infiltration. Flow-through planters are completely lined and contained systems that only allow runoff to soak through the planter's imported soil bed and then into an underdrain system. Infiltration planters are more desirable because they allow for greater volume reduction and further ease the burden on local storm drain facilities. Flow-through planters should be used where native soil conditions are unfavorable to infiltration, where there is underlying soil contamination, within 10 feet of building foundations or basements, or where the seasonal high- water table is within 10 feet of the landscape surface. When using infiltration planters and similar infiltration practices, follow the Infiltration Guidelines contained in the **C.3 Regulated Projects Guide.** Bioretention and flow-through planters typically include the following layers – an upper layer of mulch, a specified biotreatment soil mix with plants, and an underlying rock/gravel layer with an underdrain that connects to the stormwater system. Where infiltration is not possible, the facility will typically be lined with an impermeable layer and allowed to release all treated stormwater to an underdrain system.

Stormwater planters are easily incorporated into retrofit conditions and in places where space is limited. They can be built to fit between buildings and sidewalks, driveways, utilities, trees and other existing site or street elements. Planters can be planted with a simple palette of sedges and/or rushes or a mixture of trees and shrubs. Because planters have no side slopes and are contained by vertical curbs, it is best to use plants that will grow at least as tall as the planter's walls in order to help "soften" the edges. Planters can be used in both relatively flat conditions and in steep conditions if they are appropriately terraced.

◄ *A stormwater planter at Laurel Elementary School's main parking lot displays a planter's characteristic vertical drop in grade.*

URBAN RAIN DESIGN



The Anatomy of a Stormwater Planter

1. Cross section is typically flat-bottom with some form of vertical containment system
2. Planters can be either infiltrative, or use bioretention/flow-through with an underdrain system
3. 6-8” of stormwater runoff retention is ideal (Maximum of 12” of retention where space is limited)
4. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
5. Native soil condition (an underdrain system may be needed with some native soil conditions)
6. Composted wood mulch (see **C.3 Regulated Projects Guide** for mulch specification)

Why Choose Stormwater Planters?

- Are best landscape solution for urban locations, because they maximize capacity within a limited space.
- Can fit between other streetscape elements (trees, utilities, signage, etc.) and are highly versatile in shape and size.
- Can provide vegetation that buffers pedestrians and bicyclists from moving vehicles.
- Provides vegetation along streets, buildings, and parking lots which can increase community identity and soften the look of a built space.
- Can include trees that provide protection from sun, fostering a pleasant environment.
- Benches, public art, and other streetscape improvements can be integrated with stormwater planters.

Potential Constraints?

- Are generally more expensive than other green infrastructure options (like rain garden or vegetated swales) due to increased hardscape infrastructure needed to contain the stormwater planter landscape.
- Are only contextually appropriate in more urban settings.
- Depending upon depth of the stormwater planter and site context, a raised curb or low railing surrounding the landscape may be needed.
- Can be designed too deep when planters are designed with a small footprint.

2.1 Green Infrastructure Measures and Opportunities

Stormwater Planters

NEVUE NGAN ASSOCIATES

▲ *This is a flow-through and lined stormwater planter in a pedestrian plaza space that still allows for street trees.*

NEVUE NGAN ASSOCIATES

▲ *A stormwater planter integrated within a series of seatwalls elegantly manages stormwater runoff in areas of grade change.*

Opportunities for Buildings and Sites

Stormwater planters are a good candidate for building site applications to manage stormwater because they can often fit between pedestrian walkways, up against building alcoves, and between utilities, trees, and building furnishings. As long as there is a viable way to protect building foundations from direct contact of water and provide safe overflow and underdrain conditions, flow-through stormwater planters can be placed directly against building facades and can be of varying shapes and sizes. They can also be placed offset the building foundation and used for bioretention or direct infiltration of stormwater providing soil conditions are favorable for infiltration.

URBAN RAIN DESIGN

▲ *This stormwater planter at a high-density residential complex accepts building runoff and integrates a seating boardwalk over the landscape.*

Opportunities for Parking Lots

Stormwater planters can also be an effective design tool for parking lot applications. Parking lot stormwater planters can be designed to take the place of a few parking spots in the form of landscaped islands, or they can fit in the long, narrow space between the front-ends of parking stalls within the medians or perimeter zones of parking lots. Because parking lots generally lack shade from tree canopy, it is best to create large enough planters to manage stormwater and support larger shade trees.

URBAN RAIN DESIGN

▲ *This parking lot features a narrow infiltrative stormwater planter with a series of metal check dams that help slow and retain runoff.*

NEVUE NGAN ASSOCIATES

▲ *A stormwater planter within a parking lot's landscape island.*

NEVUE NGAN ASSOCIATES

▲ *A narrow stormwater planter at the edge of a parking lot.*

URBAN RAIN DESIGN

▲ *An at-grade stormwater planter within the interior median of a parking lot.*

2.1 Green Infrastructure Measures and Opportunities
Stormwater Planters

CD + A

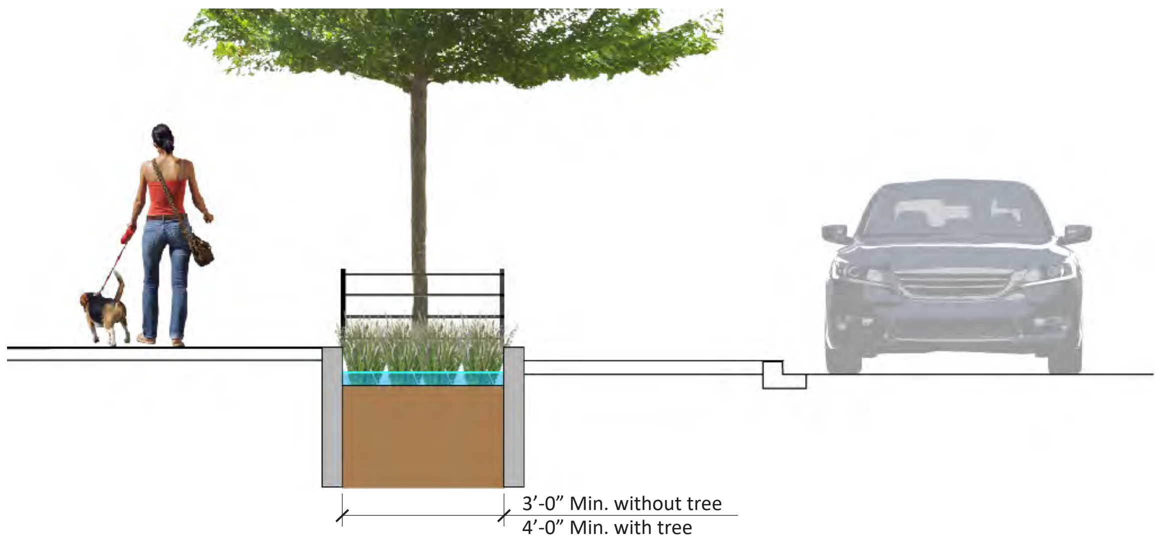
▲ *A stormwater planter separates both bicycle and pedestrian circulation from vehicular traffic.*

CD + A

▲ *This arterial street without on-street parking was retrofitted with a series of stormwater infiltration planters.*

Opportunities for Streets

Stormwater planters are very useful in new and retrofitted complete streets, because they provide benefits for all users of streets. They make excellent street retrofits where spatial conditions are constrained, such as locations where on-street parking demand is high, and/or if there is competition for space with street trees or utilities. Because of their versatility in size and shape, stormwater planters can be designed to capture significant runoff when built in a series along a street, inserted between driveways, pedestrian walkways and other street elements. Stormwater planters can be incorporated in many street types and contexts with the exception of more rural, suburban, and industrial locations or where sidewalks do not have enough space to accommodate them or they if they have the appearance of too much hardscape for the surrounding context. Stormwater planters typically occur behind the curb, in the sidewalk, but in shared streets, stormwater planters can be placed between the vehicle drive area and the primary pedestrian zone, as well as between vehicle travel lanes for traffic calming purposes. They can also be sited in medians and other islands in the roadway, if drainage patterns support these locations. In these scenarios, curbs or other techniques should be used to prevent vehicles or cyclists from entering the stormwater planter.



▲ *A stormwater planter located along a street should maintain at least a 3' width of vegetation, 4' minimum if the planter is also supporting a small street tree. Depending on the tree species, even wider stormwater planters may be required.*

Special Considerations for Stormwater Planter Design

Because stormwater planters are placed in areas that often have space constraints and near adjacent structures, the following design thoughts should be considered:

- Pedestrian access, perpendicular to the street, or where on-site circulation requires, will need to be provided across or through stormwater planters. This can be achieved with breaks between the planters, bridges, or other techniques. In lieu of breaks between planters for pedestrian access, stormwater planters can be bridged with grates, boardwalk, or pedestrian bridges to increase space provided for pedestrian travel, seating, or other transit infrastructure.

- Planters must be wider and deeper if a tree is planted in them. The size of the tree root ball and the number of trees in proportion to the planter must be considered to ensure that there is adequate space to plant the tree and that there is an adequate amount of soil in the planters to achieve C.3 credit.

- For street applications, sidewalks (the space between the back of curb and right of way/ property line) must be wide enough to accommodate minimum widths of a step out area, the stormwater planter itself, and the sidewalk zone. Sidewalk widths should be sized based on context and level of pedestrian use, as well as minimum path of travel requirements.

- For parking lot conditions, there should be wide enough space between a parking stall edge and a stormwater planter for people to enter and exit their vehicles without having to step onto or over stormwater planter. Egress widths should be sized based on context and level of pedestrian use, and, at least, the minimum path of travel requirements.

- Because planters have a vertical drop in grade to manage stormwater volumes, edge treatments and/or low railings are often utilized in the stormwater planter's design to help pedestrians detect the grade change from the walking surface to the planter's finish grade of soil (see **Section 3.1 General Design Strategies and Guidelines** for additional information on planter edge treatments).

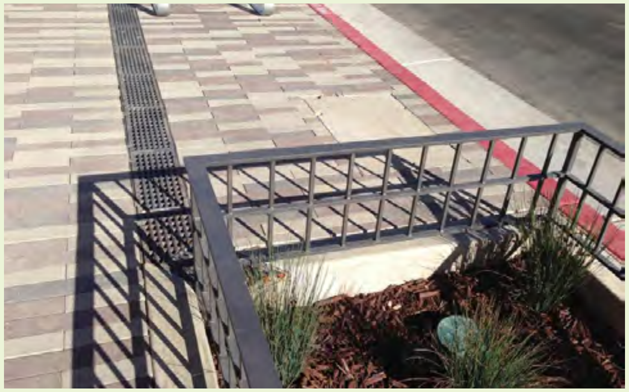
- For building applications, stormwater planters can be either elevated or in-ground to receive rooftop runoff.

KEVIN ROBERT PERRY

▲ *Pedestrians can cross over stormwater planters using bridges or metal grates without sacrificing surface landscape space.*

CD + A

▲ *Streets with on-street parking should have paved step out zones and frequent perpendicular access points to the sidewalk zone between planters.*



CD + A

▲ *Where there is significant drop in vertical grade, stormwater planters can use raised edges and/or perimeter low railings to allow pedestrians to detect the drop in grade.*

2.2 Green Infrastructure Measures and Opportunities
Stormwater Curb Extensions

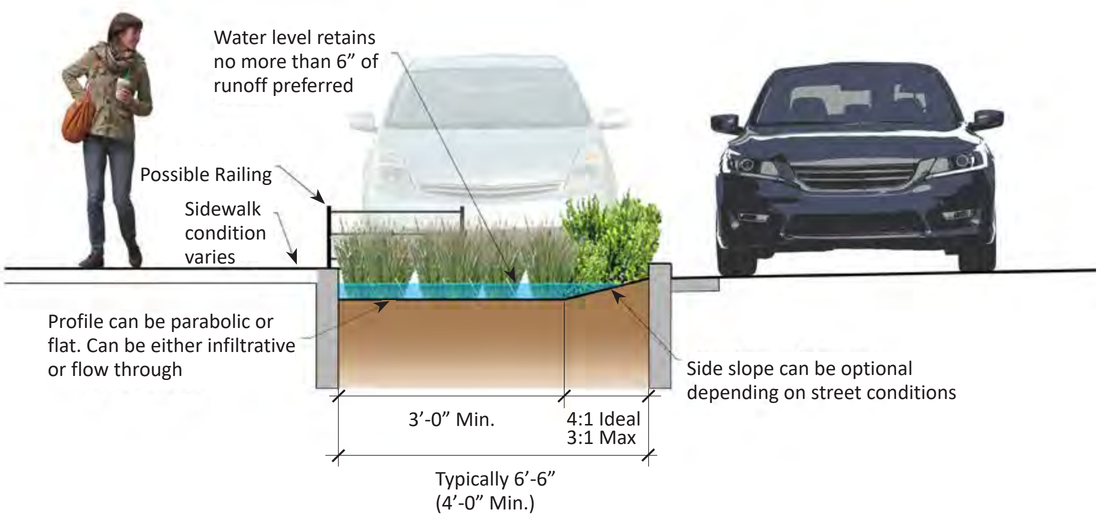

URBAN RAIN DESIGN

DEFINITION: A stormwater curb extension is a stormwater planter that is typically within the parking zone of a street or on-site parking area that captures stormwater and allows it to interact with plants and soil while also achieving complete streets goals for improving pedestrian access and safety.

A stormwater curb extension, also referred to as a stormwater bulb out or bump out, is a green infrastructure treatment measure consisting of a bioinfiltration or stormwater bioretention planter integrated into the extension of a street curb into the roadway within the parking lane. It captures, treats, and manages stormwater while also achieving complete streets goals, described below. Curb extensions are a frequently used feature in new and retrofitted complete streets as they provide many benefits for all users of streets. They are typically added at intersections to shorten the distance for people to walk across the street. In some situations, they can be added at mid-block locations.


CD+A

▲ *Stormwater curb extensions and bicycle improvements were integrated in this semi-rural mixed-use street retrofit.*



The Anatomy of a Stormwater Curb Extension

1. Cross section can be parabolic, trapezoidal, or flat-bottom
2. If side slopes are used they should be ideally set at a 4:1 slope (3:1 maximum) where a curb or low fence is not used, a flat shelf transitioning between the adjacent walking surface pavement and the slope
3. Preferred retention depth is 6" of stormwater (Maximum of 8" and in extreme constrained sites, a maximum of 12" if approved by the responsible jurisdiction)
4. Can be either infiltrative or flow-through with an underdrain system
5. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
6. Native soil condition (an underdrain system may be needed with some native soil conditions)

Why Choose Stormwater Curb Extensions?

- Useful in constrained sites.
- Useful in retrofit conditions.
- Provides complete streets benefits such as reducing traffic speeds and reducing pedestrian crossing distances.
- Can act as a "backstop" to capture stormwater flow on steep streets.
- Does not encroach into sidewalk area.
- Provides space for directional, rather than diagonal, ADA curb ramps.

Potential Constraints?

- Requires that street has on-street parking lane or shoulder to provide space for the curb extension.
- Can become overly deep due to adjacent grades and outfall flow elevations when stormwater volumes are high relative to space available.
- Available space in retrofit conditions may not align with drainage pattern.
- Where a protected bikeway passes between the curb extension and the sidewalk curb designing for stormwater function is more challenging.
- Typically results in removal of on-street parking.
- Certain intersections are not appropriate for curb extensions
- Utility lines, manhole covers, and other conflicting infrastructure often located in the parking lane of a street can limit the feasibility of a curb extension.
- Many older urban streets have a "high crown" cross section profile resulting from years of repaving with asphalt overlays, which increases the cross slope of the roadway and the grades/depth of the stormwater curb extension and can make it challenging to extend the curb out into the roadway. Removal of old asphalt will be needed, which adds to construction cost.

2.2 Green Infrastructure Measures and Opportunities

Stormwater Curb Extensions

CD+A

▲ *Example mid-block stormwater curb extension.*

CD+A

▲ *Stormwater curb extension helps frame an intersection corner bulbout. Stormwater enters the landscape from the curb cut along the parking zone in the background.*

Opportunities for Streets

Many streets can be designed or retrofitted to have a portion of the street's parking zone, other non-travel lane areas, or intersections turned into stormwater curb extensions. They are viable with parallel or diagonal parking, and particularly where red curbs currently exist. In some cases, the stormwater curb extensions can be designed so that the existing street curb and stormwater inlets can be left in place with modifications.

In areas where on-street parking is fully utilized, smaller stormwater curb extensions, spaced more frequently, can be used to minimize parking loss to any individual property, or to better take advantage of where the runoff is flowing or be more cost effective. Stormwater curb extensions can also be placed along the "downhill" portion of the block and consolidated into larger landscaped spaces to capture runoff. Places that are striped with "no parking" zones can be converted into stormwater curb extensions without any loss of parking. Existing curb extensions that are paved or have landscaping can be redesigned to manage stormwater.

Stormwater curb extensions are useful as they narrow the space between the curbs, which helps to calm traffic and improves visibility between people walking across the street and those driving or cycling along the street. This is particularly a benefit at uncontrolled crossings and at mid-block locations. The use of stormwater curb extensions can also create additional space between the curb and sidewalk for locating seating, transit shelters, public art, and other streetscape improvements.

Special Considerations for Stormwater Curb Extension Design

- Existing curb extensions can often be redesigned to manage stormwater and become stormwater curb extensions.
- Even where on-street parking is highly used there may be opportunities for smaller curb extensions.
- Where the curb extension is being used for a transit stop, tree well filters or stormwater planters can be integrated into the design of the transit stop to achieve stormwater benefits while also providing space for waiting passengers and bus shelters; see photo example and guidance for tree well filter and stormwater planter design measures in **Sections 2.1, 2.5,** and **3.5**. Transit stop curb extensions also provide complete streets benefits by allowing buses to stop in the travel lane, which reduces the amount of time a bus is stopped.
- Permeable paving placed within the parking lane of the street may complement the stormwater curb extension and allow better management of the street's stormwater runoff.
- Depending upon depth of planter and context, may need raised curb or low fence surround.
- Low vegetation is needed to maintain sight lines between vehicles and people walking or bicycling.
- Intersections with designated right turn lanes along the curb are not appropriate for curb extensions.
- Intersections with frequent right turns made by buses or large trucks may be infeasible for curb extensions.
- Locating curb extensions that include green infrastructure near drainage inlets will help ensure that street run-off flows to the green infrastructure, because the grade of the street and gutter should already flow to the inlet.
- At mid-block crossings, stormwater curb extensions should be given high-priority because of improved visibility between people walking and driving.

KEVIN ROBERT PERRY

▲ *Stormwater curb extensions placed along residential streets can help narrow the street and provide traffic calming benefits.*

CD+A

▲ *Green infrastructure is incorporated with a transit stop at this bus-bulb.*

DAVE ELKIN

▲ *A stormwater curb extension is integrated into ADA compliant intersection.*

2.3 Green Infrastructure Measures and Opportunities

Rain Gardens

DEFINITION: Rain gardens (bioretention areas) are larger stormwater facilities with sloped sides and various, often organic, shapes that can collect, slow, filter and absorb large volumes of water, delaying discharge into the watershed system.

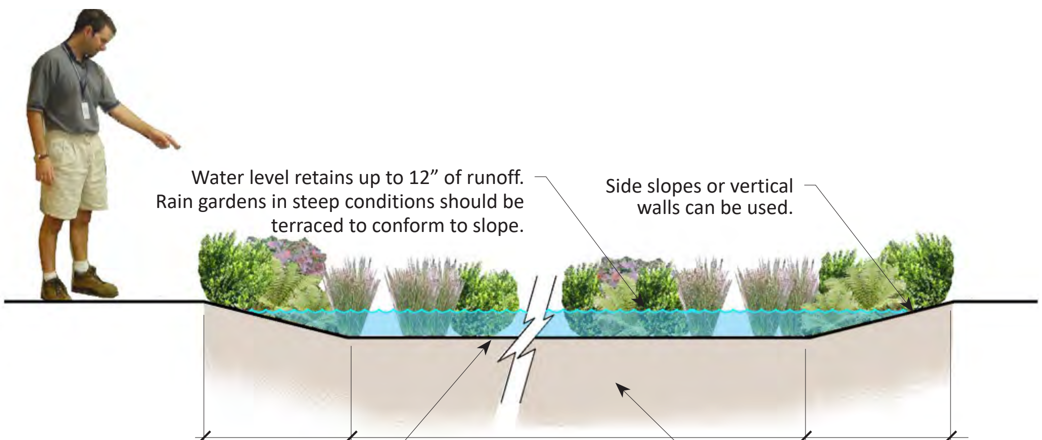
Rain gardens are large, shallow, vegetated depressions in the landscape and are often referred to as bioinfiltration areas or bioretention areas. They can be any size or shape and are often molded to fit in "leftover" spaces in parking lots, alongside building frontages, and within streetscapes. They are also often designed to be flat-bottomed with minimal or no longitudinal slope in order to maximize storage potential for stormwater. Rain gardens are also often used as a term for stormwater planters that are larger with sloped sides and various shapes, as distinguished from the more linear stormwater planters and more contained, and specific, stormwater curb extensions that are used along the curb line or within the street.

Rain gardens are often designed to enhance their detention function, because of their typically larger size, compared with other types of bioinfiltration or rain gardens. Given their larger size, rain gardens can also manage and treat greater volumes of stormwater than other bioretention or bioinfiltration treatment measures. They can also allow for infiltration, depending on the capacity of the native soil. Although rain gardens can share certain characteristics with vegetated swales and stormwater planters (they can be designed with vertical curbs or side slopes), they differ from vegetated swales in that their primary function is the maximum storage of runoff, not conveyance.

The primary advantage of rain gardens is their versatility in size and shape. Simple rain garden applications that do not use extensive hardscape or pipe infrastructure can be very cost effective to install. True to their name, rain gardens can have the visual appearance of a garden in the urban landscape.

It is best if rain gardens allow for natural infiltration. However, if infiltration is not possible, rain gardens can also be designed as a bioretention or flow-through system with an underdrain.

◀ *A well-designed rain garden at The Nueva School Bay Meadows Campus in San Mateo County captures stormwater runoff from both the building rooftop and plaza space.*



The Anatomy of a Rain garden

1. Cross section can be parabolic, trapezoidal, or flat-bottom
2. If side slopes are used, they should be ideally set at a 4:1 slope (3:1 maximum) with a flat shelf transitioning between the curb or pavement and the slope
3. Preferred retention depth is 6” of stormwater. (Maximum of 8” and in extreme constrained sites, a maximum of 12” if approved by the responsible jurisdiction)
4. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
5. Native soil condition (an underdrain system may be needed with some native soil conditions)
6. Rain gardens can be either infiltrative, or use bioretention/flow-through with an underdrain system

Why Choose Rain gardens?

- Can often significantly “green” and enhance a space that would otherwise be leftover asphalt area.
- Are highly versatile in shape and size.
- Can provide the greatest stormwater flow and volume benefit because of their large size.
- Can be integrated into complete streets projects that provide safety and traffic calming benefits by repurposing areas of excess pavement and expanding or improving pedestrian and bicyle facilities.
- Can include trees that provide protection from sun, fostering a pleasant environment.
- Benches, public art, and other streetscape improvements can be integrated with rain gardens.
- These larger landscapes can help provide a habitat for pollinators, such as bees and butterflies.

Potential Constraints?

- Can be difficult to find large spaces for rain gardens in denser and more active urban retrofit conditions.
- Can be designed too deep when rain gardens are designed with a small footprint.

2.3 Green Infrastructure Measures and Opportunities

Rain Gardens

KEVIN ROBERT PERRY

▲ *This rain garden at the Serramonte Library front entrance accepts runoff from a large parking lot.*

NEVUE NGAN ASSOCIATES

▲ *The Brisbane City Hall Rain Garden replaced what was once an under-utilized asphalt space.*

Opportunities for Buildings and Sites

Rain gardens can be retrofitted in a variety of building site applications. Large areas of unused or inefficiently used spaces are prevalent throughout mixed-use, commercial, industrial areas, and residential neighborhoods. These leftover landscape and asphalt spaces are prime candidates for building rain gardens that can accept building runoff. In some cases, rain gardens can be sited to accept runoff from both buildings and parking lots.

URBAN RAIN DESIGN

▲ *A rain garden capturing surface and roof runoff at Laurel Elementary in San Mateo County is integrated into a student drop off zone.*

Opportunities for Parking Lots

Rain garden areas are quite useful in larger parking lot conditions (i.e., shopping malls, big box stores) because they can be designed to manage large amounts of stormwater runoff. For retrofit conditions, it is often a popular choice to convert several parking stalls into one larger rain garden rather than use smaller vegetated swale and planter applications.

URBAN RAIN DESIGN

▲ *Also at Laurel Elementary, a triangular parking lot rain garden island captures roof and surface runoff. Any overflow from this rain garden is re-captured within perimeter stormwater planters.*

KEVIN ROBERT PERRY

▲ *This rain garden next to an elementary school collects runoff from adjacent neighborhood streets and the school's parking lot.*

NEVUE NGAN ASSOCIATES

▲ *This rectangular rain garden area receives runoff from both a parking lot and the building's rooftop.*

KEVIN ROBERT PERRY

▲ *This parking lot used to be completely paved. The new parking lot features a 2,000 square foot rain garden.*

2.3 Green Infrastructure Measures and Opportunities
Rain Gardens


CD+A

▲ *Check dam slows runoff in sloped street conditions. This rain garden is also used to separate vehicle and bicycle facilities.*

CD+A

▲ *An offset and angled intersection was retrofitted to include an extensive rain garden. Storm drain pipes from two streets outfall into the rain garden, which set the depth of the rain garden.*

Opportunities for Streets

Rain gardens can be used in a variety of street applications. Large areas of unused or inefficiently used spaces such as wide shoulders, parking areas, and wide and offset intersections are prevalent throughout downtown centers, industrial areas, and residential neighborhoods. These leftover landscape and asphalt spaces are prime candidates for installing rain gardens.

Within the roadway, rain gardens can be placed within roundabouts or traffic circles, medians, "porkchop" islands, and in parking lanes or other landscape areas found in urban interventions such as shared streets and pavement-to-park or pavement-to-plaza projects. When located outside the roadway, rain gardens can be sited between the curb and sidewalk or off-street bike facility, or behind the sidewalk or off-street bike facility. When designing rain gardens, consider integrating benches, outdoor seating, transit shelters, public art, or other improvements into the design to provide a potential placemaking amenity.


CD+A

▲ *This rain garden was a retrofit project specifically to implement green infrastructure, but it also helps enhance the community's character and calm traffic by installing vegetation where excess asphalt used to be.*

Special Considerations for Rain Garden Design

- Pedestrian access across rain gardens may be needed to allow convenient and direct access between two destinations, such as between an on-street parking stall and a building entry. This can be achieved with breaks between rain gardens or using pedestrian bridges constructed of decking, grates, or other acceptable and accessible materials.

- Where space permits, consider rain garden edges having a short flat bench along a pedestrian or bicycle facility and a low gradient slope leading to the bottom of the rain garden. This edge condition, rather than curbed side walls, can save construction materials costs as well as present a more garden appearance.

- The top surface of the rain garden should be kept as high as possible; however, the bottom elevation may need to be designed to accept stormwater runoff from existing storm drain pipe outlet elevations.

- For street applications, existing roundabouts, medians, traffic islands, and remnant landscape areas may be redesigned and retrofitted as rain gardens to manage stormwater, however, challenges exist when these areas are at high points of the roadway. Significant regrading of the street or additional piped infrastructure may be needed to route runoff to these spaces.

- Trees are encouraged to be planted within rain garden spaces, however, care needs to be taken to not obstruct site visibility, especially for drivers.

- For parking lot conditions, there should be wide enough space between a parking stall edge and a rain garden for people to enter and exit their vehicles without having to enter the rain garden. Widths should be sized based on context and level of pedestrian use, and at least, the minimum accessible path of travel requirements.

- If rain gardens have a vertical drop in grade to manage stormwater volumes, a flat landscaped "shelf," curb, and/or low railings can be used to prevent pedestrians or vehicles from entering the rain garden (see **Section 3.1 General Design Strategies and Guidelines** for additional information on edge treatments).

- For building applications, rain gardens can be either elevated or in-ground to receive rooftop runoff.

- When longitudinal slopes are over 2%, check dams will be needed. For slopes over 5%, the interior of the overall rain garden needs to be terraced.

KEVIN ROBERT PERRY

▲ *A rain garden in Village Homes accepts street and site runoff.*

URBAN RAIN DESIGN

▲ *This rain garden at the UC Davis campus captures roof runoff and features drought-tolerant plantings.*

KEVIN ROBERT PERRY

▲ *A large rain garden within a regional park in Los Angeles features a boardwalk and integrated seating.*

2.4 Green Infrastructure Measures and Opportunities

Green Gutters

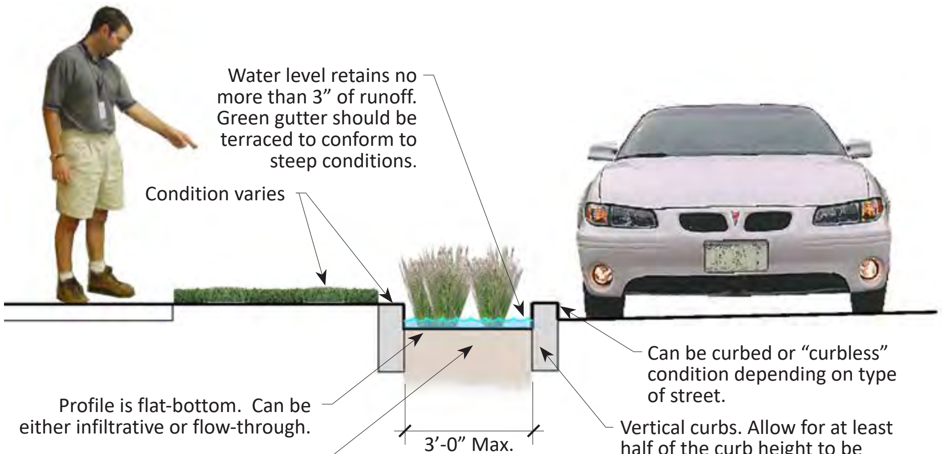
DEFINITION: Green gutters help capture and slow stormwater runoff within very narrow and shallow landscaped areas placed along a roadway or parking lot's edge. It can also be designed as a narrow stormwater planter. Green Gutters are not currently a C.3 Regulated Project Type design strategy.

Green gutters are very narrow alternative treatment landscape systems placed along building, site, parking lot, and roadway curbs to capture and slow stormwater flow. Typically less than three feet wide, green gutters most resemble planters in that they are confined by vertical curbs and have a flat-bottom profile. Unlike typical planters, however, green gutters are designed to be very shallow with little or no water retention. While infiltration of stormwater is a possibility, the primary purpose of using green gutters is to provide a site design measure using a strip of landscaping to help filter out pollutants and slow the flow of water. They can be used to transport stormwater flow to other treatment measures. Depending upon design and context, green gutters may have a raised or flush curb edge between the roadway and the landscape.

Green gutters are best used along pathways, streetscapes, or parking lot spaces that do not require frequent pedestrian crossings.

Green gutters have other benefits besides filtering stormwater pollutants from adjacent impervious areas. They also introduce more green space along spaces that could otherwise lack landscaping. Furthermore, these narrow strips of green help provide a landscape buffer between vehicles and pedestrians, resulting in a more desirable and potentially safer condition for people. Green gutters are a recent design strategy, and there are few projects built to date. The main disadvantage of using green gutters is that they require a long footprint in order to adequately filter and slow stormwater. Even with this limitation, there are abundant opportunities in San Mateo County to implement green gutter projects.

◂ *Green gutters, such as this example in Stockholm, Sweden, can provide water quality benefits within a very small footprint.*



The Anatomy of a Green Gutter

1. Cross section is flat-bottom with some form of vertical containment system
2. Maximum cross dimension of 3'-0"
3. Maximum of 3" of stormwater runoff retention
4. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
5. Native soil condition (an underdrain system may be needed with some native soil conditions)
6. Green gutters can be either infiltrative, or use bioretention/flow-through with an underdrain

Why Choose Green Gutters?

- Can provide vegetation that buffers pedestrians and bicyclists from moving vehicles.
- Provides vegetation along streets, buildings, and parking lots which can increase community identity and soften the look of a built space.
- Can be inexpensive to build depending on the site condition and local land use context.
- Are excellent choices for new residential and commercial development and can be easily retrofitted within parking lots and along constrained street and building frontages.
- Advantageous in retrofit situations as they can be added to existing streets with minimal infrastructure disturbance and can reduce costs for re-engineering existing storm drains.
- Visually narrows the space between the curbs or vehicle travel way, which helps to calm traffic—encourages people to drive within the speed limit.

Potential Constraints?

- Require a long, continuous space to effectively slow and filter pollutants.
- Are very shallow and do not retain large amounts of runoff.
- May result in removal of on-street parking.
- Not appropriate for areas with on-street parking, frequent driveway cuts, bus stops, or other features that frequently interrupt the gutter.
- Utility lines, manhole covers, and other conflicting infrastructure often located along the edge of a roadway can limit the feasibility of a green gutter.
- Many older urban streets have a "high crown" cross section resulting from years of repavement with asphalt overlays, which increases the cross slope and can make it challenging to integrate green gutters.

2.4 Green Infrastructure Measures and Opportunities

Green Gutters

KEVIN ROBERT PERRY

▲ *This green gutter captures stormwater runoff from a regional bike path and provides a vegetated buffer between a sidewalk.*

URBAN RAIN DESIGN

▲ *An urban park space with a green gutter.*

Opportunities for Sites, Parking Lots, and Streets

Because green gutters are very narrow landscape systems designed to capture stormwater runoff, there are many conditions where they are applicable. Parking lot or plaza edge treatments that do not have adjacent parking and pedestrian conflicts can easily be designed or retrofitted with green gutters. Residential, arterial, and other streets that have a wide roadway and that typically do not have a high demand for on-street parking are good candidates for retrofitting with green gutters. Places along streets that are marked as "red zones" or no parking designations can be redesigned into a green gutter. Green gutters can be placed adjacent to parallel or diagonally parking areas if they are placed outside the pedestrian path of travel unless the green gutter is bridged to allow people to pass over it. By removing a couple of feet of asphalt on both sides of the road, a green gutter system is viable without impeding vehicle travel. Like vegetated swales, green gutters can manage stormwater runoff and provide a landscaped buffer between bikes, pedestrians, and vehicles.

KEVIN ROBERT PERRY

▲ *This narrow green gutter on a rural residential street features a "curbless" condition allowing street runoff to sheet flow into the landscape.*

Special Considerations for Green Gutter Design

- Pedestrian access across green gutters may be needed to allow convenient and direct access between two destinations, such as between an on-street parking stall and a building entry. This can be achieved by using pedestrian bridges constructed of decking, grates, or other acceptable and accessible materials.

- Maximum depth of three inches of stormwater runoff retention. Shallower depths are preferred where green gutters are placed directly adjacent to pedestrian conditions, parking stalls, and where they do not have a curb between the roadway and the green gutter.

- Where acceptable, consider designing green gutters without raised curbs so that water can simply sheet flow into the landscape. In curbless conditions, the top surface of the green gutter should be no more than 2 inches below the adjacent vehicle or bicycle lane.

- Green gutters must not pass through crosswalks or driveways.

- Green gutters should be densely planted to provide effective treatment and limit erosion; provide visual cue to drivers, cyclists, and pedestrians to not enter the measure; and to look attractive.

- For parking lot conditions, there should be wide enough space between a parking stall edge and a vegetated swale for people to enter and exit their vehicles without having to step onto or over the vegetated swale. Egress widths should be sized based on context and level of pedestrian use, and, at least, the minimum path of travel requirements.

- For Regulated Project stormwater management regulatory compliance, use green gutters in conjunction with other measures to form a treatment train.

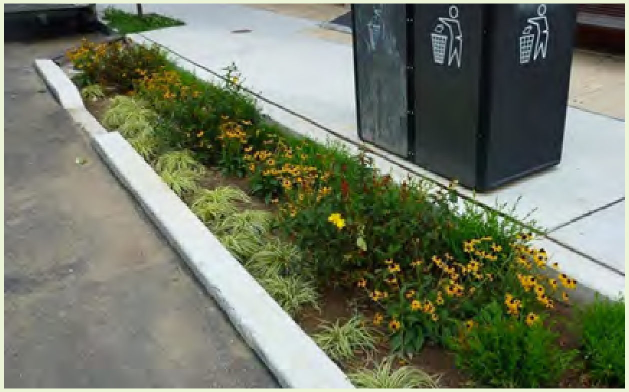
- When longitudinal slopes are over 2%, check dams will be needed. For slopes over 5%, the interior of the green gutter needs to be terraced.

URBAN RAIN DESIGN

▲ *A 12" wide green gutter accepts runoff from a building pathway.*

URBAN RAIN DESIGN

▲ *This narrow green gutter has an integrated curb with frequent curb cuts to allow parking lot runoff to enter the landscape.*



PHILADELPHIA DEPARTMENT OF WATER

▲ *A green gutter in Philadelphia accepts street runoff.*

2.5 Green Infrastructure Measures and Opportunities

Tree Well Filters

DEFINITION: A tree well filter is a small stormwater planter that has a tree planted in it – several of them may be used in series or can be used individually.

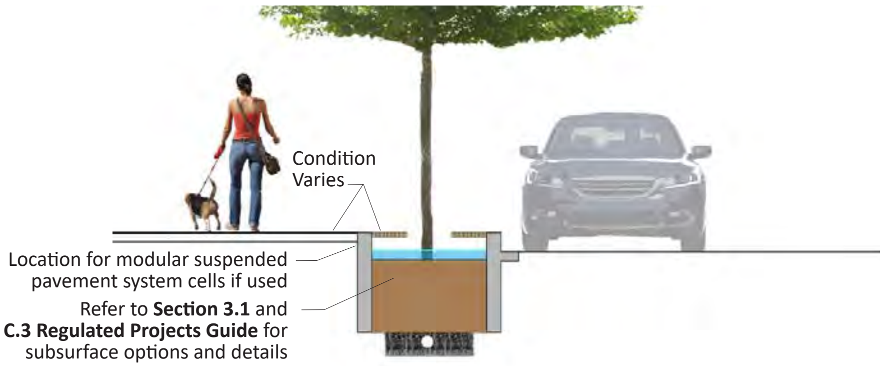
A tree well filter's basic design is similar to that of a stormwater planter, consisting of an excavated pit or vault filled with a specified biotreatment soil mix or other filtration media, planted with a tree, and underlain with drain rock and an underdrain as needed. The top of the soil is set low enough to take in water from surrounding sidewalks or from the flowline of the gutter. It will typically have a small exposed surface area and can include other vegetation. Designs that use vaults and filtration media are called high-flow rate tree well filters. Tree well filters can appear to be a standard street tree planting with a tree grate, or if the well is open, the lower level of the soil and any groundcover that is planted make its stormwater function visible.

In locations where the area available for landscape, as opposed to pavement for pedestrian or other activity, is constrained, a tree well filter may be constructed using modular suspended pavement system products; see further discussion of this construction approach in **Section 3.1 Landscaped Green Infrastructure**.

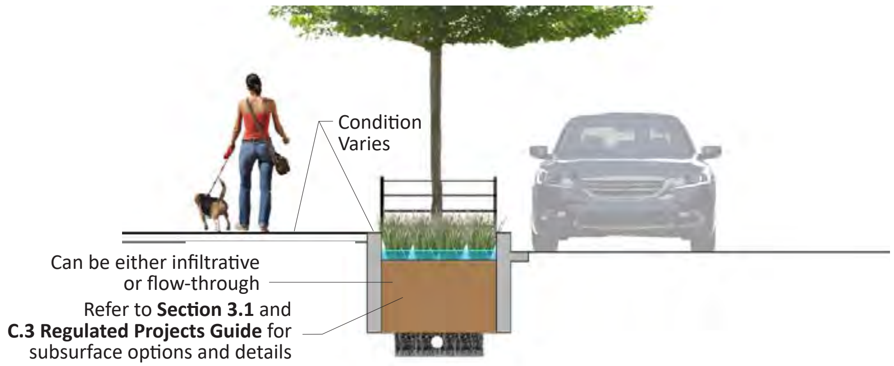
Linked Tree Well Filters are a series of tree well filters that are linked by an infiltration trench, modular suspended pavement system, pervious pavement, or other method to provide additional area for infiltration, treatment, storage, and/or soil volume to support healthy tree growth and lifespan.

This guide defines different ways that trees can be planted as green infrastructure measures: tree well filters, the subject of this section, stormwater trees (see **Section 2.6**), and trees in the landscape (see **Section 2.7**). Tree well filters are defined above and can be used in C.3 Regulated Projects. Stormwater trees are an alternative treatment measure and generally vary from tree well filters because they do not use C.3 biotreatment soil, and stormwater capacity and the amount of time water is in the measure are typically lower. Trees in the landscape are a site design measure that acknowledges the benefit of a tree's canopy to capture and/or delay rainwater from falling on adjacent impervious ground surfaces. However, it is understood that the canopy and bark of all trees can capture and/or delay rainfall, that tree roots can uptake moisture and contaminants in the soil, and that leaves can evapotranspirate. Refer to **Table 2.1 Green Infrastructure Measure Site Applicability** for additional information.

◄ *Tree well filters can be surfaced with a tree grate or left open and typically surrounded by a low railing or curb.*



Tree Well Filter with Tree Grate



Tree Well Filter with Low Railing

The Anatomy of a Tree Well Filter

1. Cross section is typically flat-bottom with some form of vertical containment system
2. The preferred retention depth is 6 inches of stormwater
3. Tree Well Filters can be either infiltrative or flow-through with an underdrain system
4. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
5. Native soil condition (an underdrain system may be needed with some native soil conditions)

Why Choose Tree Well Filters?

- Useful in constrained areas, urban areas, and retrofit projects.
- Can be easily integrated as part of standard street design.
- Provides a buffer between vehicles and pedestrians, creating a more comfortable walking experience.
- Trees can visually narrow the street, which helps to calm traffic by encouraging people to drive within the speed limit.
- Use of a tree grate can expand walking or bicycling surface area.
- Trees provide a pleasant environment and can enhance community identity.

Potential Constraints?

- May not provide much treatment volume.
- Depending upon depth of planter and context, may need raised curb or low fence surround, or tree grate.
- Requires the street to have sidewalks or an area between the curb and right of way wide enough for both a sidewalk and a minimum sized tree planter area unless the tree well filters can be accommodated in the parking lane.

2.5 Green Infrastructure Measures and Opportunities

Tree Well Filters

CD+A

▲ *Tree well filters are linked with pervious pavement and tree trench along with modular suspended pavement support cells to accommodate and treat runoff.*

NACTO.ORG

▲ *Series of tree well filters along a retrofitted street.*

Opportunities for Streets

Tree well filters are useful for new and retrofitted green and complete streets and especially in constrained and urban areas due to their small size. Refer to **Section 4.12 General Sizing of Green Infrastructure Facilities** and **Appendix A.7 Guidance for Sizing Green Infrastructure Facilities in Streets** for a discussion about BASMAA's Alternative Sizing for non-regulated and constrained street projects. Tree well filters can easily be placed along streets at or slightly behind the curb line of roadways to help manage and treat stormwater runoff and offer a dual use of what would otherwise be a standard street tree. Tree well filters can also be used as buffers in the following ways:

- Between vehicle travel or parking lanes and pedestrian sidewalks or protected bike lanes and cycle tracks.
- In shared streets, tree well filters can be placed between the vehicle drive aisle and the primary pedestrian zone.
- Along areas with or without parallel or angled parking.

Where on-street parking is highly utilized, tree well filters may be added between parking spaces to provide some stormwater treatment, and complete street benefits of shading roadways sidewalks with trees and visually narrowing the street.

Being compact, tree well filters can be designed and sited to work around utilities and other sidewalk obstructions, while accommodating pedestrian circulation needs. The surface of the sidewalk or adjacent curb lane can be paved with pervious pavement to allow a more dispersed flow of stormwater into the soil of the tree well filter or linked row of tree well filters, which can also improve tree health and the function of the biotreatment soil. Locating tree well filters near and upstream of drainage inlets and catch basins will help ensure that street runoff flows to the green infrastructure first, because the grade of the street and gutter should already flow to the inlet.

Special Considerations for Tree Well Filter Design

- Even where on-street parking is highly utilized there may be opportunities for tree well filters. Tree well filters may be added between parking spaces to provide some stormwater treatment and complete street benefits of shading sidewalks with trees and visually narrowing the street.
- Permeable paving placed adjacent to the tree well filters can complement its stormwater function and allow for more complete management of the street's runoff.
- Where there is a high demand for pedestrian space and a landscaped planter is not feasible, a tree well filter can be used.
- To increase stormwater runoff storage capacity, potential infiltration, and water and root volume space for trees, consider linking tree well filters together with infiltration trenches, structural soil, modular suspended pavement support systems, and other techniques.
- Tree well filters should be as wide as possible to increase tree and root health and vitality. Consider the use of pervious pavement and modular suspended pavement support systems to provide improved growing conditions.
- The use of tree trenches, modular suspended pavement systems, and pervious pavements can help provide additional tree rooting environments and increase management of the street's stormwater runoff. See guidance in **Sections 3.5** and **Chapter 4** that addresses these green infrastructure measures and design approaches.


MURALMOUTH.WORDPRESS.COM

▲ *Organic shaped tree well filters adjacent to accessible ramp completed as part of a retrofit project.*


MURALMOUTH.WORDPRESS.COM

▲ *Inlet/outlet is integrated into the curved curb.*

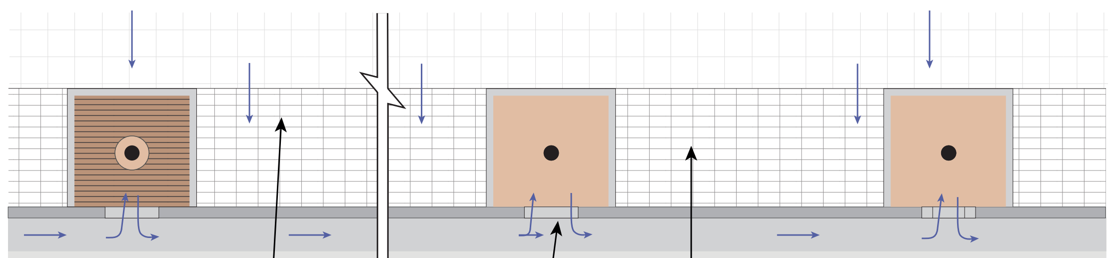
2.6 Green Infrastructure Measures and Opportunities

Stormwater Trees

DEFINITION: Stormwater trees are tree planter areas that have one or two curb cuts to allow stormwater runoff to enter the planter and the soil is depressed below the gutter to allow water to infiltrate into the soil. Runoff that does not infiltrate flows back out into the gutter and to a storm drain system inlet. Stormwater trees are not currently a C.3 Regulated Project Type design strategy.

Stormwater trees are alternative treatment measures that consist of a typical small sidewalk cutout around a street tree, but with a curb cut or inlet along the curb to allow stormwater runoff to enter from the street and infiltrate into the planter area, providing water harvesting and other stormwater benefits and functions. The ground surface of the planter area is set slightly below the adjacent street and gutter which enables the stormwater runoff to enter and infiltrate. Runoff from the adjacent sidewalk may also flow into the stormwater tree planter area.

A stormwater tree will typically not meet requirements for regulated projects; for these regulated projects a tree can be planted in a Tree Well Filter, see **Section 2.5 Tree Well Filters**. The intent of a stormwater tree is to provide some stormwater and water harvesting benefit at a minimal cost. A stormwater tree is a minor redesign of a typical street tree planting that can be easily implemented when a new street tree is being planted. Implementing stormwater trees rather than a standard street tree planting regiment can provide a greater impact over time in stormwater management and treatment as communities plant additional and replacement street trees. Once a stormwater tree reaches capacity, runoff bypasses the curb cut or inlet to flow into another green infrastructure measure or storm drain. Due to their smaller footprint, stormwater trees can be tailored to fit into retrofit situations by working around existing utilities, street furnishings, street lights, etc.

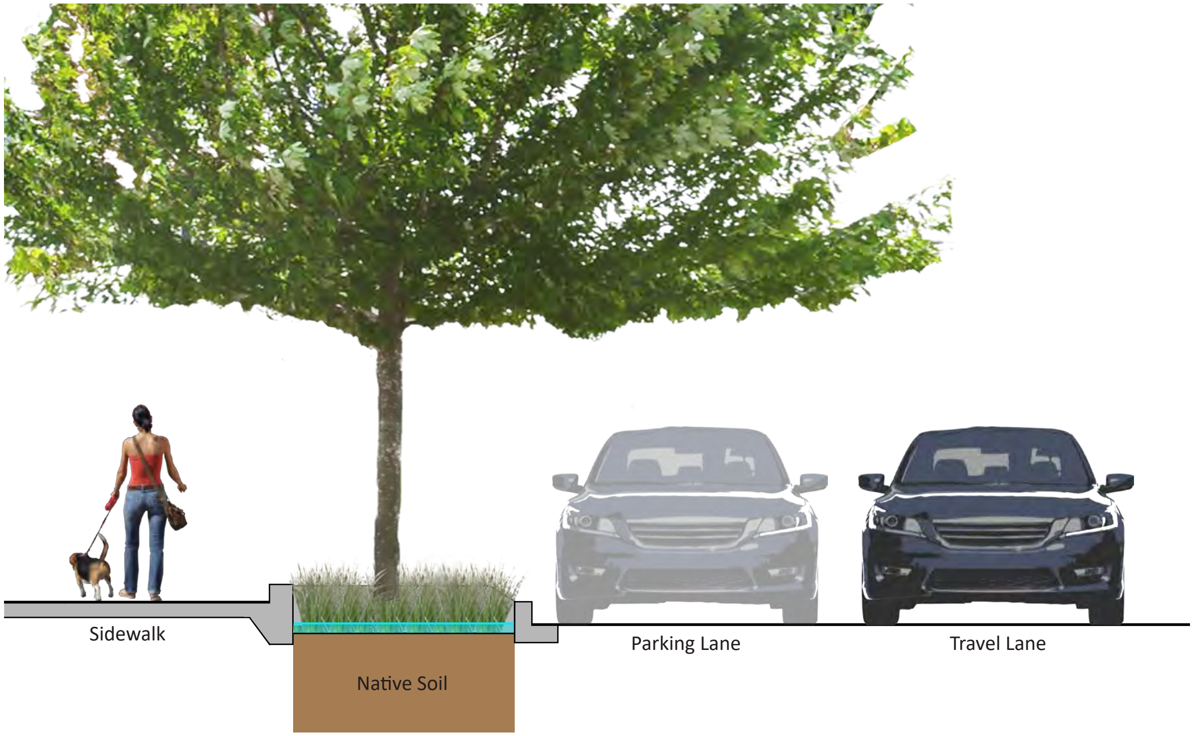


Match width of pervious pavement to width of tree planters or width of pedestrian amenity area

12-18” wide curb inlet, with wheel guard at loading and parking zones

To maximize tree health, consider the use of structural soils and load-bearing modular grid products

▲ *Stormwater tree typical plan*



The Anatomy of a Stormwater Tree

1. Cross section can be trapezoidal, parabolic, or flat-bottom.
2. The preferred retention depth is 4 inches of stormwater. More depth may be needed if there are high volumes of stormwater that cannot be directed to other treatment measures, up to 8 inches deep, if approved by the responsible jurisdiction engineer.
3. It is not required to provide an underdrain in poor soil conditions. However, if one is desired and it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and cost implications of making the connection.

Why Choose Stormwater Trees?

- Enables runoff management and treatment that would not otherwise occur from a standard tree planting.
- Flexible size and shape.
- Easily integrated as part of standard street design.
- Allows water harvesting for irrigation of vegetation in planter area.
- Small size of planter area allows flexibility to be sited between utility lines, street lights, fire hydrants, and other conflicting infrastructure.
- The use of a tree enables other community benefits such as creating a more comfortable walking experience, calming traffic by encouraging people to drive within the speed limit, and enhancing community identity.

Potential Constraints?

- Limited capacity to capture and treat stormwater.
- Does not meet Regulated Project design standards.
- Available space in retrofit conditions may not align with drainage pattern.
- Requires that street has sidewalks or an area between the curb and right of way limit wide enough for both a sidewalk and tree planting area for a minimum sized tree planter.
- Many older urban streets have a "high crown" cross section profile resulting from years of asphalt overlay repaving, which increases the cross slope of roadways and poses challenges to place stormwater trees into parking lanes. Removal of old asphalt may be needed, which adds construction costs.

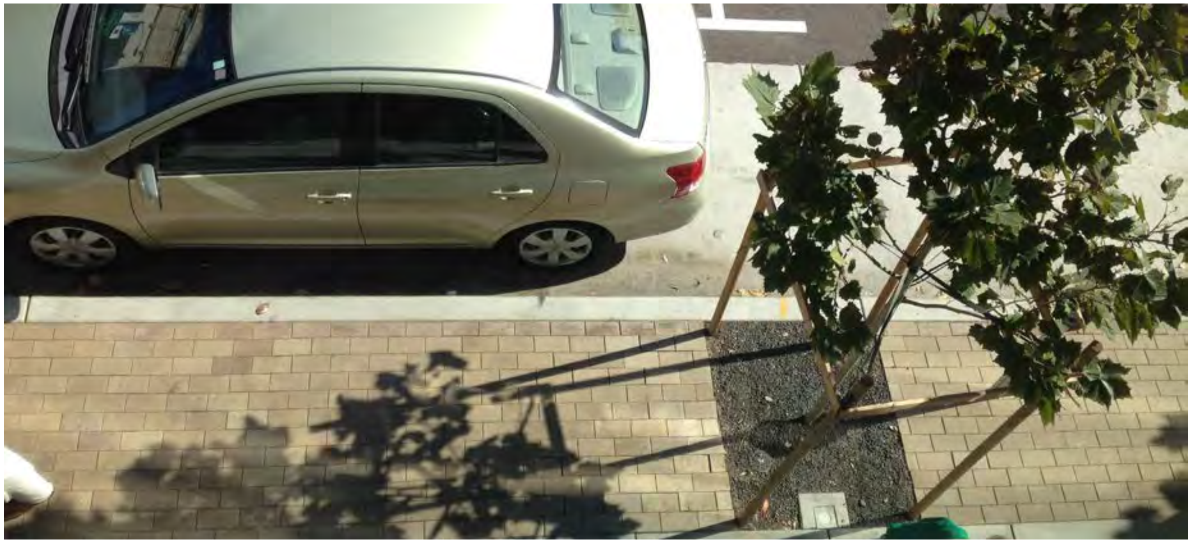
2.6 Green Infrastructure Measures and Opportunities

Stormwater Trees

▲ *Stormwater Tree. Note that the low railing is set back from the curb and is a lower height that transitions to a higher height. This allows for car doors to swing open wihtout hitting the railing.*

Opportunities for Streets

Any place a standard street tree could be located, a stormwater tree can be used. Stormwater trees are helpful in places that have limited or no storm drain systems, are in constrained and urban areas, and for retrofit projects. Even where on-street parking is highly utilized there may be opportunities for stormwater trees. Small planters may be added between parking spaces to provide some stormwater treatment and complete street benefits of shading sidewalks with trees and visually narrowing the street. The use of a tree grate can expand the walking or bicycling surface area. Stormwater trees can be used at the curb edge of sidewalk; within parking lanes; in wider buffers to cycle track facilities; with parallel or diagonal parking, and particularly where red curbs currently exist. Locating stormwater trees upstream of drainage inlets and catch basins will help ensure that street run-off flows to the green infrastructure first, because the grade of the street and gutter should already flow to the inlet. In developed urban areas, it is generally not recommended to retrofit an existing street tree into a stormwater tree due to existing planter grades and tree roots. In less urban contexts, the grades, use of curbs, tree roots, ability of tree to tolerate additional water, and other site-specific conditions should be considered before retrofitting an existing tree into a stormwater tree.



CD+A

▲ *Stormwater trees can be linked together with pervious pavement, modular suspended pavement, and other techniques to expand runoff storage capacity.*

Special Considerations for Stormwater Tree Design

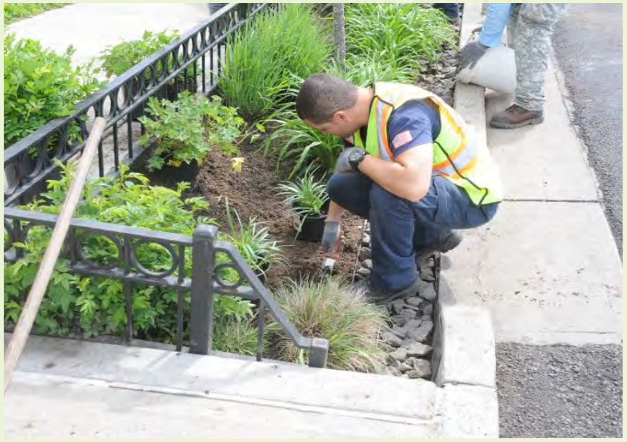
- Ensure stormwater runoff can flow back out to the street when the stormwater tree planter area is at capacity.
- Provide adequate tree root volume of planter area to support long term tree health and vitality. This is especially important for trees sited in large extents of pavement. Adequate tree root volume can be met by a variety of techniques including a minimum tree planter area size based on the expected mature size of the tree; using modular suspended pavement support cells; and using pervious pavement and/or infiltration trenches to link trees. These measures aid in allowing roots access to oxygen and water. Refer to **Section 3.5** for additional information on minimum tree planter sizes and related information.
- Stormwater tree planting areas can be planted with a variety of trees, shrubs, grasses and groundcovers, depending on site context and conditions.
- If considering turning existing street tree plantings into stormwater trees, work with an arborist to confirm the trees can tolerate the addition of new and/or larger amounts of water inundation.


BOTANIC GARDENS OF SOUTH AUSTRALIA

▲ *These stormwater trees are flanked by seating areas. A metal capped inlet should be provided across the face of the planter to prevent vehicles from entering the planters.*


ALSATHEDIRT.FILES.WORDPRESS.COM

▲ *The gravel band along the curb helps to dissipate stormwater runoff flows into the planter.*


LHCCD.NET

▲ *As with other green infrastructure measures, stormwater tree planters will need to be maintained to remove debris and sediment and replant vegetation that declines.*

2.7 Green Infrastructure Measures and Opportunities

Trees in the Landscape

DEFINITION: Trees capture and delay rainfall and allow it to evaporate back into the air before runoff is created. Through the absorption process, trees remove pollutants from stormwater and stabilize them. Root systems create voids in the soil that facilitate infiltration, and other factors improve soil's stormwater function.

The use of trees combines several methods of stormwater management including direct capture of rainfall, retention, and evapotranspiration. Trees improve water quality by intercepting and storing rainfall on leaves and branch surfaces, thereby reducing runoff volumes and delaying peak flows. A single larger canopy tree can have a total leaf surface area of several hundred to several thousand square feet, depending on species and size. This surface area created by trees and other plants greatly contributes to the water holding capacity of the land. They attenuate conveyance by increasing the soil's capacity to filter rainwater and reduce overland flow rates. By diminishing the impact of rainfall on un-vegetated soil, trees reduce soil erosion. Adding trees has other important environmental, economic, and social benefits not directly related to stormwater management such as reducing ambient temperatures and increasing property values.

It is important to preserve existing, healthy trees whenever possible. Mature existing trees should influence how and where stormwater facilities are designed. It can be more advantageous to alter the design of the stormwater facility to preserve and protect existing trees. Mature trees are often able to soak up water at a rate comparable to what can be infiltrated in a stormwater facility. In terms of overall stormwater benefit, it is usually worth reducing stormwater facility size in order to save a mature tree.

When using trees to achieve stormwater management goals, it is best to use tree species with wide canopies. Design criteria should specify species expected to attain 30 feet canopies at maturity; if 30-foot diameter trees cannot be accommodated then more closely spaces smaller canopy trees can be planted. Planting strips need to provide adequate width and depth of soil volume to ensure tree vitality and reduce future maintenance. It is possible to use suspended pavement systems under paved conditions or modular cells to provide expanded rooting space for trees. Both structual soil and suspended pavement can be specified along narrow planter strips and underneath sidewalks to enable continuous below ground soil and root connections.

◄ *A robust application of trees in the landscape not only helps capture stormwater and create shade, but they also provide great spaces for people to enjoy.*

Street trees can be integrated into stormwater treatment measures to treat runoff from adjacent roadways and other paved areas, however there are challenges to implementing this concept including the reduced water holding capacity in the typical biotreatment soil media, determining the correct tree species, providing adequate soil volume, system sizing, space in the public right of way and utility conflicts. Streets that do not have a planter strip, between the sidewalk and curb where trees can be planted, can be more challenging for conveying runoff to trees in GI measures. Refer to the **C.3 Regulated Projects Guide** for additional information on using trees in stormwater treatment measures.

KEVIN ROBERT PERRY

▲ *This residential street uses mature street trees to intercept rainfall and provide a unique and pleasant character to the neighborhood.*

Why Choose Trees in the Landscape?

- Can be easily integrated as part of standard street design.
- They can provide stormwater management on a vertical surface where ground plane space is limited.
- Helps reduce the urban heat island effect and decreases heating and cooling costs by insulating and shading buildings.
- Trees provide a pleasant environment and enhances community identity.
- Trees aid in traffic calming and creating a more comfortable place to walk.

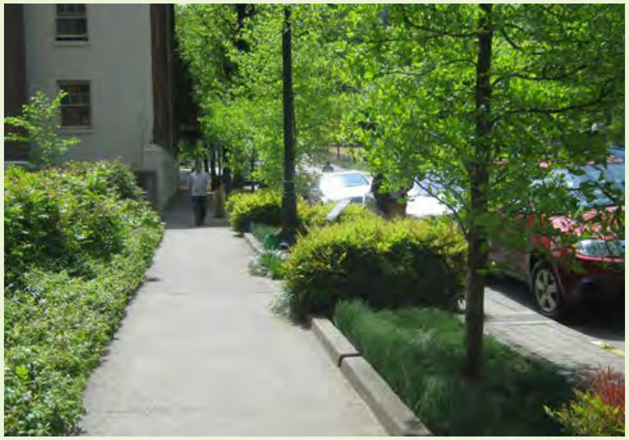
Potential Constraints?

- Need ample landscape and root volume space to sustain large canopy trees.
- Utility lines, manhole covers, and other conflicting infrastructure can often conflict with tree placement.
- May requires a wider sidewalk zone to provide the minimum sized tree planter area

KEVIN ROBERT PERRY

▲ *These mature trees in San Mateo County provide a full canopy for shade and stormwater capture.*

2.7 Green Infrastructure Measures and Opportunities
Trees in the Landscape



KEVIN ROBERT PERRY

▲ *Street trees planted within stormwater planters at SW 12th Avenue in Portland, Oregon.*

URBAN RAIN DESIGN

▲ *These younger trees in a downtown streetscape are planted in a double row pattern to help achieve greater urban tree canopy.*

Opportunities for Sites, Parking Lots, and Streets

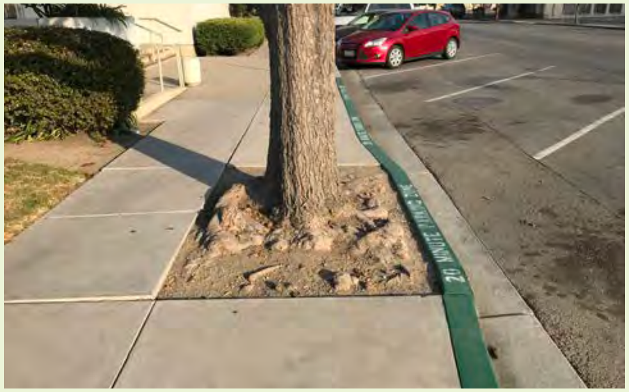
Providing tree canopy cover over impervious parking lot and street surfaces to shade and capture rainfall can be a cost-effective green infrastructure strategy. Trees can be placed within conventional landscaping or within green infrastructure measures such as rain gardens, stormwater curb extensions, and stormwater planters. In denser urban conditions, large canopy trees can be bridged with grates or infilled with pervious pavement or other acceptable ADA and walkable materials to increase space provided for pedestrian travel, seating, or other pedestrian or transit infrastructure. Even where parking is in high demand on streets or parking lots, there may be opportunities for incorporating large canopy trees in the landscape.

KEVIN ROBERT PERRY

▲ *Generous size planting strips and structural soil may be needed to allow large canopy street trees in urban conditions to thrive.*

Special Considerations for Trees in the Landscape

- Need to provide adequate tree root volume to support long term tree health and vitality. This is especially important for trees sited in large extents of pavement.
- Adequate tree root volume can be met by a variety of techniques including a minimum landscape strip or planter size based on the expected mature size of the tree. Trees can be linked using modular suspended pavement systems support cells and pervious pavement and/or infiltration trenches. These measures aid in allowing roots access to uncompacted soil, oxygen, and water.
- Current best practices suggest that adequate tree root volume is critical for the longevity of trees in the urban environment. **Section 3.5- Sustainable Streets Design Strategies and Guidelines** provides technical information on recommended tree root volume for a variety of tree conditions.
- If used in a parking lane or parking lot condition, provide protection from vehicle conflicts such as adequate bumper/overhang clearances, and use of curbs, bollards, tree grates, or tree guards.
- Where existing trees are present, be mindful of not negatively impacting roots by changing soil grades, removing roots, injuring roots to plant understory vegetation, or adding increased water to species that require a drier environment. Consultation with an arborist may be considered.
- While it is desirable to obtain quick tree canopy in urban conditions, trees should be spaced so branching patterns can mature without overcrowding or excessive pruning. Trees should be spaced for mature canopy coverage, not short-term coverage.
- When used in street conditions, be sure that there is wide enough space for both a sidewalk and tree planting area for the selected tree species and size.

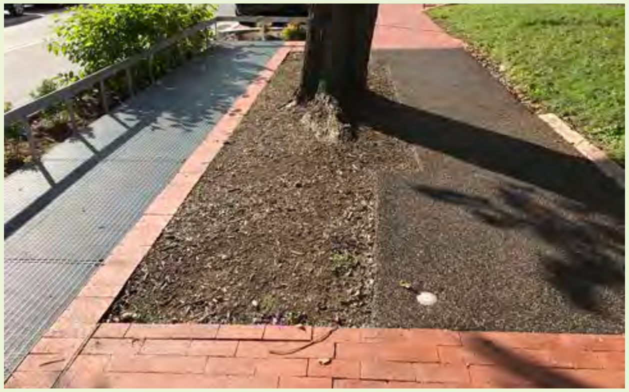


URBAN RAIN DESIGN

▲ *This street tree unfortunately was not given enough room to grow between the street and sidewalk within a downtown environment.*

URBAN RAIN DESIGN

▲ *This new streetscape planting features trees in addition to a strip of pervious pavement that allows for greater root volume.*



URBAN RAIN DESIGN

▲ *To preserve an existing street tree and provide space for a stormwater curb extension, a metal grate extends the walkway over the new landscape area.*

2.8 Green Infrastructure Measures and Opportunities

Infiltration Systems

DEFINITION: Infiltration systems are underground facilities and structures designed to collect and temporarily store runoff, such as a gravel filled trench, pipe or vault, and allows the water to infiltrate into surrounding subsurface soils. In some cases, it can include an underdrain.

Infiltration systems are designed to capture, store, and infiltrate runoff through a gravel base into the surrounding soils. There is a range of different types of infiltration systems; some systems are located completely underground, placed below paved areas such as a roadway or parking lot or under turf such as a sports field, while other systems such as infiltration trenches have an exposed gravel surface. The use of pavement surfacing can increase the stormwater role of parking lots or help to achieve complete streets goals, described below. Infiltration systems can be used in new and retrofitted projects.

Infiltration systems must be used in combination with a landscaped green infrastructure measure, such as a vegetated swale or rain garden unless otherwise allowed by local jurisdiction. The landscaped green infrastructure will pretreat the stormwater runoff, removing sediment and other pollutants, reducing the cost and frequency of maintenance, and protecting groundwater quality.

Infiltration systems can be combined with other green infrastructure improvements to increase stormwater capacity in locations where soils percolate more slowly or where more attenuation of stormwater flow is desired.

Subsurface Infiltration System

Subsurface infiltration systems, also referred to as infiltration galleries or infiltration chambers, have underground vaults or pipes that store and infiltrate stormwater. These systems allow infiltration into surrounding soil while preserving the land surface above for other uses, such as, parking lots, plazas, and streets.

Another type of subsurface infiltration system is an exfiltration basin or trench, which consists of a perforated or slotted pipe laid in a bed of gravel. It is similar to an infiltration basin or trench except that it can be placed below paved surfaces. Stormwater runoff is temporarily stored in perforated pipe or coarse aggregate and allowed to infiltrate into the trench walls and bottom for disposal and treatment.

Infiltration Trench

An infiltration trench, also referred to as percolation trench, is a long and typically narrow trench filled with a stone aggregate or similar permeable material designed to store and infiltrate runoff through the bottom and sides of the trench into the subsurface soil. While historically used mainly within larger sites, infiltration trenches can be placed within medians and along the side of the roadway. In urbanized areas, infiltration trenches can be surfaced with pavement.

Why Choose Infiltration Systems?

- Can be combined with other treatment measures to increase capacity and infiltration.
- Underground systems can be used within roadways, parking lots, or plazas.
- Systems can be modular, allowing for flexible design and increased storage area.
- Does not typically require intensive vegetation management.

Potential Constraints?

- Potential for clogging with sediment is more of a concern given the focus on infiltration; may clog without proper design (e.g.: pretreatment sediment trap) and regular maintenance.
- Not suitable on steep slopes, fill areas, areas with high potential for spills of hazardous materials, and contaminated sites.
- Not recommended for soils with poor infiltration.
- Potential for standing water and mosquitos with some infiltration system types such as subsurface infiltration.
- Need to provide access for inspection and maintenance of underground improvements. Hence, access and observation points should not be placed in places where it would be unsafe or inconvenient for the function of the above ground street, parking lot, or site.
- Where landscaped-based pretreatment measures are used additional ground surface space will be needed.
- Available space in retrofit conditions may not align with drainage pattern.

2.8 Green Infrastructure Measures and Opportunities

Infiltration Systems


CONTECHES.COM®

▲ *A variety of systems and materials can be used to provide subsurface infiltration.*


ATLANTIS-AMERICA.COM

▲ *Subsurface infiltration system being placed under a future park.*

Opportunities for Sites

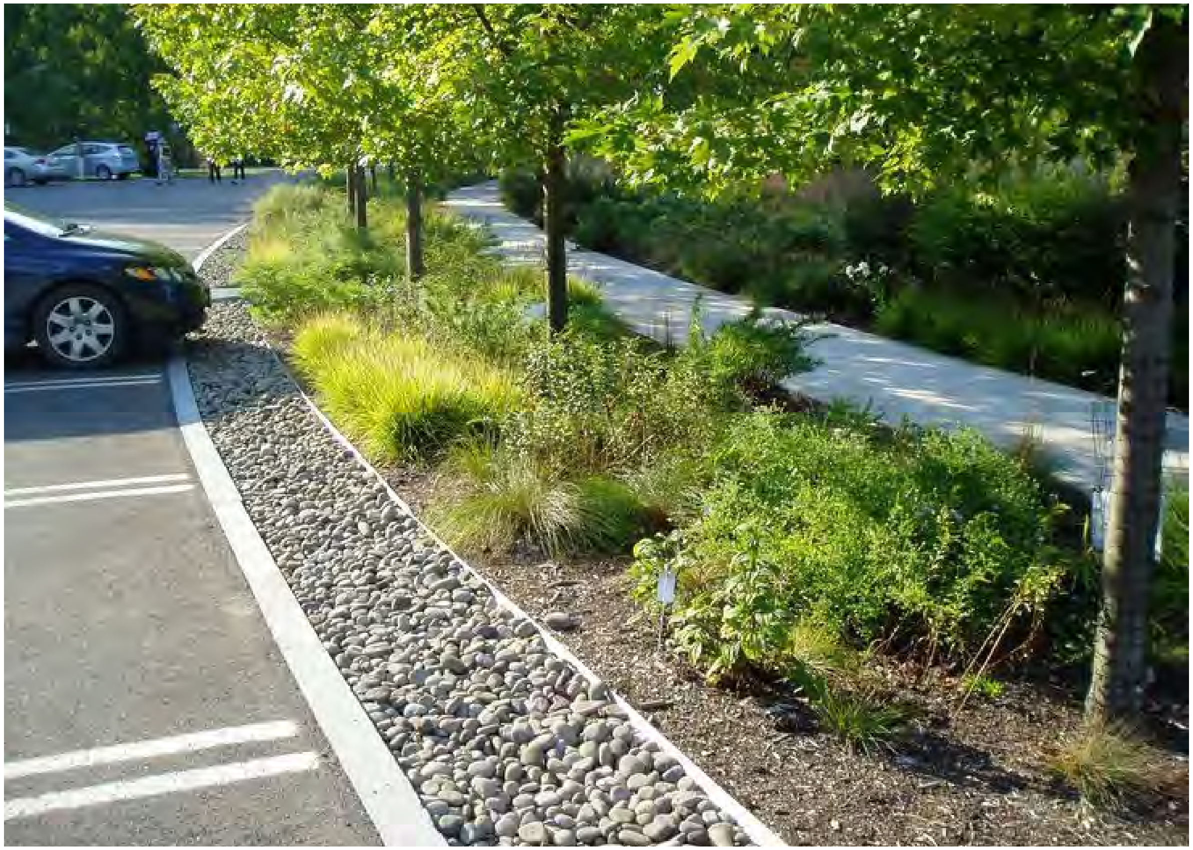
Many sites provide opportunities for infiltration systems. Private streets and alleys work well with subsurface infiltration systems, as do multi-use path corridors. Low density development and open space areas such as parks, plazas, and residential common areas afford large areas of land that can be used for subsurface infiltration or trench drains without many constraints.


CD+A

▲ *Infiltration trench placed behind sidewalk within a park.*

Opportunities for Parking Lots

Parking lots work well for the use of infiltration systems due to the lack of many constraints such as limited utility provision and few, if any, structures. Infiltration trenches can be located in landscape areas to the edges of the parking lot or within planter areas between parking stalls. Subsurface infiltration systems can be used under paved or unpaved portions of a parking lot.


COKHIIN.COM


PLAT

▲ *Trench drains and grate covered tree trenchs used together with pervious pavement in this parking lot help to provide interest while managing stormwater.*


CONTECHES.COM®

▲ *Subsurface infiltration system being placed under future parking lot.*

2.8 Green Infrastructure Measures and Opportunities
Infiltration Systems


STORMWATER.PCA.STATE.MN.US

▲ *Infiltration trench along curbless street which allows sheet flow to enter the facility.*


LANDSCAPEONLINE.COM

▲ *Subsurface infiltration systems are useful in sites that are constrained for above ground green infrastructure measures.*

** The use of this image is for general information only and is not an endorsement of this or other proprietary devices or suppliers.*

Opportunities for Streets

Infiltration systems are useful in constrained areas, such as where space is limited or the area is highly developed, and in new or retrofit conditions. Subsurface infiltration systems typically are placed under, and parallel with, the street's vehicle lanes, parking areas, bicycle lanes, and sidewalks. Placement of subsurface infiltration systems may be limited in intersections due to a high concentration of utility crossings and presence of utility lines. Depending upon the density and context of the site, subsurface infiltration systems may be located under the sidewalk.

Graveled, cobbled, or similar surfaced infiltration trenches can be placed within the median or other islands and landscape areas along the street or along the sides of streets in semi-rural or rural contexts. Pervious or impervious pavement surfaced infiltration systems can be placed in many locations within streets.


DANIEL APT

▲ *Subsurface infiltration systems can be placed into new or retrofit street projects, such as these deep wells.*

Special Considerations for Infiltration System Design

- Pre-treatment is needed to obtain regulated project credit to remove pollutants.
- Pre-treatment of runoff aids to limit clogging of the system.
- Graveled or cobbled surfaced infiltration trenches are not an appropriate surface for walking, biking, or driving.
- Infiltration systems without paved surfacing in urbanized areas need to allow for pedestrian circulation that meets ADA requirements.
- Pervious pavement placed above the infiltration trench allows it to function for a variety of other uses, such as a parking lot, plaza or walkable surface.
- Modular systems can be designed to avoid underground utilities. However, the system still must be large enough to provide adequate function and effectiveness.
- Consider landscape and pedestrian amenities such as seating above infiltration systems.
- Verify native soils can infiltrate runoff prior to selecting and designing the system.
- Refer to the **C.3 Regulated Projects Guide** for specific design, sizing, construction, and maintenance guidelines, as well as recommended setbacks from structures, sizing, and other criteria.

CONTECHES.COM*

▲ *Underground infiltration systems can be designed in a variety of configurations.*

CONTECHES.COM*

▲ *Pretreatment of runoff is needed prior to the water entering the system.*

** The use of this image is for general information only and is not an endorsement of this or other proprietary devices or suppliers.*

2.9 Green Infrastructure Measures and Opportunities

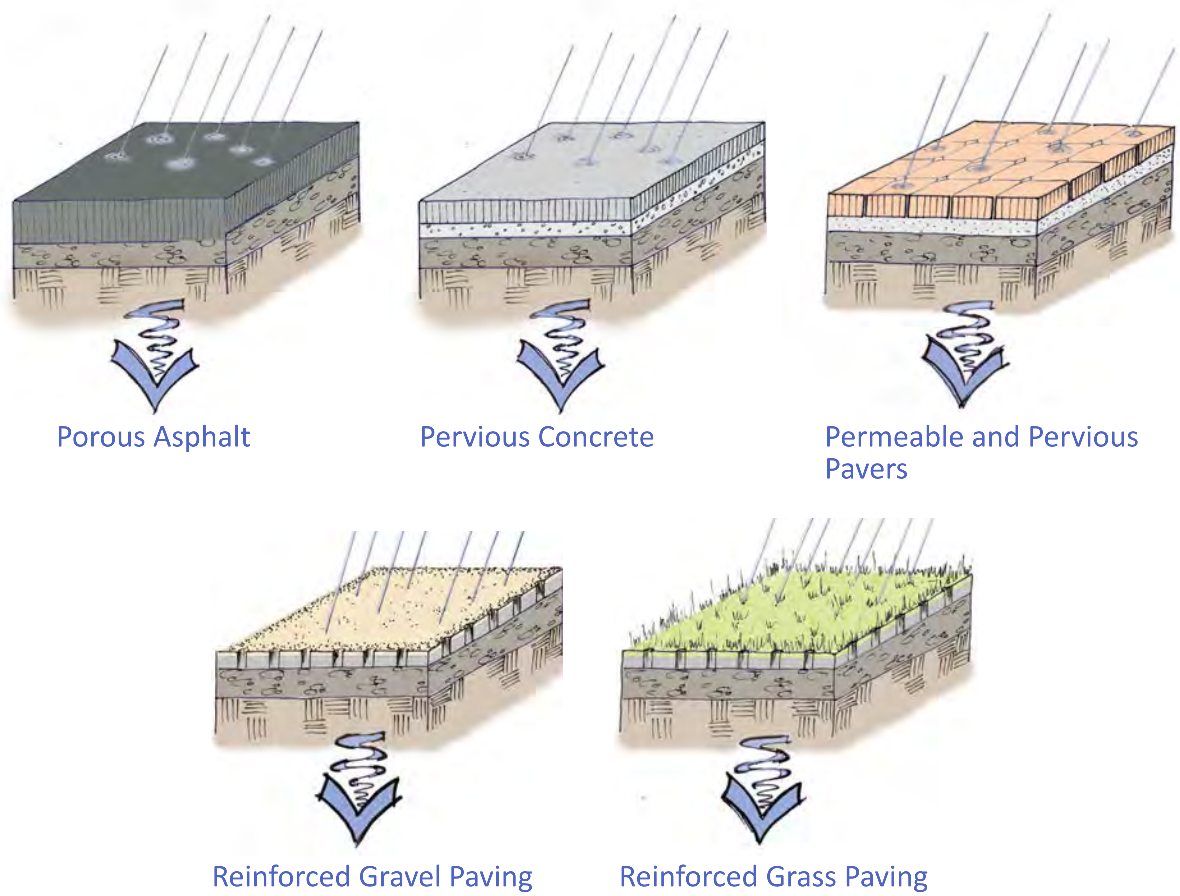
Pervious Pavement

DEFINITION: Pervious pavement allows rainwater to either pass through the pavement system itself or through joint openings between the pavers into an underlying gravel bed designed to store and infiltrate rainwater.

There are many different types of pervious pavements. Functionally, the distinguishing feature among the different pervious pavement systems is the means by which the surface is made permeable. Pervious concrete, porous asphalt, pervious pavers, and porous rubber are formulated with pore spaces within the material itself. Permeable pavers allow rainwater to pass through evenly spaced joints or gaps between the pavers' edges. Reinforced grass and gravel grid systems also allow rainwater to soak into open pore spaces in the soil medium.

Pervious pavement systems allow rain water to pass through their surface and soak into the underlying ground or be stored in the gravel base and connected to the stormwater system via under drains. Pervious pavement must be designed to manage stormwater runoff adequately and maintain the same load bearing capacity as conventional paving in order to support the weight and forces applied by vehicular, bicycle, or pedestrian traffic, and other potential loads that can occur based upon the use of the paved surface.

The most desirable approach to using pervious pavement is to combine this strategy with landscaped-based stormwater management whenever possible. Pervious pavement is primarily used within parking lots, plazas, sidewalks and walkways, and roadways. Generally, soil infiltration rates that exceed or meet the accepted standard of 0.5 inches/hour are suitable for pervious pavement systems.



▲ *Typical pervious pavement type sections – Porous asphalt, pervious concrete, permeable and porous pavers, reinforced gravel paving, and reinforced grass paving.*

Why Choose Pervious Pavement?

- Reduces volume of stormwater entering the storm drain system, especially with use of a thicker aggregate base depth.
- Reduces the landscaped area needed for stormwater treatment measures.
- Can be the only viable option in urban conditions or in parking lots that cannot be drained to a landscaped area.
- Offers stable surface for traffic and other uses.
- Versatile in size, shape, and materials available.
- Pavement design and texture can slow down traffic speed.
- Can provide a more visually attractive environment than some standard pavements.
- Some systems can have a longer lifespan over traditional pavements.

Potential Constraints?

- Requires well-drained native soil or thick gravel sub-base with an underdrain.
- Has a relatively high installation cost and can be difficult to maintain.
- Has a limited infiltration effectiveness on street slopes over 5% unless underground terracing is used.
- Some types should not be used on streets with higher speeds, heavier weight vehicles, or higher traffic volumes.
- Some types may be difficult to patch in a similar appearance.
- Should not be used in areas with soil contamination or high groundwater tables.
- Existing trees may need to be removed adjacent to pervious pavement, or a special design may be needed to protect tree roots.
- Can only be considered a treatment measure if allows for infiltration.

2.9 Green Infrastructure Measures and Opportunities

Pervious Pavement

BAYAREAPERVIOUSCONCRETE.COM*

▲ *Pervious concrete used in parking lane in a highly constrained urban area.*

CITY OF OLYMPIA, WA

▲ *Porous asphalt and pervious paver sidewalk retrofit.*

Porous Asphalt and Pervious Concrete

Porous asphalt and pervious concrete products are similar in appearance to standard asphalt and concrete. The main difference is that the fines are left out of the aggregate portion of the mixture. This results in small holes within the paving that allow water to drain through the surface. When installing porous asphalt and pervious concrete, it is critical that the subgrade is properly prepared and that the surface is poured and finished correctly. As with conventional paving, if porous asphalt and pervious concrete are not properly installed, they are prone to failure. Also, once installed, both porous asphalt and pervious concrete tend to be difficult to patch repair because the paving mixture is typically made in large batches.

One problem cited in past street and parking lot projects using pervious concrete or porous asphalt is that the forces applied by wheels turning, stopping, and can some tear up the pavement's surface and create depressions. However, the technology of pervious pavement systems is constantly evolving, and this may not be as much of an issue with current technology.

Pervious concrete and porous asphalt are more expensive than conventional concrete and asphalt and requires specialty contractor experience to install; hence, it is economically more viable to use in large batches. Pervious concrete and porous asphalt work well for streets, parking lots, larger plazas, bicycle facilities, sidewalk and long walkway applications as appropriate to the use and aesthetics of the project. Regular maintenance of porous asphalt and pervious concrete is required for the long-term viability of the paving system.

Permeable Pavers and Pervious Pavers

Any type of permeable paver can create a pervious surface if there are spaces between the pavers and those spaces are filled with sand or a porous aggregate. Many permeable pavers are designed specifically for stormwater management applications. They allow water to pass through joint gaps and infiltrate into a thick gravel subgrade. This system is widely applicable to both small and large paving applications and it offers the flexibility to be repaired more easily than other pervious pavement systems, because small sections can be removed and replaced.

Pervious pavers are manufactured pavers that allow stormwater to pass through the pavers themselves; some manufacturers refer to this type of paver as permeable pavers which should not be confused with the permeable paver with gap joints defined above. Allowing water to flow through the paver itself permits the pavers to be placed adjacent to each other, eliminating the joint space required with permeable pavers. As with the permeable pavers, water then infiltrates into a thick gravel subgrade below the pavers.

Pavers offer flexibility in color, size, style, joint configuration, and pattern. It is important to note that selected pervious and permeable pavers along pedestrian walkways must be ADA compliant and not cause tripping hazards. When installing pervious and permeable pavers, care should be taken to assure that the base and subgrade is properly constructed in order to minimize the potential for differential settlement.

CD+A

▲ *Bus pads and other places where pervious pavement is placed must consider the weight and type of vehicles to be used on it.*


KEVIN ROBERT PERRY

▲ *A new development along El Camino Real in San Mateo County features permeable pavers throughout the parking lot.*


KEVIN ROBERT PERRY

▲ *Permeable pavers offer a wide variety of colors, patterns, and sizes for the designer to choose from. Many paver distributors offer ADA accessible pavers for pedestrian conditions.*

2.9 Green Infrastructure Measures and Opportunities

Pervious Pavement

ASLA

▲ *This metal grate allows for pedestrian travel over a landscaped system while still allowing rainfall to pass through the void space between metal grate paving.*

NEVUE NGAN ASSOCIATES

▲ *Grass paving installed in a residential driveway.*

Porous Rubber

Made from recycled rubber and small stones, porous rubber works like pervious concrete, but can be installed over tree roots and other locations where its more flexible characteristics are a benefit.

Reinforced Gravel Paving

A reinforced gravel paving system uses small, angular gravel without the fines and a plastic or concrete structure that helps provide support to create a rigid load-bearing surface. Gravel can be a viable alternative to a traditional paved surface in areas of low use that still require a rigid surface, such as low trafficked parking lots, infrequently used overflow parking lots, or emergency vehicle routes on sites.

Reinforced Grass Paving

In the right situations reinforced grass paving, or other hybrids between paving and planting, can be used to provide structural support while also allowing for some plant growth and stormwater infiltration. These systems may be appropriate in areas of low use and where soil, drainage, sunlight, and other conditions are conducive to plant growth.

Suspended Decking and Boardwalks

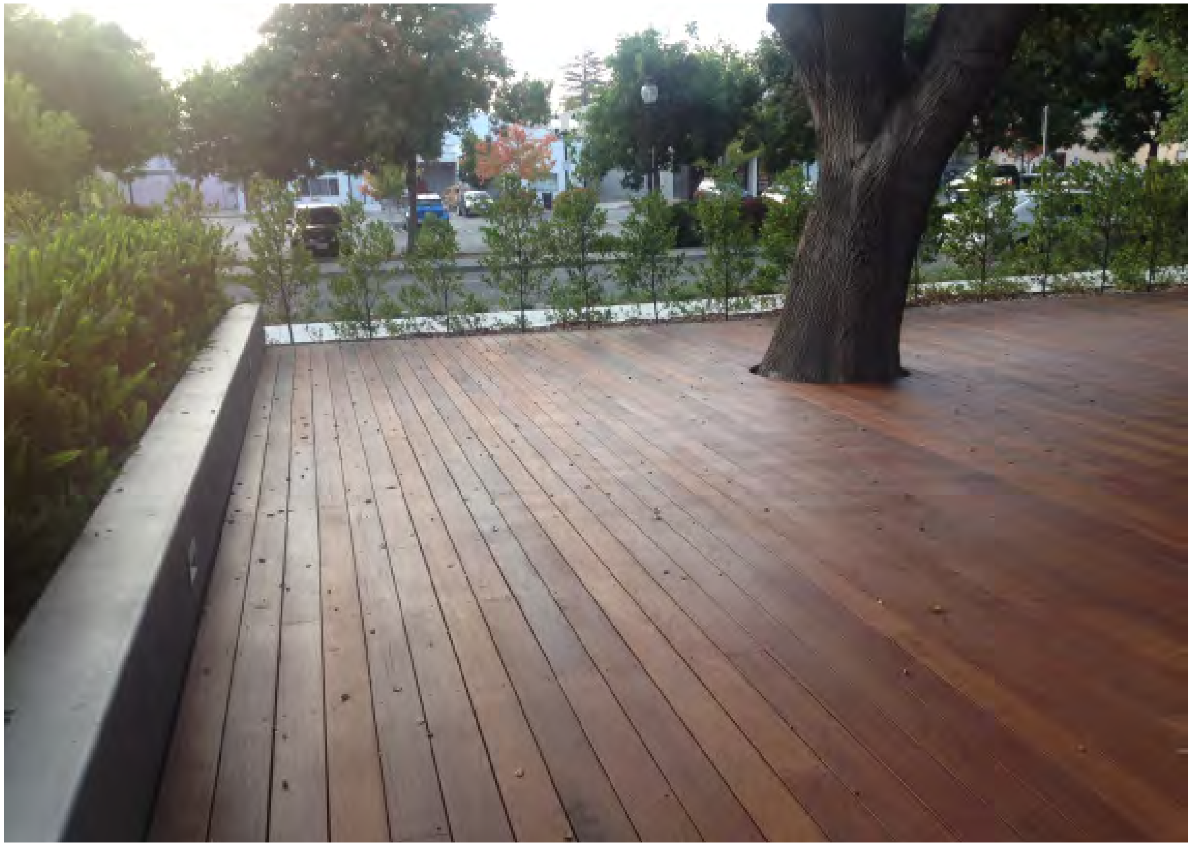
Decking and boardwalks can provide an alternative pervious pavement material. While it has typically been used in more residential and commercial applications, it can be used within pedestrian areas of streets as well. Suspended decking and boardwalks can vary in size to meet the conditions where it is used and can be as small as a bridge spanning a landscape-based green infrastructure facility to spanning a large rain garden for seating and circulation purposes.

Grates

Grates can be used to span landscaped green infrastructure measures to provide a pervious surface. Depending upon the use and weight load requirements, grates can be metal, fiberglass, or another material. Grates can be designed to perform different functions ranging from providing a walking surface to a tree surround.

Opportunities for Plaza and Patio Spaces

There are a wide variety of pervious pavement materials suitable for pedestrian plazas and patio spaces. Interlocking concrete joint pavers and suspended decking offer the greatest flexibility for colors and patterns, while pouring a pervious concrete pad is the most efficient use of labor. For plaza spaces, if heavy vehicles are planned to use the space for maintenance or emergency access, vehicular load-rated pavers or pervious concrete should be used.



URBAN RAIN DESIGN

▲ *A suspended decking system allows for rainfall to easily reach the underlaying soil. This patio space creates a beautiful space and helps preserve an existing mature tree from foot compaction.*

KEVIN ROBERT PERRY

▲ *Permeable pavers are placed at an urban plaza in Portland, Oregon. During heavy rain events, any surface overflow from the pervious pavers will sheet flow into an adjacent rain garden.*

KEVIN ROBERT PERRY

▲ *The Elk Grove Rain Garden Plaza demonstration project features several pervious pavement examples. This plaza area showcases both permeable pavers and a boardwalk.*

2.9 Green Infrastructure Measures and Opportunities
Pervious Pavement

URBAN RAIN DESIGN

▲ *Permeable pavers can accomodate meandering walkways and slopes to meet ADA compliance.*

URBAN RAIN DESIGN

▲ *Boardwalks are effective to suspend pedestrian travel over landscaped-based stormwater facilities.*

Opportunities for Walkways

Material choice is further expanded for standard pedestrian walkways as these surfaces are not typically designed for heavy vehicle access. As long as the surface is ADA-compliant with no gaps between the paving/walking surface over ½-inch wide, pervious material options for walkways is extensive. Pervious concrete and permeable pavers are widely accepted surfaces. Suspended boardwalks over infiltration areas or landscaped-based green infrastructure facilities are becoming more popular choices for walkways within or adjacent to the green infrastructure. Even sleek metal grates that allow passage of rainfall and light can be suspended over landscape areas (and can even support vehicular loads) while at the same time allow people to walk on the grates.

URBAN RAIN DESIGN

▲ *An apartment complex in San Mateo uses permeable pavers throughout the walkway system.*

Opportunities for Parking Lots

A variety of pervious pavement materials can be utilized in parking lot conditions. Like with streets, pervious paving systems can be placed in the parking zone (stalls), the drive aisles, or a combination of both. Permeable and pervious pavers are a common choice for designers as they provide the greatest flexibilty in size, color, and patterns. Pervious concrete is also frequently used throughout an entire parking lot or simply within the parking stall zone. Regardless of material type, parking lots offer specific challenges with high sediment accumulation. Hence, regular inspection and upkeep of parking lot pervious paving should be encouraged to maintain the longevity of the stormwater system.

▲ *Permeable pavers within a parking lot application. Any overflow from the pervious pavement system drains into a vegetated swale.*

▲ *A parking lot utilizing reinforced gravel paving within the parking lot stall area. This parking lot also has a vegetated swale to accept any potential overflow from the reinforced gravel area.*

▲ *Pervious concrete allows for stormwater management and its light color helps reflect heat rather than absorb it.*

2.9 Green Infrastructure Measures and Opportunities

Pervious Pavement

FORCONSTRUCTIONPROS.COM

▲ *Porous asphalt was used in this street's repaving.*

CD+A

▲ *This road is made of permeable pavers that can be easily biked on.*

** The use of this image is for general information only and is not an endorsement of this or other proprietary devices or suppliers.*

Opportunities for Streets

Pervious pavement can be used in a variety of locations within streets. Pervious paving is primarily used on roadways with low-traffic speeds and volumes, but there are successful examples of it used on high-traffic streets. Pervious concrete, porous asphalt, and permeable and pervious pavers are good choices for center turn lanes or paved median areas, parking lanes, or the entire roadway; bicycle facilities; sidewalks; and bus stop areas. The use of different pervious pavement materials, patterns, colors, and textures can be used to create designated areas in a roadway such as loading zones; parking areas; and primary pedestrian areas and vehicle areas, such as in a shared street. Some cities are using porous rubber for sidewalks to allow the pavement section to flex to accommodate tree surface rooting and reduce replacement of sidewalk pavement. Raised elements such as medians, islands, roundabouts, and dividers can be paved with pervious pavement to reduce runoff from these areas into the roadway or adjacent areas. Pervious pavements are commonly used between tree planter areas along a street to not only manage runoff but to provide increased area for air and water access to tree roots which can improve tree health and long-term viability. Suspended boardwalks and grates can be used to provide a pervious solution for pedestrian circulation over landscaped green infrastructure measures.

BAY AREAPERVIOUSCONCRETE.COM*

▲ *This project uses pervious concrete to manage runoff from the street.*

Special Considerations for Pervious Pavement Design

- In dense neighborhoods where on-street parking use is high, pervious pavement may be more appropriate than other, landscaped based, green infrastructure measures.
- The aggregate base of the pervious pavement may be thickened (deepened) to provide additional storage capacity, especially if the native soils percolate slowly and no subdrain is used.
- Pervious pavement can be combined with other green infrastructure measures to expand and provide additional treatment and management, with other measures being used to pretreat run off to remove silts and other contaminants that can clog pervious pavement. Also, pervious pavement can be installed adjacent to other treatment measures to enhance their performance. For example, pervious pavement could be installed between tree well filters in a linked tree well filter design to allow for broader irrigation of the trees and treatment of stormwater in a continuous trench.
- Pervious pavement and aggregate base thicknesses need to be designed to support the planned vehicle and/or pedestrian weight load requirements.
- Appropriate sweeping, power washing, and other maintenance protocols are needed to limit clogging for all pervious materials, while limiting removal of gravel in permeable paver joints. Semi-annual vacuum cleaning of the pervious pavement surface can help prevent clogging and extend the longevity of the system.
- Some pervious pavement materials may clog from asphaltic concrete fines. A one-foot wide concrete band separating the two materials can be used to limit the spread of asphaltic concrete fines into the pervious pavement.
- Pervious materials are being used in increasingly different ways. For instance, pervious concrete panels are replacing grates for drop inlets and catch basins, as small permeable pavers, and as larger panels as a walkable surface over infiltration basins and other measures.
- Installation requires contractors knowledgeable and experienced in the construction of the specific pervious pavement type, and possibly manufacturer, being used.
- For regulated projects, pervious pavement must store and infiltrate the runoff volume described in the MRP, see the **C.3 Regulated Projects Guide** for more details.

NEVUE NGAN ASSOCIATES

▲ *Residential driveway with permeable pavers in San Mateo County.*

CD+A

▲ *Raised islands can be surfaced with pervious pavement.*

2.10 Green Infrastructure Measures and Opportunities

Green Roofs

DEFINITION: Green roofs are landscaped systems placed on rooftops designed to capture rainfall and allow it to evaporate back into the air before runoff is created, as well retain and filter stormwater.

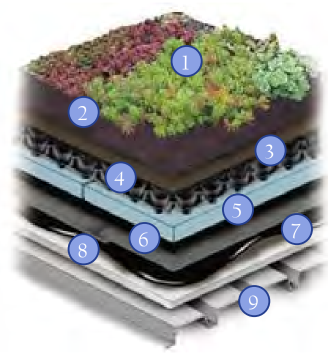
Green roofs, also called eco-roofs, function very much like trees, with a living landscape system that intercepts rainfall on building rooftops before it can reach the ground. Water that normally runs off the roof and is conveyed directly into a piped stormwater system is absorbed by soil and plants on the roof, evaporates, or is collected below the soil media and drained into downspouts. Any discharged water is greatly reduced in volume and pollutant load. Unlike conventional rooftops, green roofs have the added benefit of insulating buildings thereby reducing energy consumption, lessening the urban heat island effect, and providing wildlife habitat for insects and birds.

There are two classifications of green roofs: intensive and extensive. Extensive green roofs are light-weight, allow for 4-6 inches of soil coverage, and usually support only grass-like plants and sedum species. Intensive green roofs allow for greater soil volumes and wider variety of plant species including shrubs and even some tree species. In both green roof systems, adequate building structural support is needed to safely hold up the plant and soil volumes during saturated conditions.

Green roofs can thrive on flat or sloped roof conditions, residential or commercial buildings, and small or large building footprints.

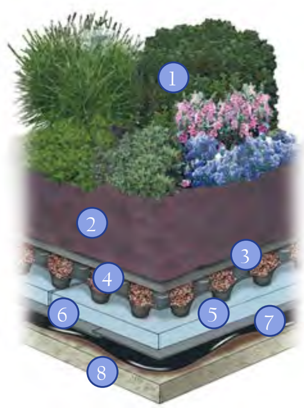
While integrating the use of green roofs is more common with new construction, retrofitting conventional roofs with green roofs is possible. For retrofit conditions, it is necessary to determine whether the structure can accept the additional loading of a saturated green roof condition.

◀ *Green roofs are an excellent stormwater facility strategy because the can be used in a wide-variety of sizes and building contexts.*



The Anatomy of an Extensive Green Roof

1. Extensive Vegetation (sedums/grasses)
2. Growing Media (4-8 inch depth)
3. Filter Fabric
4. Moisture Retention/Drainage Panel
5. Insulation
6. Root Barrier
7. Protection Course and Capillary Break
8. Waterproofing Membrane
9. Roofing Substrate



The Anatomy of an Intensive Green Roof

1. Extensive Vegetation (groundcovers, shrubs, trees)
2. Growing Media (greater than 8 inch depth)
3. Filter Fabric
4. Moisture Retention/Drainage Panel
5. Insulation
6. Root Barrier
7. Waterproofing Membrane
8. Roofing Substrate

Why Choose Green Roofs?

- They can provide stormwater management where land value is at a premium and ground plane space is limited.
- Decreases heating and cooling costs by insulating and shading buildings.
- Helps reduce the urban heat island effect.
- Provides wildlife habitat and potentially open space for people if designed as roof garden.

Potential Constraints?

- In retrofit projects, building structure will need to support the added weight of green roof media.
- Landscape maintenance is required on the roof.
- Limited number of landscape professionals trained to install and maintain green roofs.


ASLA

▲ *Green roofs can also be great spaces for people.*

CHAPTER 2

2.10 Green Infrastructure Measures and Opportunities
Green Roofs


WOOLY BLUE LANDSCAPING

▲ *Green roofs can be placed on angled roofs, though special design consideration is needed to assure that plants and soil are adequately stabilized.*


GREEN ROOF ALIANCE

▲ *A small green roof covers a portion of a residential complex in Northern California.*

Opportunities for Small-Scale Green Roofs

Small-scale green roofs can be placed on a variety of roof contexts including single family homes and garages, office buildings, roof awnings, and shade structures. Many smaller green roofs are retrofit applications; however, they are perfect to plan for new construction. In either situation, the most important consideration is having enough structural capacity to support the green roof system. Most retrofit conditions will feature extensive green roofs because they are lighter in weight and would require less structural support.


URBAN RAIN DESIGN

▲ *This small green roof retrofit in Portland, Oregon showcases sedums on an extensive roof. Note there are some chairs up there for people to sit on the roof.*

Opportunities for Large-Scale Green Roofs

With rapid infill development occurring within San Mateo County, larger buildings are being constructed for multi-family, mixed use, and industrial buildings, and parking garages. These new developments are ideal candidates for large-scale green roofs because they can be built from the beginning to structurally hold the weight of green roofs. Both extensive and intensive green roofs can be used in these larger roof contexts, including roofs used for people to gather as a dynamic above ground landscape.

SERGIO GRAZIA

▲ *This large rolling green roof at a high school is an example of how the roof can help insulate the building.*

ANDREA COCHRAN LANSCAPE ARCHITECTURE

▲ *The Nueva School green roof in Hillsborough, California features multiple green roof applications.*

BRICK LLP

▲ *This commercial building in Mountain View has an intensive green roof that supports gardens and pedestrian seating.*

TIM GRIFFITH

▲ *This university dorm building at UC San Diego features a larger extensive green roof.*

2.11 Green Infrastructure Measures and Opportunities

Green Walls

DEFINITION: Green walls are landscaped systems placed or grown vertically/near-vertically, on building facades to capture rainfall and allow it to evaporate back into the air before runoff is created. Green walls are not currently a C.3 Regulated Project Type design strategy.

Like green roofs, green walls are designed to capture rainfall with plant material before the rainfall hits an impervious surface and becomes runoff. During storm events involving wind that drives rainfall sideways, building walls can act as impervious surfaces just like roofs. Unlike green roofs though, green walls are vertical landscape systems that need to work against the pull of gravity. There are two general types of green wall systems: structurally contained and free-growing green walls.

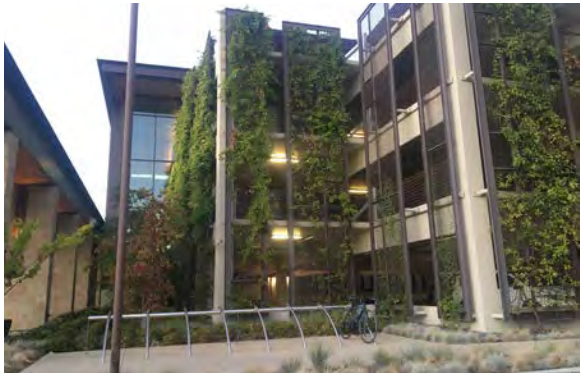
Structurally contained green walls are soil-filled landscaped cells, often held into an array of cells, that are structurally mounted onto a wall or vertically constructed support system. Structurally contained green wall systems are often sold as proprietary products, but many are custom designed green walls of different shapes and sizes.

Free-growing green walls are landscaped systems that are rooted in the ground, but the plant material can grow vertically up a wall or vertically constructed support system. Free growing green walls may have cost and structural advantages over structurally contained green walls in that less resources need to be used to vertical hold the weight and structure of soil.

Like green roofs, green walls have the added benefit of insulating buildings thereby reducing energy consumption, lessening the urban heat island effect, and providing wildlife habitat for insects and birds. Depending on the design of green wall system, there also may be an aesthetic value of covering building facades with an artistic structural and plant forms.

◄ *This beautiful green wall application in downtown San Mateo is the perfect entry into a commercial building.*

REID BOGERT



▲ *Vines grow up a rigid screen system to create a green wall effect at the Palo Alto Medical Facility in San Carlos.*

ROBERTO PORTOLESE VIA CTBUH

▲ *This building uses multiple green wall technologies to help vegetate a high-rise facade.*

URBAN RAIN DESIGN

▲ *A large green wall wraps around the Golden One Center in Sacramento. This green wall captures runoff from vertical surfaces and helps soften the overall feel of the space.*

Why Choose Green Walls?

- They can provide stormwater management on a vertical surface where ground plane space is limited.
- Decreases heating and cooling costs by insulating and shading buildings.
- Can create interesting and artful effects with the green wall structure and/or planting arrangement.
- Helps reduce the urban heat island effect.
- Provides wildlife habitat and potentially people space if designed as a garden space.

Potential Constraints?

- They are not currently recognized to meet C.3 stormwater treatment requirements.
- Depending of the green wall system, can be expensive to design and construct.

URBAN RAIN DESIGN

▲ *A small green wall panel in Portland, Oregon.*

2.12 Green Infrastructure Measures and Opportunities

Rainwater Harvesting

DEFINITION: Rainwater harvesting is the direct capture of rainfall from an impervious surface into a storage container for future use, release to the landscape, or for other uses, such as toilet flushing.

Rainwater harvesting and re-use involves rainwater catchment systems (i.e., rain barrels and cisterns) that intercept wet-weather or storm event runoff in a storage unit, enabling use of the retained water for non-potable purposes. Rainwater harvesting systems can be installed on rooftops, along buildings where downspouts are located, or even underground. They also can be incorporated inconspicuously into the side of a building. Depending upon the jurisdiction and setting, harvested rainwater may be used for indoor potable use; however, non-potable uses such as toilet flushing or landscape irrigation are most common.

Success of rainwater harvesting systems depend on frequent use of the captured water so that storage capacity is continuously available for the next storm event. These devices can be used to control stormwater runoff, reduce stormwater flow, and remove pollutants by preventing them from entering storm drains. The principal water quality and volume management benefits of rainwater harvesting is reduced use of potable water for non-potable needs and reductions in the volume of wet-weather flows that enter the public storm drainage system. To provide additional pollutant reductions, the overflow of the system can be routed to any of preceding landscaped-based stormwater facilities described in this chapter.

Depending on the size of the rainwater harvesting capture device and the amount of runoff captured, there can also be a flow reduction benefit. Any water that is stored, delays downstream time of concentration. If the cistern or rain barrel is at capacity, a valve can be placed at the overflow orifice to regulate the rate of water to be released from the system.

◄ *A metal cistern collects rainwater from a high-density residential development and is a focal point of the architecture for the project.*

▲ *A series of interconnected rain barrels captures roof runoff for reuse at an elementary school.*

▲ *Simple residential rain barrels are available in many shapes, sizes, and colors.*

▲ *A series of large cisterns stores water at the University of California, Davis.*

Why Choose Rainwater Harvesting?

- Water can be used for non-potable purposes, which leaves more water in public reservoirs to fill drinking water needs.
- Rainwater harvesting provides an important public education tool for the conservation of water resources.
- Reusing water can ultimately save water bill expenses.
- Storage containers can be made of various sizes, shapes, and materials.

Potential Constraints?

- With San Mateo County's climate, rainwater stored during the wet winter months may need to be potentially stored for several weeks or months of time for to be used in active irrigation periods.
- Often there is not enough storage capacity in rainwater harvesting units compared to the roof's supply of rainwater.
- Water captured from non-roof areas may require a permit.
- Irrigation demand may not be high enough to warrant rainwater harvesting on regulated projects.

▲ *This oak rain barrel at a residential property captures rainfall. Any overflow is directed to a stormwater planter.*

2.13 Green Infrastructure Measures and Opportunities

Vegetated Swales

DEFINITION: Vegetated swales are shallow, linear, and relatively narrow landscaped areas designed with gentle side slopes and bottom areas that capture, slowly convey, and potentially infiltrate stormwater runoff as it moves to downstream discharge points. Vegetated swales are not currently a C.3 Regulated Project Type design strategy.

Vegetated swales are primarily used to convey stormwater runoff on the land's surface while also providing some water quality treatment. As water flows through a vegetated swale, it is slowed by the interaction with plants and soil, allowing trash, sediments, and particulate-based pollutants to settle out. Runoff in vegetated swales travels more slowly than it would through pipes in a traditional stormwater conveyance system, allowing for some attenuation of peak flows. The longer a vegetated swale is, the greater the residence time for slowing and filtering of stormwater runoff; however, the gradient of the vegetated swale and the use of weirs may affect flow rates. Vegetated swales have some potential to infiltrate stormwater runoff as it moves downstream depending on the specific conditions of the site and through the use of check dams to retain shallow amounts of runoff. Vegetated swales are typically built very shallow and contain runoff that is only a few of inches deep.

Parking lots, streets, and certain site/building locations that have a long, continuous space to support a functioning landscape system are excellent candidate sites for vegetated swales.

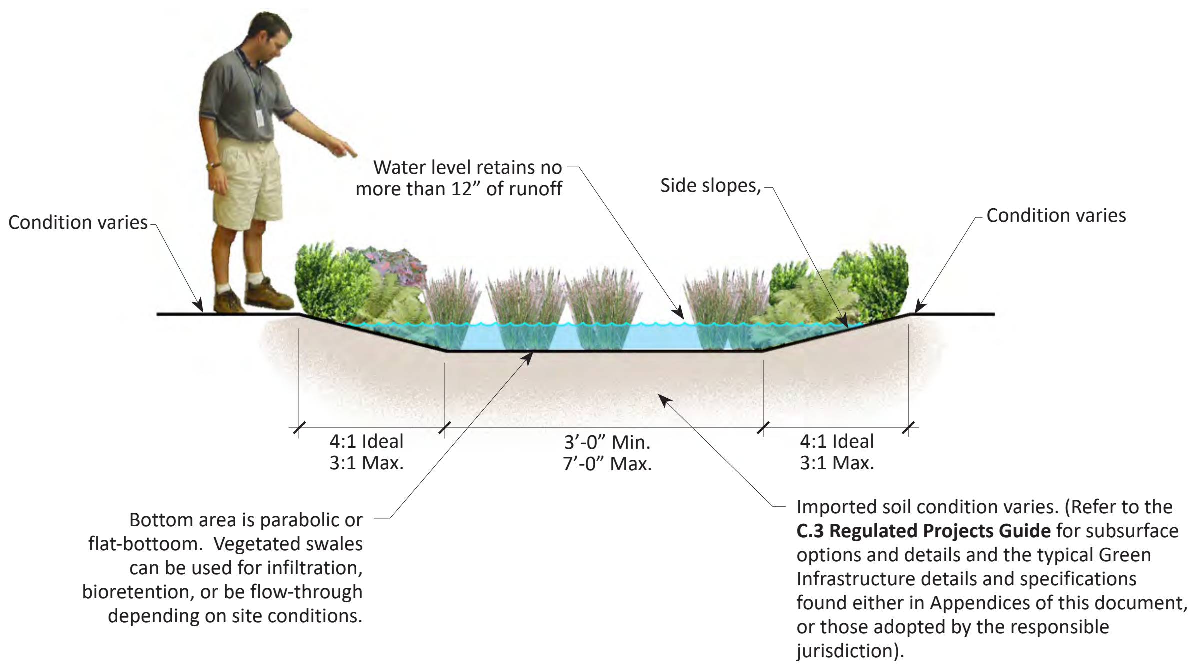
Vegetated swales are relatively low-cost compared with standard landscaped areas, simple to construct, and widely accepted as a stormwater management strategy. Vegetated swales can be planted in a variety of ways ranging from mown grass to a diverse palate of grasses, sedges, rushes, shrubs, groundcovers and trees.

For building, site, street, and parking lot applications, vegetated swales can be used in both relatively flat conditions or steeper conditions up to a 5% longitudinal slope.

For regulated projects, vegetated swales can only be used for conveyance or pre-treatment as they are not a regulated treatment measure unless they are part of a treatment train; see the **C.3 Regulated Projects Guide** for more details.

URBAN RAIN DESIGN

◂ *This parking lot in San Mateo County utilizes a vegetated swale to manage a large portion of impervious area runoff.*



The Anatomy of a Vegetated Swale

1. Cross section is parabolic or trapezoidal with defined side slope conditions (no vertical drop in grade)
2. Side slopes are ideally set at a 4:1 slope (3:1 maximum)
3. For street conditions, use a 12-inch flat shelf transitioning between the curb or pavement and the slope when used adjacent to a parking lane, bicycle facility, or sidewalk
4. 6" preferred, maximum of 12" of stormwater runoff retention
5. Imported soil mixture (see **C.3 Regulated Projects Guide** for soil specifications)
6. Native soil condition (an underdrain system may be needed with some native soil conditions)
7. Vegetated swales can be either infiltrative, or use bioretention/flow-through with an underdrain system

Why Choose Vegetated Swales?

- Can complement the rural and semi-rural character that exists in several San Mateo County communities.
- Can provide vegetation that buffers pedestrians and bicyclists from moving vehicles.
- Provides vegetation along streets, buildings, and parking lots which can increase community identity and soften the look of a built space.
- Can include trees that provide protection from sun, fostering a pleasant environment.
- They often require less infrastructure to build and are simple and inexpensive to construct.
- Are excellent choices for new residential and commercial development and can be easily retrofitted within parking lots and along street and building frontages.

Potential Constraints?

- They need long, continuous spaces which can be difficult to find.
- They are often designed to be "too deep" and, as a result, are not aesthetically pleasing.
- Does not meet design standards for regulated projects but can be used as part of a treatment train to transport stormwater to a regulated project treatment measure.
- Difficult to incorporate on street parking with vegetated swales and provide good pedestrian circulation, unless space is provided for people to step out of vehicles and bridging is provided across the vegetated swale.

2.13 Green Infrastructure Measures and Opportunities
Vegetated Swales

URBAN RAIN DESIGN

▲ *This vegetated swale in San Mateo County captures both parking lot and building rooftop runoff.*

URBAN RAIN DESIGN

▲ *An urban park space with a vegetated swale.*

Opportunities for Buildings and Sites

Building sites can be ideal places to incorporate vegetated swales, if there is a long uninterrupted stretch of landscaped area along the perimeter of buildings that can be used to capture and manage runoff. Often existing building sites and new building designs have a wide perimeter landscape area that are under-utilized. These areas can often be redesigned to serve as vegetated swales that capture roof or site runoff. In addition, some vegetated swales can be sited to accept both parking lot and building runoff.

URBAN RAIN DESIGN

▲ *This vegetated swale in Portland, Oregon is beautifully integrated into the building frontage.*

Opportunities for Parking Lots

There are many creative ways to include vegetated swales in parking lots. For example, shorter parking stalls can yield a few extra feet of area that can be used for vegetated swales. The leftover space in front of angled parking configurations can also be consolidated into landscaped vegetated swales. Narrowing driveway/back-up aisles can free up space for extra landscape area. One of the best applications is to incorporate vegetated swales into the perimeter of existing parking lot landscaping. If there is an abundance of surface parking available, it is possible to redesign this extra space into vegetated swales.

NEVUE NGAN ASSOCIATES

▲ *This vegetated swale in Oakland, California was retrofitted within an existing parking lot.*

NEVUE NGAN ASSOCIATES

▲ *By transferring this area of wasted space to the front row of parking stalls, a vegetated swale could fit without affecting the function of the parking lot.*

URBAN RAIN DESIGN

▲ *A vegetated swale within a large parking lot. Notice that there is pedestrian pathway along on side of the vegetated swale to facilitate better site circulation.*

NEVUE NGAN ASSOCIATES

▲ *This commercial parking lot was retrofitted with shorter parking stalls to allow for a vegetated swale.*

2.13 Green Infrastructure Measures and Opportunities
Vegetated Swales

KEVIN ROBERT PERRY

▲ *This vegetated swale contextually fits well along this low-density residential arterial street and also features a pervious concrete sidewalk and new street trees.*

URBAN RAIN DESIGN

▲ *This vegetated swale retrofit in Spokane, Washington preserves existing street trees and features check dams to slow water down as it moves through the landscape system.*

Opportunities for Streets

Streets can be ideal places to incorporate vegetated swales if there is a long uninterrupted stretch of landscape or paved area that can be converted to capture and manage runoff. Rural, suburban, industrial, residential, and low-volume streets are candidates for including vegetated swales. For retrofit conditions, existing streets often have a wide right-of-way space that is under-utilized. Look for long, unplanted median strips or unused planting strips between the sidewalk and the street. Vegetated swales can be implemented in medians, along travel or parking lanes, or adjacent to the sidewalk. Bridges can be provided where needed for pedestrian or vehicle access. In some cases, existing under-utilized paved areas in streets such as center turn lanes, oversized travel lanes, or low use parking lanes can be converted into space for vegetated swales. In some applications, and at the discretion of the jurisdiction's traffic engineer, vegetated swales can be designed with flush curbs to allow sheet flow of stormwater runoff into the landscape.

URBAN RAIN DESIGN

▲ *This shallow vegetated swale along Delaware Avenue in San Mateo captures stormwater runoff and buffers pedestrians from vehicular traffic.*

Special Considerations for Vegetated Swale Design

- Pedestrian access across vegetated swales may be needed to allow convenient and direct access between two destinations, such as between an on-street parking stall and a building entry. This can be achieved by using pedestrian bridges constructed of decking, grates, or other acceptable and accessible materials.

- Side slopes should be designed at a 4:1 slope with a maximum allowed slope of 3:1, with a 12-inch flat shelf transitioning between the curb or pavement and the slope when used adjacent to a parking lane, bicycle facility, or sidewalk. Refer to **Section 3.1 General Design Strategies and Guidelines** for additional information regarding design of edge conditions.

- Where space permits and in more rural and suburban contexts, consider vegetated swale edges having a short flat bench along a pedestrian or bicycle facility and a low gradient slope leading to the bottom of the vegetated swale. This edge condition, rather than having curbs, can save construction materials costs as well as present a more garden appearance.

- For street applications, existing center medians may be redesigned and retrofitted as vegetated swales to manage stormwater, however, challenges do exist as these areas are often already the high points of the street and stormwater does not typically drain towards these spaces. Significant regrading of the street or additional piped infrastructure may be needed to route runoff to these spaces.

- Trees are encouraged to be planted within vegetated swales, however, care needs to be taken to not obstruct site visibility along streets.

- For parking lot conditions, there should be wide enough space between a parking stall edge and a vegetated swale for people to enter and exit their vehicles without having to enter into or over the vegetated swale. Egress widths should be sized based on context and level of pedestrian use, and, at least, the minimum path of travel requirements.

- Preferred retention depth is less than 6 inches of stormwater. A depth of up to 12 inches can be acceptable, if approved by the jurisdiction's engineer.

- For swales above a 2% slope, check dams or terraces should be used to help slow the flow of water. Additional guidance on check dams is provided in **Chapter 4** of this design guide. For street slopes over 5%, consider changing from a vegetated swale to a series of terraced planters.

URBAN RAIN DESIGN

▲ *A beautiful vegetated swale adds significant greening and character to a residential street.*

URBAN RAIN DESIGN

▲ *Urban plazas can integrate vegetated swales into seating elements and capture stormwater runoff.*

URBAN RAIN DESIGN

▲ *Parking lot vegetated swales, like this example in Coeur d'Alene, Idaho provide a visual buffer between parked cars.*

CD+A

Chapter 3

Design Strategies and Guidelines

◄ *Green infrastructure measures can provide a range of benefits to communities.*

3.0 Design Strategies and Guidelines
Introduction

CD+A

This chapter provides strategy considerations and guidance for green infrastructure measures applicable to buildings, sites, parking lots, and streets and how to apply them to real-world examples.

Section 3.1 provides general design strategies and guidance that are applicable to most green infrastructure measures for buildings, sites, parking lots, as well as guidance that is applicable to multiple types of green infrastructure in streets. This guidance builds upon the key considerations discussed in **Chapter 2**.

Section 3.2 presents design strategies and guidance specific to buildings, sites, and parking lots.

Section 3.3 focuses on before and after design examples shown in different contexts that illustrates how to implement the key considerations and design strategies for building, site, and parking lot projects.

Section 3.4 introduces the concepts and elements of green streets and complete streets that when combined create sustainable streets. A summary of the different types of street classifications and land uses that define complete streets is presented to provide an understanding of the transportation component of sustainable streets and how street design and improvements can support and enhance green infrastructure. Prototypical examples of how one can approach the planning, design, and implementation of sustainable street projects are also provided.

Section 3.5 offers a series of detailed design strategies and guidance for green infrastructure measures specific to streets to support the development and implementation of sustainable streets. This guidance expands upon the key design considerations and general guidance provided in **Chapter 2** and **Section 3.1**. This guidance is relatively detailed due to the general lack of design guidance, that is available to the public, for the integration of green infrastructure into streets, and because there are additional regulatory and engineering considerations that apply to green infrastructure within streets.

Section 3.6 illustrates how the sustainable streets design strategies and guidance presented in the previous chapter and sections can be used and developed in prototypical projects in San Mateo County. These before and after examples illustrate a range of green infrastructure measures, street types, and land use contexts.

The careful planning, design, and implementation of green infrastructure facilities are important to develop successful, functional, and attractive community infrastructure and buildings, sites, parking lots, and streets as well as to facilitate effective and cost-efficient ongoing operations and maintenance.

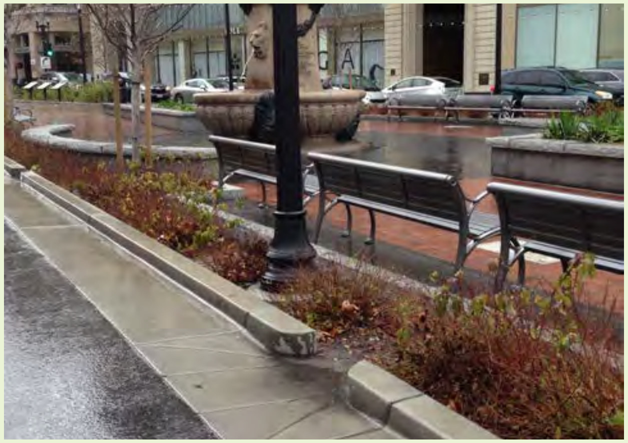
See also **Chapter 2 Additional Design Considerations** that are provided for each green infrastructure measure, **Chapter 4 Key Design and Construction Considerations, Chapter 6 Operations and Maintenance, Appendix 3 Sustainable Streets Typical Design Details**, and **Appendix 4 Sustainable Streets Specifications** for additional discussion, strategies, and guidance.

CD+A

▲ *Stormwater planters and permeable pavers are used in this retrofit street project that reduced the wide width of the roadway, enhances the low density residential neighborhood character, and manages runoff.*

CD+A

▲ *While these stormwater curb extensions have been designed to be fairly deep in relation to the surrounding walkways and roadway, the vegetation is densely planted and fairly tall, which helps discourage people from entering them.*



CD+A

▲ *While this plaza retrofit project was not required to provide green infrastructure, curb cuts were designed into the project to allow street runoff to enter depressed landscape areas to provide some water quality treatment and debris catchment.*

3.1 General Design Strategies and Guidelines

For All Locations

SMARTGROWTH.ORG

This section provides guidance for design treatments and considerations related to green infrastructure, green streets, and complete streets that are applicable to many or all the green infrastructure measures and project locations included in the Design Guide. This section provides guidance under the categories of general, green infrastructure, and complete streets. **Section 3.5** provides more detailed guidance and considerations specific to each treatment measure type when located within street rights of way. See **Appendices 3** and **4** for typical green infrastructure construction details and specifications, and the **C.3 Regulated Projects Guide** for additional technical information related to these and other measures.

General Guidance For All Locations

- From an aesthetic and safety perspective, where space permits, green infrastructure measures should be designed to have the top of the biotreatment soil media (BSM) as high as possible in relation to the adjacent sidewalk surface elevation.
- For streets and public projects, where space constraints are present and regulated projects requirements cannot be met, providing green infrastructure facilities should still be considered and implemented as part of a project, if the project is not a regulated project. These undersized treatment measures can provide many community, social, environmental, and public health benefits regardless of whether it achieves full or reduced regulated projects credit or credit towards reducing pollutant load targets.
- Grade and construct inlets, streets, parking lots, sidewalks, and other improvements and locate inlets along green infrastructure measures so that water does not back up and pond in walkways, the street, or along the gutter.
- Evaluate existing utilities during the conceptual phase as presence of existing utilities may alter the location and design of the green infrastructure measure.
- Pavers should be bounded by edging, such as raised or flush concrete curbing, to keep them in place and reduce paver movement or turning, especially when used where vehicles will drive over them.
- Mulch is an important part of any planted GI system. Composted wood mulch is the best option. See section 6.3 for more information on mulch.

Green Infrastructure Guidance

All Green Infrastructure

General

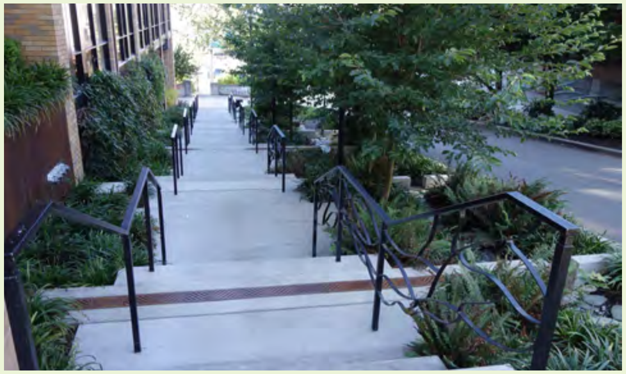
- Consider grades and direction of roadway runoff as well as locations of drainage inlets and catch basins when determining where to locate green infrastructure facilities.
- If it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and cost implications of making the connection.
- Review the infiltration considerations presented in the **C.3 Regulated Projects Guide** to protect groundwater from contamination by pollutants in stormwater runoff, as well as for other guidance.

Siting in Constrained Areas

- In places where a green infrastructure measure is difficult to site due to space constraints, or the measure needs to be expanded to meet regulated projects sizing requirements, the following methods can be considered. See **Section 4.12** for additional information.
  - Focus on more urban measures such as vertical sided stormwater planters, repurposing existing landscape areas, placing measures in the parking lane or shoulder, using pervious pavements, and using underground systems.
  - Use pedestrian bridges and platforms to span the landscaped green infrastructure facilities rather than having a pedestrian walkway terminate the measure.
  - Implement a shared use agreement with adjacent public or private property to collect and treat runoff from both the right of way and development parcels.
  - Depending upon the locations of existing utilities, break up green infrastructure measures into smaller units or consolidate into a larger feature.
  - Regrade street and other elevations.
  - Add new connections to storm drain infrastructure.
  - For mulch selection in constrained areas, see Section 6.3

CD+A

▲ *In highly developed projects, rainfall captured from roofs can be directe to building adjacent stormwater planters for treatment. Weirs allow the system to step down the sloping ground plane.*



CD+A

CD+A

▲ *In dense and constrained areas, green infrastructure can be strategically integrated and shared between public and private. A building downspout in this private building is built into the stairs and ties into the street's stepped sotrmwater planters.*

CHAPTER 3

3.1 General Design Strategies and Guidelines
For All Locations

NEVUE NGAN ASSOCIATES

▲ *Retaining walls double as weirs to expand the capacity of the stormwater facility and to retain and slow the runoff.*

KENNEDYSTREETPROJECT.COM

▲ *The use of underdrains is important in places with poor infiltration and other conditions.*

- Determine if lane width reductions or a parking lane can be removed to create new space.
- To create less engineered-looking facilities that are a consistent sloped and/or deep facility, the facility can step down away from the outer edges with the use of slopes or retaining curbs. These shall be designed by a structural engineer to ensure it is stable.
- Link to underground measures or techniques that can be placed below adjacent sidewalk or street areas to expand the storage area.
- If achieving C.3 credit is desired for constrained non-regulated streets projects that cannot achieve the treatment facility sizing requirements of regulated projects, use BASMAA's guidance for alternative, or reduced, sizing of treatment facilities. Refer to **Section 4.12 Alternative Sizing Methodology for Streets Projects** for greater information.

Underdrains and Associated Elements

- Underdrains should be included when infiltration is prohibited or imprudent, the measured subgrade infiltration rate is low, and when the maximum surface pool drawdown cannot be achieved.
- Consider installing the underdrain pipe in the upper portion of the stormwater facility's aggregate storage layer to promote infiltration below the underdrain, when feasible. Designer should also consider the use of orifices or other control structures to provide additional infiltration and flow control benefits where applicable.
- Underdrain pipes shall be slotted pipe, or other acceptable substitute material per jurisdiction's engineer's specification, such as perforated pipe. Slotted pipe is preferred over round perforated pipe as aggregate may have more difficulty penetrating and completely blocking slots of the pipe.
- Geotechnical engineer or designer to recommend the need for underdrains based on the native soils ability to infiltrate.
- Do not wrap underdrain in geotextile liner.
- Refer to **Appendices 3** and **4** details and specifications and the **C.3 Regulated Projects Guide** for further information related to underdrains and other related design and components.
- If no subdrain is provided, ensure that there is an outlet or other overflow system to allow runoff that cannot be infiltrated to exit the facility and flow back out to a street or other use as appropriate to prevent flooding.

Check Dams

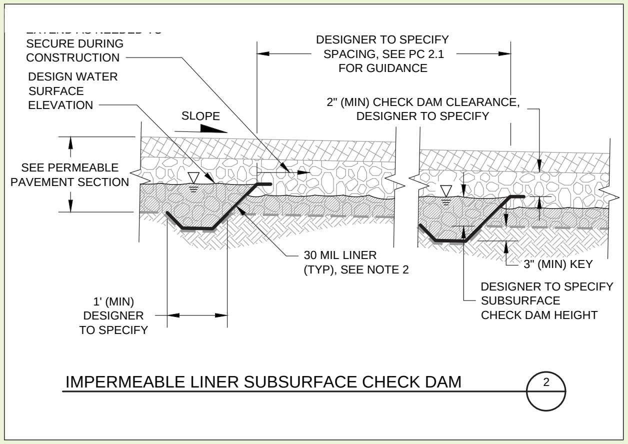
- Use check dams or weirs in sloped conditions or when high flows are anticipated to slow velocities and allow ponding, storage, and infiltration of runoff.
- Subsurface check dams may be warranted for pervious pavement applications to detain subsurface flow, allow infiltration, and aid in reduction of structural problems associated with subsurface erosion; however, engineering challenges may be experienced with slopes greater than 5%. Refer to **Appendix 3, Green Infrastructure Typical Details** for further information.

Liners

- Do not use applied (sprayed on, etc.) liners on concrete structures as they will typically crack if the concrete cracks.

Stable Soils for Structures

- All structural elements, including pavements and curbs, must be founded over structurally stable soils. Structurally stable soils should extend laterally from the point of support at a slope of 1:1 horizontal to vertical in the downward position. This should be verified by a geotechnical engineer.



SFPUC

▲ *Detail of a typical impermeable liner subsurface check dam. Other techniques can be used for subsurface check dams.*

CD+A

▲ *Soils shall be stabilized for the placement of all structural elements including planter walls and adjacent pavements.*

3.1 General Design Strategies and Guidelines
For All Locations

CD+A

▲ *When utilities are placed in, or cannot be relocated out of a green infrastructure facility in a retrofit project, they can be placed at the edges of the stormwater facility and grouped to reduce visual clutter and limit the need for maintenance and emergency personnel having to enter the facility.*

SFPUC

▲ *By extending these stormwater curb extensions into the street, the existing utility boxes were not impacted.*

Utility and other Element Conflicts and Protection Techniques

Unwanted Migration of Infiltrated Stormwater

- Consider and use techniques to limit or prevent the migration of infiltrated stormwater into surrounding utility systems, adjacent road beds, or adjacent structure foundations. Philadelphia's *Green Streets Design Manual*, 2014, provides a robust discussion regarding potential techniques on page 53 of that design manual. Designer shall confirm these techniques are applicable to specific jurisdictional regulations and utility providers requirements.
- In areas of good soil permeability, water will primarily infiltrate downward rather than laterally. However, on streets with heavy service vehicles such as buses and trucks, it may be desirable to include techniques to limit potential lateral movement of infiltrated stormwater.

Utility Placement, Protection and Clearances

Review of national guidance on the placement of and clearances to utilities in relation to green infrastructure measures were adapted and provide a basis for the following guidance provided for reference. *Project proponents shall contact local project specific utility providers and jurisdictions to determine the final required materials, placement, clearances, and other accommodations.* Refer also to typical construction details in **Appendix 3**, which contain designer notes and guidance pertinent to utility crossings.

Utility Placement

- When siting green infrastructure measures, the design should locate and assess all known utility crossings and conflicts and adjust the design to avoid as many utilities as possible. The criticality of utility conflicts in terms of their potential impact to the project's design performance, cost, and schedule should be carefully evaluated during the planning and design development phases.
- It is likely that as-built drawings, record drawings, and other source materials provided by utility companies and local jurisdictions may be inaccurate. If a utility has the potential to impact the project design and/or the performance of the green infrastructure measure, the exact location, depth, and condition of this utility should be field verified during the design phase to prevent costly redesign and/or project delays during construction.

- If designing new or retrofitting existing utilities, place utilities outside of the planned or potential future green infrastructure measures as feasible. Align or cluster utilities, vaults, and other equipment wherever possible.
- Utilities should be placed to minimize disruption to pedestrian through travel and potential green infrastructure locations while maintaining necessary access for maintenance and emergencies and ADA compliance.
- Refer to the following Utility Clearances section for additional information.
- Small utility vaults such as residential water vaults, residential water meters, gas valves, gas vaults, or street lighting should be located to minimize conflicts with existing or potential green infrastructure and tree locations.
- Utility vaults associated with green infrastructure measures that are located in the roadway must be rated to each jurisdictions' loading standards based on expected use and vehicle type.
- Utility vaults and boxes should be located wherever possible to maximize the number and size of green infrastructure facilities and the ability to connect these measures into continuous strips.
- Utility laterals should run adjacent to, not directly under, potential green infrastructure locations wherever possible (such as through driveways or between planters or tree basins).
- Utility laterals and vaults should be located so as to avoid potential green infrastructure locations. Particularly in instances where there are frequent driveways, alternate locations for utilities should be sought so as not to take up available street tree and green infrastructure locations. Utility boxes may be located in driveways if the sponsor provides a vehicle-rated box; however, this is not a preferred solution due to access difficulties.
- Street design, new development, and redevelopment projects should consider the overall pattern of green infrastructure facilities, plantings, lighting, site furnishings when placing new utilities in the street, and locate utility lines so as to minimize disruption to the prevailing streetscape rhythms.
- The presence of overhead wires or the need for fire department aerial ladder access may conflict with the siting of trees placed within green infrastructure measures. Appropriately sized trees should be selected based on anticipated mature tree height and width, and overhead wire and aerial ladder locational needs as per local fire standards.

CD+A

▲ *Utilities located next to this green infrastructure facility are located outside the primary pedestrian crossing location. Designers should consider replacing utility covers and boxes in poor condition when designing retrofit projects.*

CD+A

▲ *Stormwater facility cleanouts and other utilities should be placed to be easily accessed and maintained, and not in the middle of the facility.*

3.1 General Design Strategies and Guidelines

For All Locations

SFPUC

▲ *When utilities such as this irrigation backflow preventer are placed within the stormwater facility, they must be protected from water intrusion or placed above the water line as required by code and jurisdictions.*

CD+A

▲ *This retrofit example has the stormwater curb extension to allow the backflow preventer to be placed adjacent to the stormwater curb extension. Care should be taken to verify vehicle overhangs will not hit the backflow preventer.*

Utility Protection

- Consider site specific conditions, utility requirements, and the function the protection measure must perform when determining the type of protection measure required. Protection measures may include soil or engineered fill with overlying impermeable liner, sleeve/casing, utility trench dam, and/or insulating wrap.

Utility Clearances

- Utilities may be placed under, in, or over green infrastructure facilities subject to acceptance by the utility owner and each jurisdiction's standards. Individual projects should be coordinated with for specific requirements.
- Refer to each jurisdiction's standards to provide the minimum clearance between trees and major utilities (sewers, fire hydrants, gas and water meters and mains, manholes and utility vaults, and utility poles) and minor utilities (laterals, vaults, valves, etc.)
- Contact each utility owner and jurisdiction, including fire departments, to confirm minimum required setback from their infrastructure, including but not limited to gas, communications, water, sewer, storm, street light and signal poles, and fire hydrants, and any additional requirements such as access routes, and paved zone around the utility or infrastructure.

Landscaped Green Infrastructure

Planting

- Consider the proportional area and size of tree root balls in relation to the size and width of the planted green infrastructure measure in order to ensure there is adequate width, depth, and space to install the trees and to maintain required stormwater function.
- Where trees are used, the soil depth shall be a minimum of 30 inches, with possible reduction in depth for smaller trees as determined by a licensed landscape architect or arborist.
- Green infrastructure measures can be planted with a variety of trees, shrubs, grasses and groundcovers, depending on site context and conditions.
- If infiltration systems are surfaced with landscape, plant with grasses, perennials, groundcovers, and shrubs that do not require deep soil profiles to grow.

- In areas where it is necessary to maintain sight lines between vehicles and between vehicles and people walking or bicycling, use vegetation (other than trees) that is typically 30 inches and lower in height.
- Plants used at intersections, crossings, and cycle track buffers must meet local requirements for corner visibility regulations, sometimes referred to as sight triangle visibility.
- Current best practices recommend not using understory plants in small tree planter areas or maintaining a minimum of 18 inches clearance between a tree trunk and an understory plant to reduce competition for water, nutrients, and root space.
- Do not specify plants or place plants too close to a curb, flush curb edge, or planter edge that have the potential to encroach into sidewalks, bicycle lanes, or cycle tracks.
- Use plants that grow by sending out "runners" that root such as beach strawberry or easily reseed carefully near pervious pavements as they can root into the pervious materials and become a maintenance issue.
- With tree plantings, consider the use of suspended pavement systems such as structural soil and modular suspended pavement systems to increase tree rooting area and stormwater attenuation.
    - Other strategies are available to provide improved growing conditions for trees within green infrastructure measures. These include placing tree root balls onto a structural soil or existing site soil base or pedestal. Trees can also be placed within an area of improved amended planting soil that is within or adjacent to a biotreatment soil media area, or within deeper areas of bioretention soil media than the rest of the green infrastructure facility. In addition, modular suspended pavement systems can be incorporated with tree plantings used as green infrastructure, such as adjacent to a tree well filter or stormwater planter. This can allow for the placement of improved planting soil that still meets the required minimum infiltration rate and avoids the use of heavily compacted soils under pavement, providing dual benefits of stormwater treatment and storage as well as tree root and overall health.

▲ *Plants should be selected and placed to not impair the visibility of pedestrians and cyclists to drivers while still providing an attractive appearance to the community.*

▲ *Public art, seating, and other pedestrian and furnishings can enhance the stormwater facility planting.*

▲ *Design the planting plan so that vegetation covers most of the stormwater facility after two years.*

3.1 General Design Strategies and Guidelines
For All Locations

CD+A

▲ *Mulch shall be selected to limit floating.*

SFPUC

▲ *The use of gravel as a mulch in this stormwater curb extension also helps control water velocity.*

Mulch

Mulch can aid in maintaining soil moisture, reduce weeds, limit erosion, act as a barrier to sedimentation, and if wood, can provide additional soil amendment and nutrient. Refer to **Appendix 4, Composted Arborist Mulch**, for specifications.

- Mulch specified shall be as low floating as possible. Bark shall be not used unless is part of the following mulch types.
- Wood mulches described as "forest floor," tree trimming mulch, arborist, or composted mulch work best. Mulch pieces should be variable in size to allow the pieces to "knit" together as they settle after placement.
- For composted arbor mulch, inquire of the ability to obtain unscreened or coarse compost (with adequate range of mulch sizes), also referred to as compost overs. Composted arbor mulch is thought to float less due to the composting process it undergoes. However, larger pieces may still be buoyant.
- Mulch shall be composted for at least the minimum requirement by CalRecycle for pathogen reduction.[1]
- Inert materials such as gravel or small stone are acceptable and are non-floating. These should especially be considered when runoff velocities are expected to be high entering and where runoff flows directly through the system.
- The Countywide Program has a specification for composted wood mulch and a list of some mulch suppliers. See www.flowstobay.org/preventing-stormwater-pollution/with-new-redevelopment/c-3-regulated-projects/ for more information.

1 See https://www.calrecycle.ca.gov/ for further information.

Trench Drains and Through Sidewalk Pipes

- Where a trench drain or through sidewalk pipe is used, avoid 45-and 90-degree angles and size it to support cleaning with equipment available to the municipality. Incorporate long radius sweeps rather than hard angles and provide clean out opportunities where possible. Provide trench drain and through sidewalk pipe designs, types, and models to the specific jurisdiction's infrastructure maintenance department for approval if no standard details or specifications exist.
- A trench drain can be extended beyond the sidewalk edge into the green infrastructure measure. Particularly for measures that are designed without sidewalls, extending the outlet of the trench drain can help limit potential erosion undercutting of the sidewalk and side slopes of the measures.
- Through sidewalk pipes should be used sparingly and typically only when a green infrastructure planter is bisected by a crossing walkway.

Side Slopes

- Where side slopes are used in green infrastructure facilities, they shall be 3:1 maximum (horizontal to vertical); with 4:1 preferred. Refer to the following individual green infrastructure measure treatments for other measure specific gradients such as longitudinal.
- To aid in erosion control, cobbles and other techniques should be used along the path where runoff flows between the source and where it enters the measure.
- In situations where the maximum side slope gradient is used, and vertical sides are not desired, the following alternative solutions to increase the capacity of the measure can be considered:
  - The facility can step down away from the outer edges with the use of slopes or retaining curbs. These shall be designed by an engineer to ensure it is stable and will not fail or erode.
  - Link to underground measures that can be placed under adjacent sidewalk or street area.
  - Use pedestrian bridges and platforms to span the measure rather than having it terminate the measure.
  - Shared use agreement with adjacent public or private property to collect and treat runoff from both the right of way and development parcels.

M. FABRY

▲ *Through sidewalk pipes may offer an alternative to trench drains.*

J. LEE

▲ *Trench drains that are wider and straight are less likely to clog. Consider metal topped curb inlets at curbs where bus and truck loading areas and vehicle parking stalls are to limit damage to the trench drain grate and frame.*

CD+A

▲ *Gravel or cobbles should be used in areas that may erode due to higher volumes or velocities of runoff.*

3.1 General Design Strategies and Guidelines
For All Locations

▲ *A concrete splash pad to catch sediment and cobbles to dissipate runoff velocity aid in the longevity and maintenance of the facility.*

▲ *Overflow structure set above ponding level, but below adjacent walkway and street.*

Inlet Design

- To better enable runoff to enter inlets, consider slanting the beveled ends of the inlet towards the stormwater facility or using rounded inlet ends or to direct runoff into the facility.

Inlet and Outlet Sediment Control and Energy Dissipation

- A variety of techniques may be used for sediment and dissipation control. Refer to **Section 4.7** and **Appendix 3** and each responsible jurisdiction's typical details for some materials and designs.
- Techniques must be effective and easy to maintain.
- The use of a concrete apron to catch sediment and debris shall be placed immediately adjacent to inlets.
- Cobbles or other approved materials by the responsible jurisdiction shall be placed adjacent to the concrete apron at all inlets and at the opening of all outlets.
- As cobbles can be displaced over time, the cobbles shall be embedded into a concrete pad unless otherwise approved by the local jurisdiction.

Overflow Outlet and Overflow Structures

Recognized best practices guides[2] were adapted from or used directly in preparing the following. Refer to **Appendix 3** or the responsible jurisdiction for additional design notes, guidelines, standards, and detailing. Refer to the Pervious Pavement discussion in this section for pavement overflow outlet and structure guidance.

- Provide convenient access to cleanouts and outlet structures for ease of maintenance.
- Storm drain pipe in areas subject to vehicular traffic or other loading must be designed with appropriate cover depth and materials to prevent damage to the pipe and associated components.
- Provide an overflow outlet and/or structured area drain to convey excess runoff from green infrastructure measures. Exceptions are overflow outlets for tree well filters and tree filters. Typical overflow techniques and devices include outflow curb outlets to the gutter and overflow structures.

---

[2] *Philadelphia's Green Streets Design Manual*, 2014; and San Francisco's Green Infrastructure Typical Details, 2016.

- Overflow structures shall provide for the design ponding elevation, as is specific to the green infrastructure facility design.
- Locate bioretention planters upstream of catch basins instead of at catch basins, unless detail can be provided to allow overflow into existing curb inlet.
- Locate inlets or overflow drains into stormwater planters so that water does not back up and pond in the street, gutter, or adjacent paved areas.
- Need to consider and minimize the amount of and sizing of infrastructure (overflow units, clean outs, etc.) in bioretention planters, especially smaller and narrower facilities, in order to maximize the area of functional green infrastructure.
- Locate overflow units, clean outs, etc. requiring access by vacuum trucks and other maintenance vehicles and equipment within 10 feet of face of curb for all projects.
- Avoid placing overflow structures too close to curb openings s oas not to block flow to treatment.
- If infiltration planters are used within a street, always provide surface overflow back out into the roadway.
- Nearby inlets, catch basins, or manholes can provide a convenient discharge location from under drains.
- If the overflow inlet will replace an existing curb inlet, make sure the overflow inlets is sized appropriately to handle larger storms.
- Consider constructing overflow inlets directly over existing storm drain systems to save on piping costs.
- Consider conveying overflow to another treatment measure if feasible, or to the storm drain system. Provide a means of overflow, even if planted measures are not connected directly into the storm drain system. Overflow points can include, but are not limited to, curb outlets, riser pipes, or spillways.
- Provide a thicker aggregate base layer to increase storage and infiltration as necessary.


EOA

▲ *Beehive drain in a building-adjacent stormwater planter.*


CD+A

▲ *Overflow systems can be staggered and combined between green infrastructure components. As one area overflows, it can spill into an adjacent treatment measure, and ultimately into an adequately sized overflow structure or outlet.*


CD+A

▲ *The clean outs for this project could have been better placed and not sited immediately downstream of the curb cut inlets.*

3.1 General Design Strategies and Guidelines

For All Locations

CD+A

▲ *This multi-family project uses porous asphalt in this pedestrian walkway that doubles as a fire lane, and complements the adjacent stormwater planter that treats building rooftop runoff.*

CD+A

▲ *This pervious paver parking lane contains a clean out and is located downstream of a stormwater facility and upstream of a drop inlet, which manages runoff that does not infiltrate into the paver system.*

Pervious Pavement

General

- Pervious pavement must be protected during construction so that it does not get clogged. It cannot be used as laydown for loose landscaping materials such as soil, compost, and mulch; or have muddy tires driven across it.
- Complement other green infrastructure measures such as stormwater planters and stormwater tree well filters by linking a series of measures together with pervious pavement as well as expand the area of stormwater management, depending on site context and conditions.

Pervious Pavement Overflow Outlet and Overflow Structures

Recognized best practices guides[3] were adapted from or used directly in preparing the following. Refer to the San Francisco Public Utilities Commission's Green Infrastructure Typical Details, most current version or as adapted by the Countywide Program or the responsible jurisdiction, for additional design notes, guidelines, standards, and detailing.

- Provide convenient access to cleanouts and outlet structures for ease of maintenance.
- Provide subsurface overflow and subsurface underdrains to convey excess flow to an approved discharged point. Underdrains are only recommended when an available daylight condition exists.
- Overflow riser elevation shall provide for the maximum design ponding depth in the pavement base, as is specific to the green infrastructure facility design.
- Emergency overflow for large storm events can be provided by surface sheet flow upon inundation of the pavement section (requires surface conveyance system or other runoff collection method).
- Consider the flow path of water when the pervious pavement section is fully saturated to the maximum design depth to confirm there are not unanticipated discharge locations (e.g., intersecting utility trenches) and to ensure the design provides emergency overflow conveyance to an approved discharge point.
- Provide a thicker aggregate base layer to increase storage and infiltration if necessary.

3 *Philadelphia's Green Streets Design Manual*, 2014; and *San Francisco's Green Infrastructure Typical Details*, 2016.

Pervious Pavers

- In public rights of way or parking lots, it is not recommended to design pervious pavers as narrow bands, such as along/as gutters or used as a catch basin, in water "run on" conditions due to their tendency to clog. Contact individual municipal jurisdictions for their specific requirements.
- It is recommended that joints between permeable pavers are a minimum of 3/8 inch to allow adequate capture of runoff.
- Cross section of pervious pavements should have up to a 1-2% cross slope in ADA pedestrian areas, and a maximum of a 5% cross slope, or up to 16% with an underdrain per C.3, or as recommended by the manufacturer.
- If it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and cost implications of making the connection.
- A thicker, or wider, section of aggregate base under the pervious pavement can be used as storage of runoff until it can infiltrate.

Infiltration Trenches and Basins

- Infiltration trenches work best when the upgradient drainage area slope is less than 5%. The downgradient slope should be no greater than 20% to minimize slope failure and seepage.
- If runoff is piped or channelled to an infiltration trench, install a level spreader to uniformly distribute the concentrated flow over a larger area to reduce runoff velocity and erosion. In street applications, this can include underground perforated pipes and half sections of pipe, curbing or trough, or surface flow (rain garden, stormwater planter, vegetated swale, etc.).

ACKERSTONE.COM

▲ *This plaza is made up of permeable pavers, allowing water to infiltrate at the source.*

TOUR.KORTRIGHT.ORG

▲ *This infiltration trench absorbs runoff from the parking lot.*

TOUR.KORTRIGHT.ORG

▲ *Infiltration trench with plantings located in a low density residential setting.*

CHAPTER 3

3.1 General Design Strategies and Guidelines
For Sustainable Streets

NACTO

▲ *A combination of pervious pavers and a stormwater curb extension manages runoff and protects riders on this cycle track and pedestrians at the intersection.*

BLOOM-LA.COM

▲ *Step out area between stormwater planters and parking allows for convenient entry for pedestrians into and out of vehicles. Intermittent walkways between the step out area and sidewalk allows convenient access to and access to destinations.*

Complete Street Guidance

General

- Evaluate existing roadways, pedestrian and bicycle facilities, and landscape area configurations during the conceptual phase, and incorporate sight distances and driveway ingress and egress, as appropriate, into the green infrastructure feasibility assessment.

Bicycle Lane, Bike Route, and Cycle Track Considerations

- On streets with protected bikeways or cycle tracks, the green infrastructure can be between the bicycle lane and the vehicle lane, see figure in **Section 3.5 Stormwater Curb Extension**.
- On streets with designated bicycle routes or with sharrows, but no bicycle lane, provide a shared vehicle/bike lane width of 12 feet to face of curb adjacent to the curb extension. Where high volumes of trucks and transit occur, increase this dimension to 13 feet. These dimensions should be verified with local agency's city engineer.

On-street Parking Stall Step Out Area

- The minimum width for a step out area, not counting the curb, adjacent to a parking stall is a subject of discussion in several communities around the Bay in regard to developing disabled access requirements suggests a minimum of 3 to 4 feet, while other guidance suggests a 5-foot minimum step out area in addition to the curb width to provide for universal access. Many existing rights of way and sidewalks are not wide enough to accommodate both a wider step out area and a stormwater planter. The designer should discuss this issue with the responsible jurisdiction’s ADA coordinator to achieve direction on the width of step out area for the specific project.
- Infiltration trenches and similar systems used along sidewalks or parking need to provide a paved or otherwise ADA acceptable walkable material step out area within or next to the infiltration system; this dimension should be verified with jurisdiction’s ADA coordinator, see also **Section 4.2 Designing for Pedestrian Circulation**.

Pedestrian Access Between Curb and Fronting Uses

- Provide preferred 6 feet width access between green infrastructure measures and between a green infrastructure measure and other obstacle for pedestrians to cross between parallel parking and adjacent uses. A preferred minimum width of 5 feet is allowed in constrained or low pedestrian volume areas. Access walkways to be provided a minimum of every two parallel parking stalls. The quantity of access points connecting between parking stalls and adjacent uses is a subject of discussion in several communities around the Bay. The designer should discuss this issue with the local jurisdiction's ADA coordinator for their specific requirements.

Green Infrastructure at Crosswalks

- Do not place green infrastructure measures in line with crosswalks and where a blind or visually impaired pedestrian would expect a curb ramp to be placed. This is especially important at corners without directional accessible ramps, such as where one accessible ramp is used for pedestrians to cross in two different directions.
- If vertical sided stormwater curb extensions or sloped stormwater curb extensions with a short flat shelf at the edge are adjacent to an accessible ramp, a low rail fence or curb should be used to define its edge. See following **Edge Conditions section** for additional information.

Corner Stormwater Curb Extensions

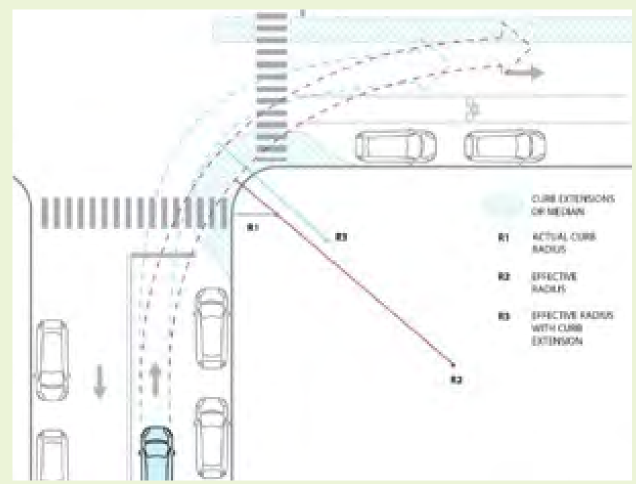
- To reduce pedestrian crossing distances and provide space for stormwater planters, intersection corners should be extended into parking lanes and shoulders. Where bike lanes off set vehicle lanes from the curb, the effective radius of vehicle turning movements can be accommodated with a smaller built curb radius. This design encourages lower speeds of turning vehicles and improves the ability to provide directional handicap ramps.

CD+A

▲ *Pedestrian bridges allow convenient crossing of recessed green infrastructure measures. This crossing is not ADA accessible at the street side.*

CD+A

▲ *Do not terminate crosswalks into green infrastructure facilities. This vertical walled stormwater planter was retrofitted to add a guardrail to keep people from entering the facility from the crosswalk.*



CITY OF SAN MATEO

▲ *Using an effective turning radius at corners allows for a smaller curb radius which can aid in traffic calming.*

CHAPTER 3

3.1 General Design Strategies and Guidelines
For Sustainable Streets


H2OC.ORG

▲ *This gently sloped green infrastructure design does not have a steep grade that requires a vertical edge such as a low railing or curb.*


CD+A

▲ *Low rail fence placed on raised curb of stormwater curb extension.*

Edge Conditions

- The design of the edge between walkways and green infrastructure facilities shall be considered for meeting accessibility regulations and discouraging people and vehicles from entering facilities. A flat buffer separation (also called a "shelf"), curb, low railing, guardrail, or other edging shall be provided and designed appropriately when required by the **American's with Disabilities Act** (ADA)**; Public Rights of Way ADA Design Guide**, pending approval, (PROWAG); and the **California Building Code** (CBC). Refer to ADA, PROWAG, and the CBC for more detail.
- To visually and/or physically denote a vertical drop in grade, larger grade changes, or where higher levels of pedestrian activity occur, a minimum one-foot wide transition shelf, curb, low fence, or guiderail may be warranted depending on conditions.
- Where there is an abrupt vertical grade change of more than 4 inches immediately adjacent to a walkway or sidewalk (excluding between a sidewalk and an adjacent street or driveway, or where a guard or handrail is provided[4]) a raised six-inch curb or a guard or handrail with a low "guide rail" is required.
- Low rail fences shall be between 16 to 18 inches tall, with vertical and horizontal member spacing meeting ADA and California State Building Code requirements. To limit impeding vehicle door swings when used adjacent to a parking stall, low rail fences may step down in height to a minimum of 4 inches and/or be pulled back from the back of curb for a maximum of 18 inches.
- Grade differentials between the bottom of the green infrastructure measure and the adjacent walking, riding, or driving surface of 30 inches or more requires the use of a guard rail. Refer to the current version of the CBC for further information. If used, guard rails shall be designed as attractive and complementary elements within the pedestrian realm and streetscape.
- When raised curbs or steel edging are used, the minimum edging height shall be 4 inches when used in a pedestrian or bicycle area and shall be 6 inches when used in conditions where vehicles will be present.
- The minimum width and height of curb edging can be increased to provide a variation in design, integrate seating walls, enable public art opportunities, and other elements.

[4] California Building Code, section 11B-303.5 Warning Curbs for more information.

- Where the front and/or rear of a maneuvering or parking vehicle may overhang a stormwater facility, the height and placement of any edging on top of a standard 6-inch street curb needs to be considered so to avoid damaging the vehicle and/or stormwater facility elements.
- If a solid material edging is used such as a low curb or metal edging, provide drainage notches or gaps for runoff to flow from adjacent pavement into the green infrastructure facility. Gaps in curb edgings shall be 4-inches wide and have a bottom that slopes down into the planter to direct runoff the green infrastructure measure. For thinner materials such as metal edging, the metal plate can be held off the planter wall by a ½-inch to 1-inch spacer.
- Where a flat or low gradient transition buffer (under 8%) is used in lieu of a curb or rail fence between the walkway and the deeper portion of a green infrastructure facility, the transition shelf should be a minimum of 12 inches wide and meet flush with the adjacent sidewalk.
- At the discretion of the local jurisdiction's traffic engineer, where the street has low traffic volume and speed, a vertical barrier may not be needed. In these cases, the measure's edge can be a flat area of at least 12 inches when adjacent to a walking path or sidewalk, and 12 to 24 inches when adjacent to vehicles or cyclists, or as directed by the local jurisdiction.
- Consider the street type, vehicle speeds, land use, and context when designing green infrastructure in or directly adjacent to a roadway, such as rain gardens in roundabouts or stormwater planters along the roadway. This will determine the need for a curb, low fence and/or guardrail; and width of flat area between roadway, including travel lanes, shoulders, and bicycle facilities and treatment measures.
- Where a depth of 30 inches or more exists between a pathway, sidewalk, or bikeway and the bottom of the green infrastructure measure, a minimum 24-inches flat to low gradient (under 8%) buffer is required if no curb or railing is provided.
- For green infrastructure measures with a raised curb and planted adjacent to on-street parking or loading, it is strongly recommended that the facility be designed with steel topped curb cuts. This can prevent vehicle tires from entering the stormwater facility and provides a continuous raised curb for people accessing their vehicles.

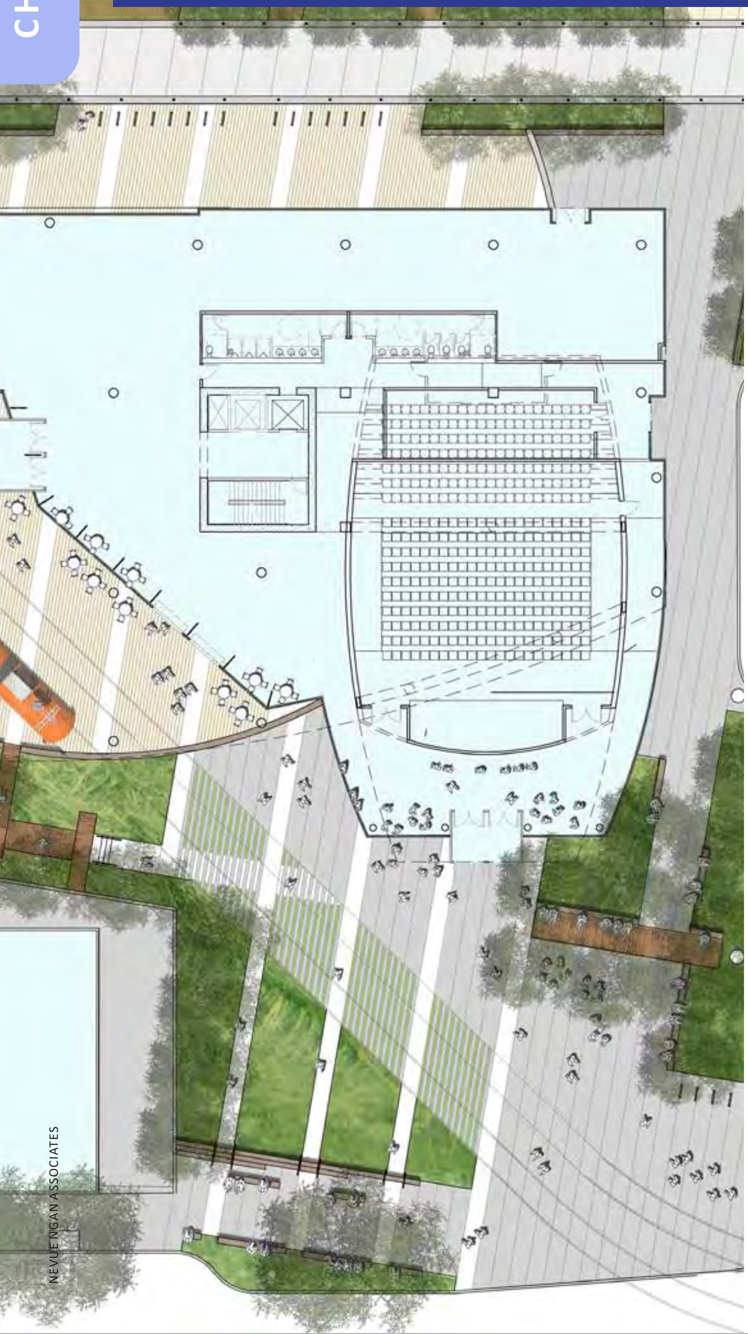
▲ *This stormwater planter's edge is designed as a seat wall and includes gaps to allow runoff from the adjacent sidewalk to flow into the stormwater facility.*

▲ *Low fences and light bollard seats can be used to prevent people from entering green infrastructure facilities and to protect the function of the utility.*

▲ *Bridges over green infrastructure, such as this one connecting the street to the sidewalk and multi-family project entry, can be designed to be significant gateways and gathering places for people within the public realm.*

3.2 Design Strategies and Guidelines

Buildings and Sites Design Strategies



The Importance of Efficient Site Design

One of the first questions a designer or builder should ask themselves about their project is: Has the impervious area from sites, parking lots, and/or buildings been minimized? From a design perspective, there are several effective strategies to minimize these areas. However, what makes sense from a design perspective may conflict with prevailing policy. Design and policy must work together in order to achieve site-specific stormwater goals. A carefully thought out site plan will often yield the space for a stormwater facility(s) that fits seamlessly with the other site uses. This holds true for new sites, parking lots, and buildings, but is especially evident when designing street and parking lot retrofit projects. The following describes possibilities for gaining additional landscape space for sites, parking lots, and building envelopes.

Providing Efficient Design for Sites

Sites can maximize the efficient use of space in many ways without compromising the programming or design of the site. As redevelopment continues in San Mateo County, existing sprawling one-story structures can be redesigned to reduce building footprints by using compact, multi-story structures, as allowed by local zoning regulations. Where sites have multiple building footprints, cluster buildings and mix building use to reduce the length of streets and driveways, minimize land disturbance, and protect natural areas. Where buildings and sites require large amounts of vehicular parking, integrate parking within the building structure or provide separate parking structures. These design strategies can be an efficient way to reduce the amount of impervious surface needed for parking. Lastly, provide adequate and efficient space for sidewalks, walkways, driveways, and/or plaza spaces, but do not over pave the site with these elements. All the strategies mentioned above help save space for integrated and perimeter landscape spaces that can also be used as stormwater facilities.

◀ *A block development site plan that shares both private and public stormwater landscape facilities.*

Providing Efficient Design for Parking Lots

Shorten parking stall lengths to 15 feet and/or shorten the drive/back-up aisles to 22 feet (this will most likely require revisions in municipal code). The shorter stalls can still accommodate SUVs, and the drive aisles can still allow cars to comfortably back up and travel within the parking lot. Portland, Oregon and other cities have allowed even smaller parking lot dimensions within their city codes. These strategies are especially effective for creating landscape space in parking lot retrofits. When looking at parking lots, it is important to ask the question of how much parking is needed on an "average day." Parking lots often have many empty parking stalls for most of the year. This is especially true with shopping mall and "big box" store parking lots. As municipal requirements allow, parking lots can provide for the average day (as opposed to peak) condition, or at least can provide peak overflow parking zones with pervious pavement.

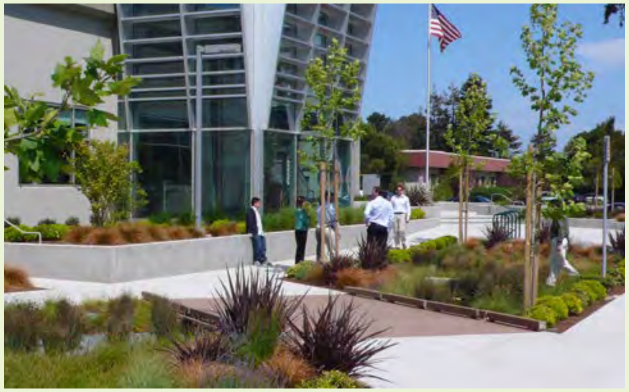
Sometimes local planning and design codes require more surface parking than is necessary for a business or use to thrive. Furthermore, parking lots are also often designed with oversized parking stalls and travel/back-up aisles. By fully utilizing the amount of space for parking and reducing the oversized dimensions, a considerable amount of space can be created for landscape-based stormwater management. The hypothetical parking lot conditions illustrated on the following pages shows how small and large conventional parking lots with oversized parking stalls and travel aisle dimensions compare with more efficient parking lot designs. Both scenarios have the same number of parked cars. However, the more efficient parking lot designs yield far more potential green space.


GOOGLE EARTH

▲ *The Brisbane City Hall site prior to retrofitting with a new parking lot and building landscape space was very inefficient in its layout.*


NEVUE NGAN ASSOCIATES

▲ *After the retrofit, the Brisbane City Hall replaces under-utilized asphalt with a new rain garden without losing any parking spaces.*

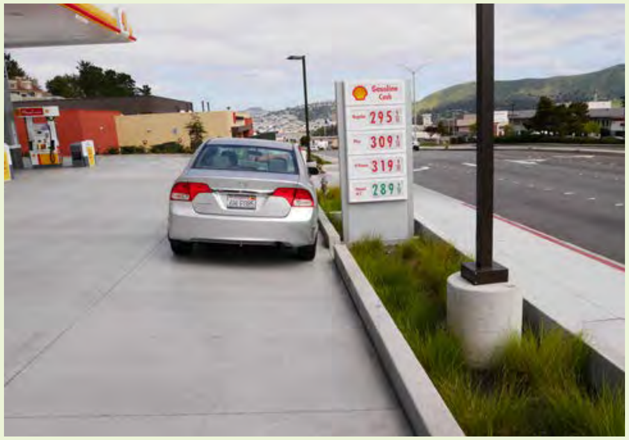

KEVIN ROBERT PERRY

▲ *The Brisbane City Hall Rain Garden even saves space by managing runoff under a boardwalk.*

CHAPTER

3.2 Design Strategies and Guidelines

Buildings and Sites Design Strategies

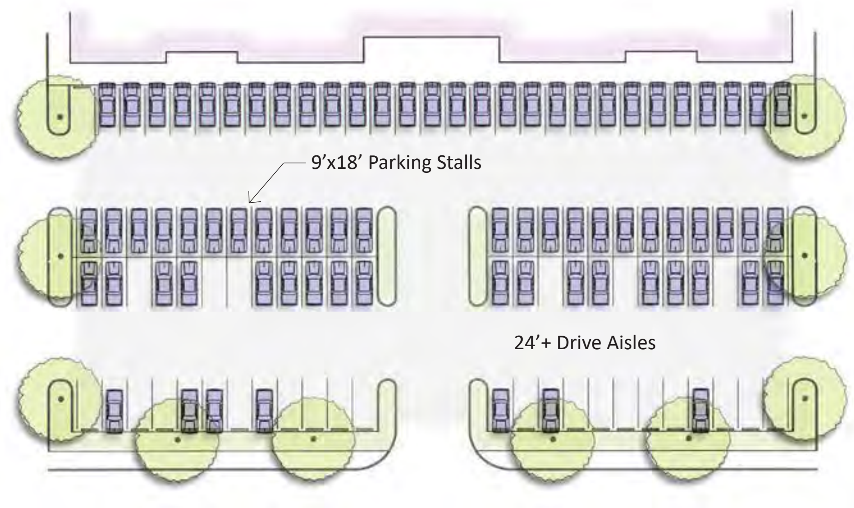


URBAN RAIN DESIGN

▲ *This gas station parking lot in San Mateo Conty provides a stormwater planter within a confined space used for capturing runoff.*

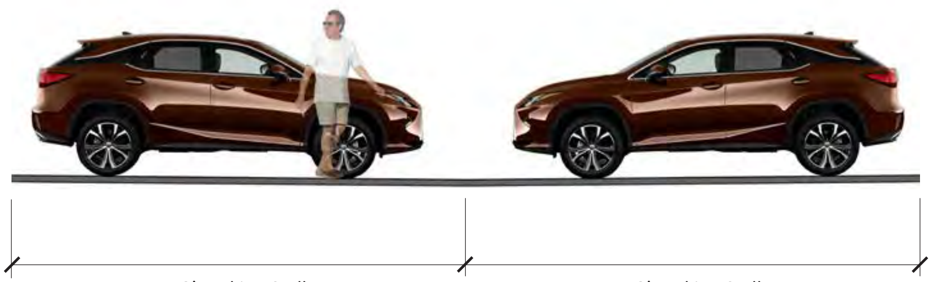
URBAN RAIN DESIGN

▲ *This site development installed a rain garden to manage both building and parking lot runoff.*

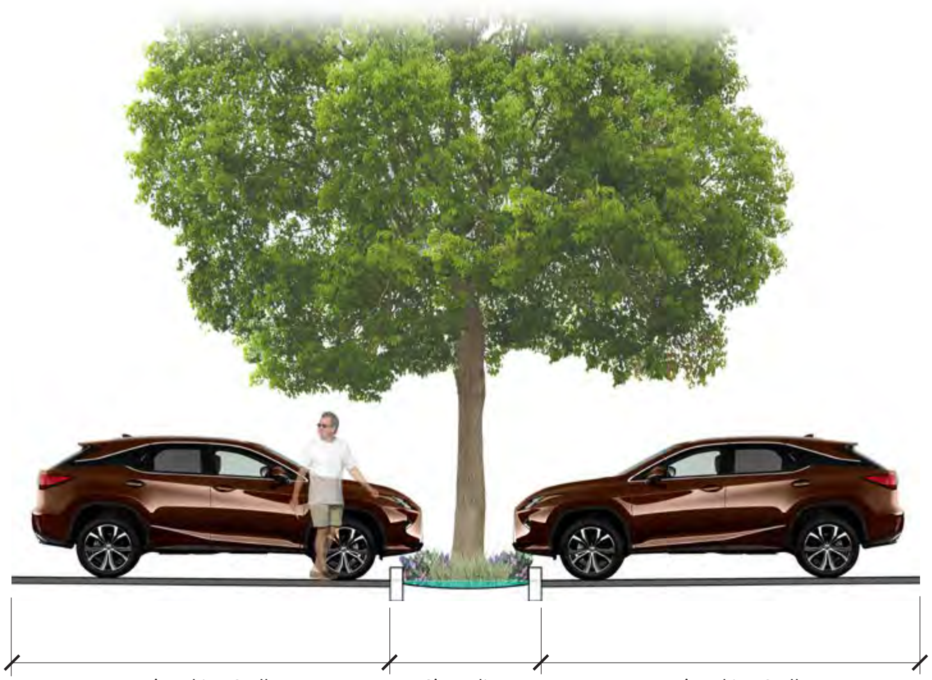


Oversized Parking Lot Dimensions

Efficient Parking Lot Dimensions



▲ *This typical cross section illustrates a conventional parking lot condition with 18 feet long parking stalls.*



▲ *This cross section shows how a 15 feet parking stall can help create room for landscaping used for stormwater management. Note that the parked cars in both scenarios are placed in the same place and fit within reduced length the parking stalls.*

NEVUE NGAN ASSOCIATES

▲ *This parking lot is oversized based on its parking demand and has an inefficient design layout. The result is a considerable amount of impervious area.*

KEVIN ROBERT PERRY

▲ *An existing, inefficiently designed parking lot with little landscaping.*

KEVIN ROBERT PERRY

▲ *The same parking lot (compared to the above photo) was redesigned to efficiently use space yielded a rain garden, sidewalk, and landscape zone for street trees.*

CHAPTER

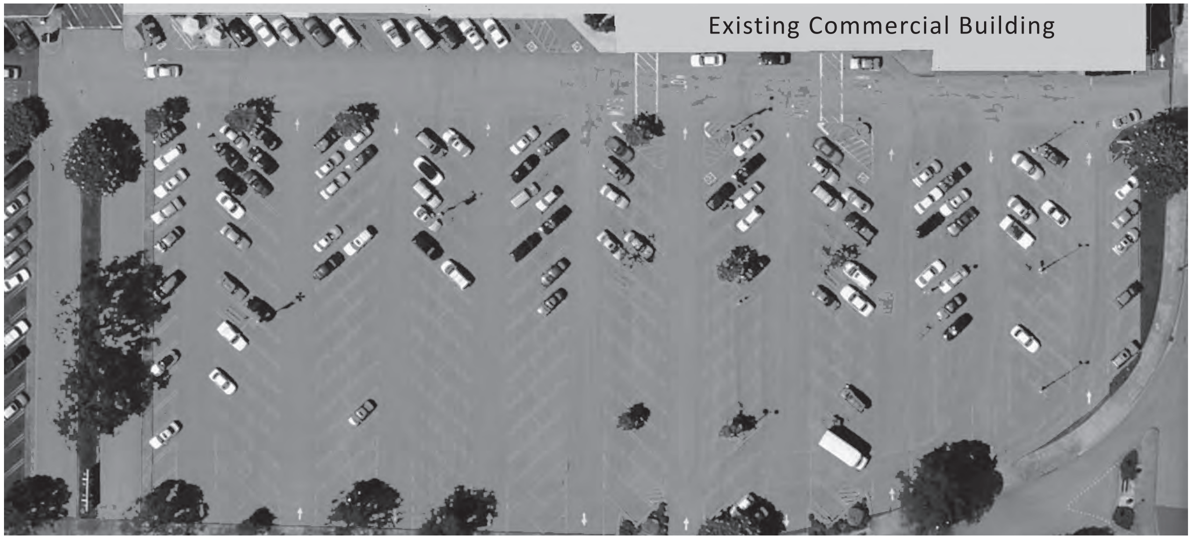
3.2 Design Strategies and Guidelines

Buildings and Sites Design Strategies

NEVUE NGAN ASSOCIATES

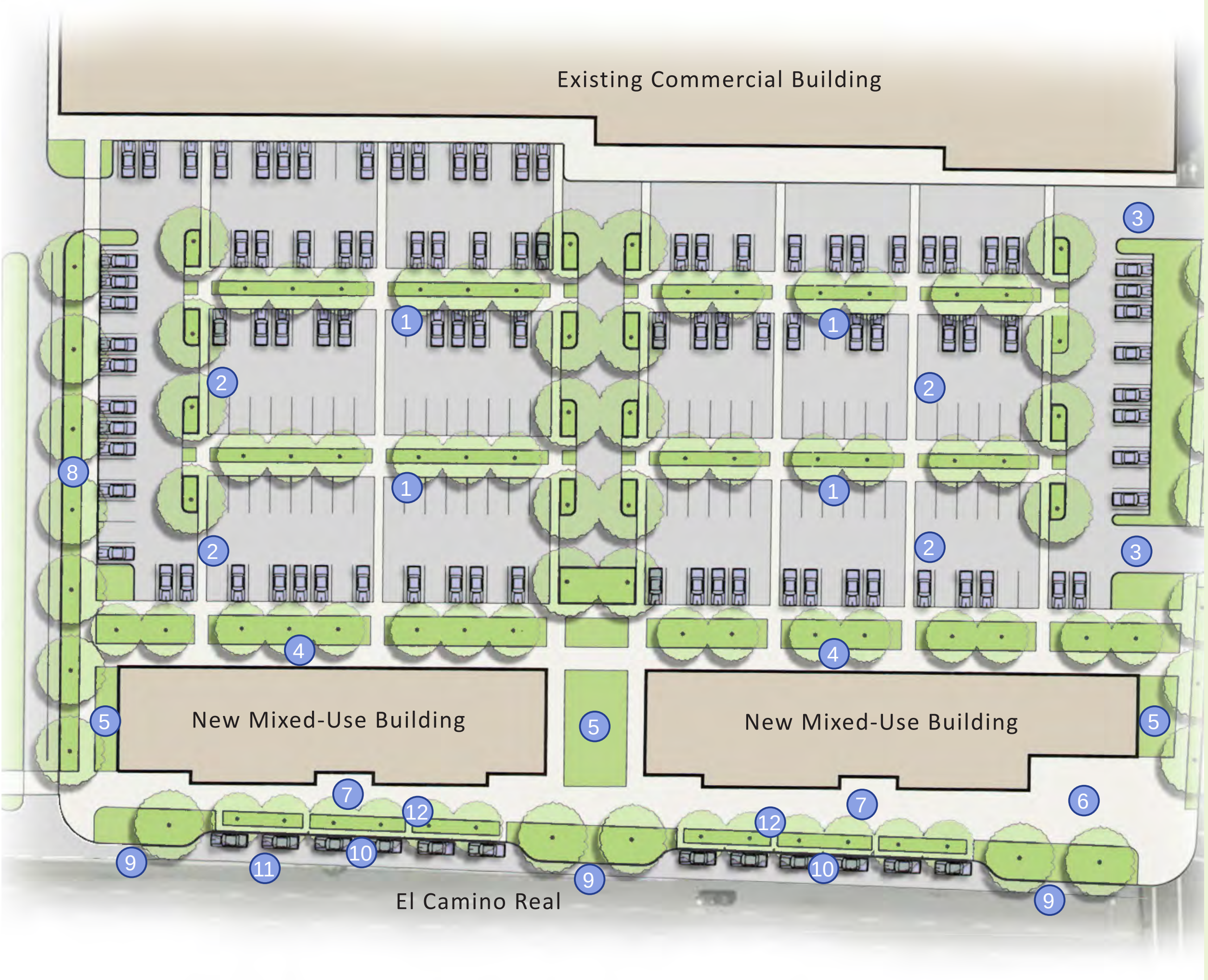
Efficient Site Design for Large-Scale Sites

There are many opportunities in San Mateo County for large development sites and parking lots to be redeveloped with a more efficient site design. Many have already been identified and are in the works towards implementation. The aerial photo below illustrates a typical large parking lot in San Mateo County immediately adjacent to El Camino Real. One can see in the photo the vast amounts of pavement with only a small percentage of the parking spaces being occupied. The plan on the opposite page illustrates how a commercial site like the one shown can be reorganized with a more efficient site design and retrofitted for various stormwater facilities. This plan now incorporates vegetated swales, stormwater planters, rain gardens, stormwater curb extensions, new trees, better pedestrian circulation, and the potential for additional clustering of higher-density mixed use buildings along the street frontage. Parking stalls measure 9 feet x 15 feet from the back of the stall to the front of the wheelstop/curb, and travel aisles are 22 feet wide. This conceptual design provides plenty of available parking and depicts the same number of parked cars as shown in the existing photo below. Though the new conceptual design is not a planned demonstration project, the site does exist in San Mateo County and gives perspective of larger-scale opportunities.



GOOGLE EARTH

▲ *An aerial view of a typical large shopping mall parking lot in San Mateo County.*



▲ *This is the same shopping mall site illustrating how much space can be repurposed to landscape, stormwater, pedestrian circulation, and even new building footprints when utilizing a more efficient site design.*

Key Design Elements

1. New stormwater planter/rain garden systems with enhanced pedestrian circulation
2. Defined pedestrian walkways throughout parking lot
3. Secondary parking lot entrances
4. Rain gardens capture runoff from both the parking areas and building rooftops
5. Rain gardens for building runoff
6. Plaza space in front of new retail building
7. Comfortable sidewalk zone along El Camino Real
8. Vegetated swale captures drainage from parking lot and primary entrance road
9. Stormwater curb extensions capture runoff from El Camino Real
10. On-street parking in front of new retail
11. Bike lane
12. Stormwater planters can either capture runoff from El Camino Real or adjacent retail buildings

PINTEREST-SOPHIE LAURENT

▲ *This parking lot places a premium on creating space for both landscape, stormwater management, and pedestrian circulation.*

3.2 Design Strategies and Guidelines

Buildings and Sites Design Strategies

Balancing Parking Spaces with Landscape Space

The goal of green parking lots is to incorporate as much green space as possible in order to better manage stormwater runoff. However, adding green space can often conflict with the need for storefront or residential parking. The best green parking lot designs should provide balance between parking and landscape space. Given that many parking lots are often oversized, some level of compromise will be necessary to truly design a balanced condition. Some parking loss might be acceptable or even desirable if the overall parking lot condition has a stronger aesthetic appeal due to increased landscape area and enhanced pedestrian spaces. Studies have shown that greening of business districts increases community pride and positive perception of an area, drawing customers to the businesses (Project Evergreen, 2008).

LES VICTOIRES DU PAYSAGE

▲ *This innovative parking lot example in Strasbourg, France boldly greens the parking lot with trees, pervious pavement, stormwater planters, and provides superb pedestrian circulation. This is an excellent example of balancing parking spaces with landscape and people space.*

NEVUE NGAN ASSOCIATES

▲ *This parking lot has significant amounts of landscape area balanced with parking spaces.*

URBAN RAIN DESIGN

▲ *A parking lot in Sacramento incorporates a vegetated swale and sites tree islands every two to three parking stalls to help shade asphalt surfaces.*

Balancing People Spaces with Landscape Space

The best places for people to live, work, or shop often have a vibrant landscape associated with them even in the most urbanized settings. Like parking lots and streets, it is all too common to have pedestrian areas over-paved resulting in significant impervious area runoff, not to mention a harsh visual and physical environment. Whether it be a pedestrian plaza, schoolyard playground, or even a building rooftop, a functional landscape space should be a valuable placemaking component. Rain gardens, stormwater planters, green roofs, green walls, and other landscape-based stormwater strategies can be strategically designed to fit and complement hardscape elements.

MARTHA SCHWARTZ PARTNERS

▲ *This project in China shows the potential to green entire city blocks while still creating a beautiful balance between pedestrian space and landscape space. This project manages all of its stormwater runoff on site.*

URBAN RAIN DESIGN

▲ *A narrow stormwater planter is strategically cut into a staircase without impacting pedestrian flow.*

URBAN RAIN DESIGN

▲ *Landscape areas designed to capture stormwater can be an amenity to plaza spaces in commercial and high-density residential areas.*

MARTHA SCHWARTZ PARTNERS

▲ *In this example, the hardscape is the leftover space, while the landscape dominates providing maximum potential to manage stormwater runoff.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

Existing Site Conditions in San Mateo County

There are various building, site, and parking lot conditions that generate stormwater runoff in San Mateo County. These distinctions are important to consider because the successful design of green infrastructure responds to the context, opportunities, and constraints found in differing land use conditions.

In terms of buildings and sites, six general site types can be described for San Mateo County based on the surrounding land use context. They are:

- Low-Density Residential Sites
- High-Density/Mixed-Use Residential Sites
- Large Commercial/Office & Industrial Sites
- Schools/Public Building Sites
- Parks and Plazas Sites
- Small and Large Parking Lots

The predominant land use type found in San Mateo County are residential sites of varying built-out densities. While residential sites individually do not generate the same amount of runoff as larger commercial or industrial sites, their cumulative impervious area of rooftops, walkways, and driveways/parking areas results in significant amounts of stormwater runoff.

For parking lots in San Mateo County, it is important to note the prevalence of extremely large parking lots that are connected to high-traffic volume arterial streets such as El Camino Real. In many cases, these large parking lots are so extensively paved that they contribute runoff from up to 20 acres of surface area. Even the smallest storm events, given this amount of impervious area, can generate substantial amounts of stormwater runoff.

◄ *A rain garden courtyard within an elementary school in San Mateo County, California.*

Due to the predominance of residential sites and large-size parking lots within San Mateo County, these areas might be high-priority zones to retrofit with green infrastructure practices.

The following pages illustrate a “snapshot” of common San Mateo County site conditions found in the region ranging from low-density residential to ultra-urban parking lots. All the aerial photographs are taken at an altitude of approximately 1,000 feet. Take notice of the impervious area for each land use type, such as building, parking, and other paved areas. When taking this into account, realize that runoff attributed to these land use types contains pollutants that, if left untreated, will eventually reach a waterbody in San Mateo Couty.

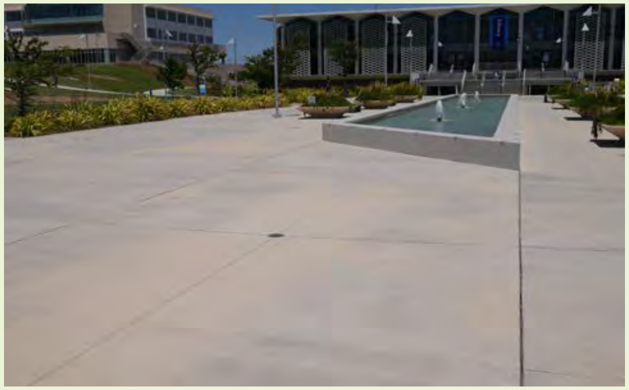
Commercial Buildings High-Density Residential/Mixed-Use

Parking Lots

Low-Density Residential Sites

URBAN RAIN DESIGN

▲ *This existing industrial/commercial site in San Mateo County has an adjacent landscape area that could be used for managing building runoff.*



URBAN RAIN DESIGN

▲ *This existing school’s plaza area could be retrofitted with more landscaping and pervious pavement.*

NEVUE NGAN ASSOCIATES

▲ *A typical parking lot void of landscape space and completely impervious.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

URBAN RAIN DESIGN

▲ *A typical low-density residential yard in San Mateo County.*

Low-Density Residential Sites

As the most prevalent site type in San Mateo County, low-density residential sites offer some of the best opportunities for green infrastructure design solutions. These types of sites have the fewest conflicts with utilities, the greatest ability to retrofit under-performing landscape space or modify existing landscape space for stormwater management, and typically have consistent maintenance regimes. Some low-density residential sites in San Mateo County have been built on very steep slopes that quickly convey stormwater runoff downstream. Even these sites can be redesigned to help slow the conveyance of stormwater runoff.

GOOGLE EARTH

▲ *This aerial photo illustrate the impervious area that generates runoff from low-density residential sites.*

High-Density/Mixed-Use Residential Sites

There is currently a significant emphasis on infill development along under-performing parcels and arterial streets in San Mateo County. Like low-density residential sites, high-density/mixed-use residential sites also offer opportunities for green infrastructure design solutions. However, the proximity and frequency of driveway entrances, overall complex site programming, plus a higher demand for vehicular parking, can create little space for landscape-based stormwater facilities. For green infrastructure to work on high-density residential sites, some compromises will need to be made. Pervious pavement and narrower stormwater planters could be used alone or in conjunction with landscape solutions in high-density residential conditions, providing that the site conditions support it.


GOOGLE EARTH

▲ *This aerial photo illustrate the impervious area that generates runoff from high-density residential/mixed-use sites.*


URBAN RAIN DESIGN

▲ *A typical high-density residential site in San Mateo County.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

URBAN RAIN DESIGN

▲ *A typical commercial office building site in San Mateo County.*

Large Commercial/Office & Industrial Sites

There are many differing types and sizes of commercial, office, and industrial sites in San Mateo County though they all share the common features of a large building and parking lot footprint, perimeter landscaping, and single-story rooftops with little or no building shading. The combined large amounts of impervious area and under-performing landscape provides a great opportunity to manage stormwater runoff with various green infrastructure techniques. A subset of to this general category of commercial/office sites are the various low-density strip mall conditions found along major arterial streets. The future trend for strip mall sites appears to be infilling these properties with vibrant mixed-use development. During this redevlopment process, these projects would apply green infrastructure strategies.

GOOGLE EARTH

▲ *This aerial photo illustrate the impervious area that generates runoff from commercial/office/industrial sites.*

Schools/Public Building Sites

School sites, whether it be K-12, community colleges, or larger university sites typically have both large amounts of stormwater runoff associated with buildings, asphalt playgrounds, plazas, walkways, and parking areas. They also usually have perimeter landscaping, open landscape space, ancillary paved areas that can be redesigned with green infrastructure strategies. The challenge of school sites often is not finding enough space for green infrastructure, it is finding a means to maintain green infrastructure for the long-term. Public building sites such as city halls, libraries, public works facilities have many characteristics of school sites, but at a smaller scale. Both school and general public building sites offer a highly visible canvas to display and educate visitors on urban watershed issues and solutions.

GOOGLE EARTH

▲ *This aerial photo illustrates the impervious area that generates runoff from a typical school campus.*

URBAN RAIN DESIGN

▲ *A typical school site in San Mateo County.*

CHAPTER

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *A typical neighborhood park in San Mateo County.*

Public Parks and Plaza Spaces

There many successful public park and plaza spaces in San Mateo County that help provide a valuable function of giving residents a space for active and passive recreation as well as contributing to the overall liveability of the region. These spaces can also function on a higher level to manage on-site stormwater runoff, and in some cases, manage off-site stormwater runoff with large stormwater basins or underground infiltration systems. San Mateo County has examples of both residential park-like settings and ultra-urban parks and plaza spaces and will continue to create these types of public spaces. There are opportunities to create green infrastructure projects within these parks and plaza spaces both with new development and in retrofit conditions.


GOOGLE EARTH

▲ *This aerial photo illustrate the impervious area that generates runoff from a low-density park condition as well as the amount of landscape available to capture stormwater runoff.*

Small and Large Parking Lots

Parking lot sizes vary significantly from site to site in San Mateo County. However, their sum contributes to significant amounts of impervious area. Smaller parking lots are the most difficult to retrofit because there is a high demand for available space. When landscape-based stormwater facilities cannot adequately fit in small parking lots, pervious pavement is a good choice. As for larger parking lots, most are oversized for an average day's parking demand and can be easily redesigned with a variety of stormwater solutions. The most prevalent constraint for larger parking lots is that their sheer size requires considerable investment to adequately manage stormwater runoff.

NEVUE NGAN ASSOCIATES

▲ *A typical large-scale parking lot in San Mateo County.*

GOOGLE EARTH

▲ *The red areas superimposed on this aerial photo illustrate the impervious area that generates runoff from large and small-scale parking lots.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

What to Build and Where?

The design scenarios presented in this chapter illustrate common ways that stormwater planters, rain gardens, pervious pavement, green gutters, vegetated swales, rainwater harvesting, and green roofs can be applied to the variety of building, sites, and parking lot conditions found in San Mateo County. The examples shown are just a sampling of the many opportunities that exist in the region are not limited to the variety of potential green infrastructure solutions. Designers and developers are encouraged to adapt these examples to best fit the needs and conditions of their own projects.

Several "before and after" sketches show the potential for buildings, sites, and parking lot retrofit opportunities in San Mateo County. The goal of illustrating multiple site strategies is to give the user of this guidebook a broad range of site-scale design applications that can be similarly reproduced throughout the region. The examples shown are for reference only and are not "real" projects, but perhaps projects like those illustrated can be developed into future demonstration projects. Whether a site is located in a low or high-density residential neighborhood, a large-scale industrial site, or within a small or large parking lot, there are multiple stormwater design options available.

The graphic on the opposite page provides a matrix for choosing what types of stormwater facilities are best suited for various conditions within San Mateo County. This is to be used as a *general* guide to acceptable design strategies based on land-use type. Successful exceptions can also be made to this matrix depending on the site conditions and the thoughtfulness of design solutions.

◀ *A building downspout disconnection into a stormwater landscape in San Mateo County.*

	VEGETATED SWALE	STORMWATER PLANTER	RAIN GARDEN	PERVIOUS PAVEMENT	GREEN GUTTER	RAINWATER HARVESTING	GREEN ROOFS	GREEN WALLS	INFILTRATION SYSTEMS
Low-Density Residential Sites	●	● (site dependent)	●	●	●	●	● (site dependent)	● (site dependent)	
High-Density Residential/ Mixed-Use Sites		●	●	●		●	● (site dependent)	● (site dependent)	●
Commercial/Office & Industrial Sites	●	●	●	●		●	● (site dependent)	● (site dependent)	●
Schools and Public Building Sites	●	●	●	●	●	●	● (site dependent)	● (site dependent)	●
Parks and Plazas Sites	●	●	●	●	●	●	● (site dependent)	● (site dependent)	●
Residential Driveways				●	●				
Large Parking Lots	●	●	●	●					●
Small Parking Lots	●	●	●	●	●				

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

URBAN RAIN DESIGN

▲ *EXISTING: A typical low-density residential home front yard in San Mateo County.*

WOOLY BLUE LANDSCAPE CONTRACTORS

▲ *EXAMPLE: An example residential yard rain garden captures roof runoff and features low-water plant communities.*

Low-Density Residential Vegetated Swale Example

Small, linear front and back yards in low-density residential settings can be strong candidate sites for directing roof downspout runoff into vegetated swales. Simply disconnecting downspouts, re-grading the landscape, and planting with drought-tolerant plant species can retain stormwater runoff on site during the wet season and become a beautiful dry garden during summer months.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same residential yard that converts un-watered grass areas into a rain garden with drought-tolerant landscaping. Roof downspouts direct water into the rain garden and a bridge connects the spaces.*

Low-Density Residential Stormwater Planter Example

Another possibility to direct roof downspout runoff into landscape area next to driveways or alongside residential homes is to use stormwater planters. These planters do not have to be very deep and any excess runoff that can't be managed can overflow over the low points in the landscape.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same residential landscape that converts a grass areas into a stormwater planter with drought-tolerant landscaping.*

URBAN RAIN DESIGN

▲ *EXISTING: A typical side landscape separating two residential properties in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example residential stormwater planter that captures roof runoff first into a rain barrel and an excess runoff is directed to a stormwater planter.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *EXISTING: A typical low-density residential home front yard in San Mateo County.*


URBAN RAIN DESIGN

▲ *EXAMPLE: An example of a residential front yard rain garden that captures site runoff and features low-water use plant communities.*

Low-Density Residential Rain Garden Example

This residential home example illustrates how drought-tolerant rain gardens can easily replace tired un-watered grass yards. Runoff from roof downspouts can simply enter these landscape areas and any overflow during strong storm events would sheet flow into the street. Many front yards in San Mateo County are considered "blank slates" with little landscaping, and no street trees. With new rain gardens and street trees in place, front yards can be more ecologically diverse, absorb stormwater, and be more aesthetically pleasing.


QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same residential yard that converts un-watered grass areas into a rain garden with drought-tolerant landscaping. Roof downspouts direct water into the rain garden and a bridge connects the spaces.*

Low-Density Residential Rainwater Harvesting Example

Rainwater harvesting for residential yards is an easy way to save water for irrigation during the fall and spring months. Rainfall can be captured in rain barrels and applied to the landscape during dry spells between storms.


QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same residential landscape that added a rain barrel to collect and re-use rainwater and converts a grass area into drought-tolerant landscaping.*


URBAN RAIN DESIGN

▲ *EXISTING: A typical residential yard condition in San Mateo County.*


URBAN RAIN DESIGN

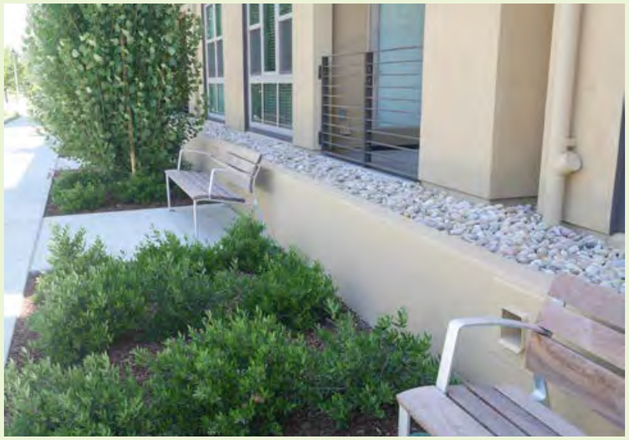
▲ *EXAMPLE: An example residential rain barrel that captures roof runoff first and then re-uses runoff to irrigate the adjacent landscape area.*

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

High-Density Residential Stormwater Planter Example

Many new high-density/mixed-use development projects continue to be built in San Mateo County. These building sites maximize the development's footprint, however, there is often landscape space dedicated along the perimeter of the building that is also in proximity of roof downspouts. The downspouts can be disconnected into either raised or recessed stormwater planters. Some development projects are already utilizing stormwater planters next to buildings, while others, such as the retrofit opportunity shown below, can modify the landscape to accept stormwater runoff.



URBAN RAIN DESIGN

▲ *EXISTING: A typical high-density residential home front yard in San Mateo County.*

URBAN RAIN DESIGN

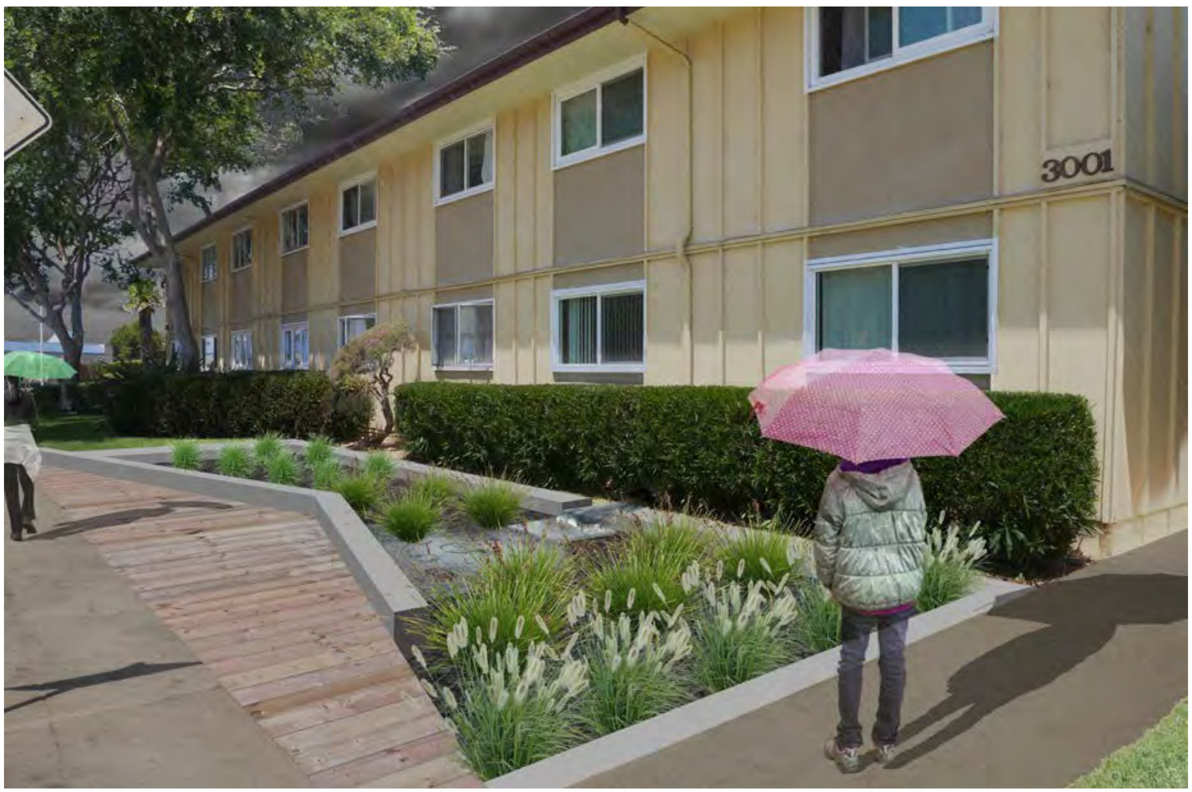
▲ *EXAMPLE: An example high-density residential building captures roof runoff and features low-water plant communities.*

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same high-density residential yard that disconnects roof downspouts and converts existing landscape areas into a stormwater planter with drought-tolerant landscaping.*

High-Density Residential Rain Garden Example

For some high-density residential buildings, adding a more dynamic rain garden landscape where space is available can help change the character of the site and provide a more functional space for the residents. This example illustrated below converts the existing lawn space into a rain garden with an integrated boardwalk and seating area. The roof downspouts direct runoff away from the building foundation to the rain garden using metal channels.



QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same high-density apartment complex that converts perimeter grass and landscape areas into a rain garden with drought-tolerant landscaping. Roof downspouts direct water into the rain garden.*

URBAN RAIN DESIGN

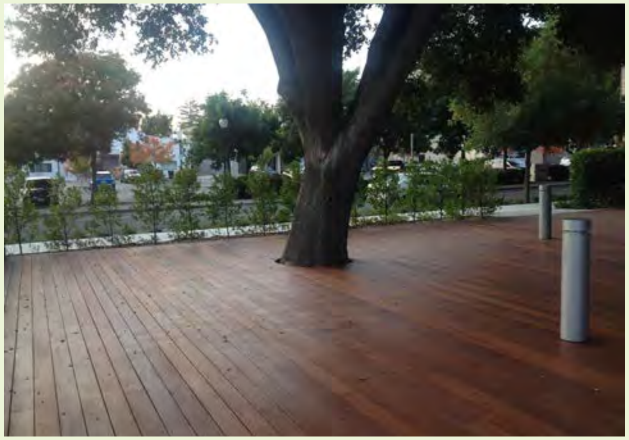
▲ *EXISTING: A typical lawn space next to an apartment complex in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example high-density residential rain garden captures roof runoff and features a boardwalk overlook and seating area.*

CHAPTER

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *EXAMPLE: A mixed use development uses a raised boardwalk allowing rainfall to pass through the decking and into the soil.*


URBAN RAIN DESIGN

▲ *EXAMPLE: A high-density residential building uses pervious pavers at bike parking zones.*

High-Density Residential Pervious Pavement Examples

Because of the competition for space, many high-density residential/mixed-used developments will need to use both landscape strategies and pervious pavement material to adequately manage on-site runoff. For pervious pavement, there are a wide variety of materials that can provide a viable walking surface and help infiltrate water into the soil. Pervious pavers and raised boardwalks are becoming more common materials used for pervious pavement.


URBAN RAIN DESIGN

▲ *EXAMPLE: This high-density residential apartment complex uses pervious pavers throughout all of its walkways. This paving material choice also provides some visual appeal over standard concrete.*

High-Density Residential Vegetated Swale Example

A simpler approach with less concrete infrastructure is integrating shallow vegetated swales next to perimeter building landscape in high-density residential projects. Simply regrading and replanting to accommodate roof runoff is a cost-effective means to manage small amounts of drainage.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same high-density apartment complex that converts perimeter grass and landscape areas into a vegetated swale with drought-tolerant landscaping. Roof downspouts direct water into the landscape.*

URBAN RAIN DESIGN

▲ *EXISTING: A typical lawn space next to an apartment complex in San Mateo County.*

URBAN RAIN DESIGN

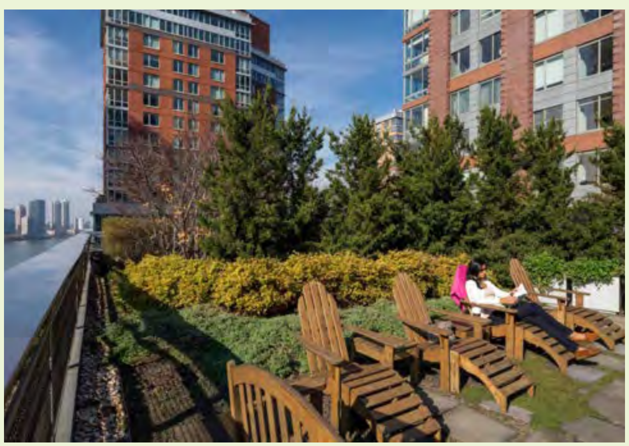
▲ *EXAMPLE: An example high-density residential vegetated swale captures roof runoff and features low-water plant communities.*

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

QUADRIGA INC.

▲ *EXISTING: A typical high-density residential rooftop.*



STREETEASY.COM

▲ *EXAMPLE: An example high-density residential building roof garden that provides stormwater management benefits and an outdoor meeting space.*

High-Density Residential/Mixed-Use Green Roof Example

Green roofs and roof gardens with high-density residential offer incredible opportunities provide rainwater capture and outdoor meeting space for residences depending on the conditions. New developments can easily build in green roofs, large or small, into the building programming; and these green infrastructure features can be combined with stormwater planters and rain gardens on the ground plane. In retrofit conditions, lighter-weight extensive green roofs can often replace existing conventional roofs offering building energy savings and a reduced urban heat island.

QUADRIGA INC.

▲ *RETROFIT OPPORTUNITY: The same high-density residential rooftop retrofitted with an extensive green roof condition.*

High-Density Residential Rainwater Harvesting Examples

Having larger building footprints, high-density/mixed-use buildings can generate significant amounts of stormwater runoff that can be directed to above-ground cisterns for future use. This water can be potentially used inside the building in bathroom toilets and urinals or can be applied as irrigation for outdoor landscaping. These cisterns can be off-the-shelf units or be custom designed and integrated into the form of the adjacent building.

JOHNSTON ARCHITECTS

▲ *EXAMPLE: A Seattle, Washington example of a proposed above-ground cistern incorporated into the "front yard" of a new high-density mixed-use building.*

PHILADELPHIA DEPARTMENT OF WATER

▲ *EXAMPLE: An example high-density residential above-ground cistern.*

TIMOTHY HURSLEY

▲ *EXAMPLE: An example high-density residential above-ground cistern.*

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *EXISTING: A typical landscape in a commercial zone in San Mateo County.*


URBAN RAIN DESIGN

▲ *EXAMPLE: An example industrial stormwater planter captures roof and sidewalk runoff via a trench drain.*

Office Building Stormwater Planter Example

Many office buildings in San Mateo County have very low-performing landscapes adjacent to buildings with exterior downspouts. These landscape areas can be dramatically altered to not only manage stormwater, but to also provide a more inviting and invigorated street appeal to customers and workers. Refurbishing these left-over landscapes, and disconnecting downspouts into rain gardens and planters is a definite possibility in San Mateo County.


QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same office perimeter landscape converts un-watered grass areas into a stormwater planter with drought-tolerant landscaping. Roof downspouts direct water into the rain garden.*

Industrial Warehouse Rain Garden Example

There is considerable land dedicated to light and heavy industrial use in San Mateo County. On many of these sites, landscape areas are often non-existent, and land is nearly 100 percent impervious. Also, roof downspouts are often directing large amounts of runoff onto paved spaces. Creating pockets of green space in the form of rain gardens or stormwater planters can help manage roof and site stormwater runoff. The example below sacrifices some under-utilized parking spaces into new green space.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same industrial building site redirects a series of downspouts into a new stormwater planter. These stormwater planters can help add much-needed trees into industrial building sites.*

URBAN RAIN DESIGN

▲ *EXISTING: A typical large-scale industrial building site in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example light-residential parking lot rain garden captures roof runoff.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

URBAN RAIN DESIGN

▲ *EXISTING: A typical office side landscape in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example office rain garden captures roof runoff and features a pervious paver sidewalk.*

Commercial Rain Garden Example

Simpler rain gardens can also be placed along the frontages of many low-performing landscapes in San Mateo County. These landscape areas can often be retrofitted between existing vegetation such as perimeter shrubs and existing street trees.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same office perimeter landscape converts un-watered grass areas into a rain garden with drought-tolerant landscaping. Roof downspouts direct water into the rain garden.*

Commercial/Industrial Green Roof Example

New and existing commercial, office, and industrial buildings can utilize green roofs to limit the amount of on-site stormwater runoff. If using lighter-weight extensive green roof technology, many of these existing building types can be retrofitted with minor structural enhancements depending on the building design and age.

QUADRIGA INC.

▲ *RETROFIT OPPORTUNITY: The same commercial/office building rooftop with a light-weight extensive green roof application.*

URBAN RAIN DESIGN

▲ *EXISTING: A typical commercial/office building rooftop in San Mateo County.*

HYDROTECHUSA.COM

▲ *EXAMPLE: An office building with an extensive green roof application.*

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical school rooftop in San Mateo County.*


URBAN RAIN DESIGN

▲ *EXAMPLE: An example university green roof captures rainfall and features low-water plant communities.*

School Green Roof Example

As school buildings in San Mateo are being built and/or renovated, there is an opportunity to apply green roof technologies to limit the amount of on-site stormwater runoff. Schools can be selective as to what extent the various rooftops can be green roofs and these green roofs can be combined with other green infrastructure elements such as rain gardens and vegetated swales to provide additional stormwater treatment.


QUADRIGA INC.

▲ *RETROFIT OPPORTUNITY: The same school rooftop retrofitted with an extension green roof system.*

School Pervious Pavement Example

Given the amount of space required for students to circulate and gather at school sites, there will always be a need for vast amounts of paving. However, these sites can and should as much as possible utilize pervious pavement material to allow water to soak into the ground and limit the amount of on-site stormwater runoff.

▲ *EXISTING: A typical school paved courtyard in San Mateo County.*

▲ *RETROFIT OPPORTUNITY: The same school courtyard using pervious pavers to allow for rainfall to soak into the ground.*

▲ *EXAMPLE: An example of a school walkway using pervious pavers.*

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

URBAN RAIN DESIGN

▲ *EXISTING: A typical schoolyard lawn in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example school rain garden captures roof and plaza runoff and features low-water plant communities.*

School Rain Garden Example

Many school sites in San Mateo County have large existing lawns/landscape space adjacent to buildings with exterior downspouts. These landscape areas can be altered to manage stormwater as well as break up the visual monotony of all lawn landscapes commonly found at school sites.

QUADRIGA INC./URBAN RAIN DESIGN

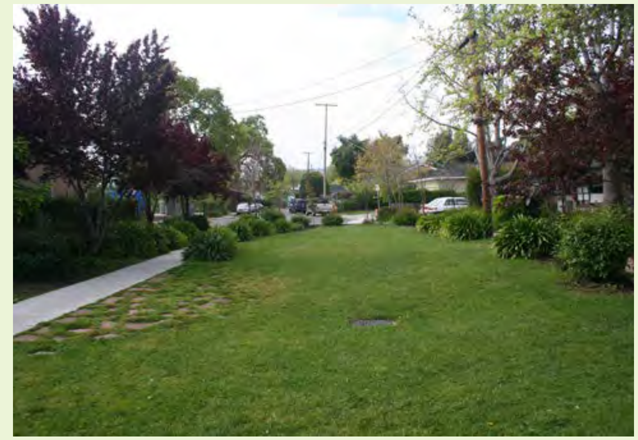
▲ *RETROFIT OPPORTUNITY: The same school landscape that converts a portion of the lawn area into a rain garden.*

School Site Vegetated Swale Example

Schools often also have linear lawn/landscape space that can be easily regraded to create recessed areas designed for capturing and conveying stormwater runoff. In some cases, seating and outdoor classrooms can be built into the design of both vegetated swales and rain gardens.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same school site replaces a portion of the existing lawn with a meandering vegetated swale that features drought-tolerant landscaping.*



URBAN RAIN DESIGN

▲ *EXISTING: A typical schoolyard lawn landscape in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example of a schoolyard vegetated swale.*

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *EXISTING: A typical schoolyard building perimeter area in San Mateo County.*


URBAN RAIN DESIGN

▲ *EXAMPLE: An example school stormwater planter captures roof and plaza runoff and features low-water plant communities.*

School Stormwater Planters

School sites have considerable amount of peripheral building spaces that are ideal to convert into stormwater planters. These types of space conversions reduce impervious area, reduce the urban heat island, and create additional seating/gathering spaces for students. These stormwater planters can be tucked against building facades or located adjacent to large asphalt play areas to accept stormwater runoff.


QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same schoolyard that converts a portion of its asphalt area into a stormwater planter.*

School Rainwater Harvesting

Schools offer incredible opportunities to utilize rainwater harvesting at their sites. Many existing school buildings have exposed exterior downspouts that can be easily connected to a wide variety of rainwater harvesting systems. The scale of such systems can vary from simple 55-gallon rain barrels to several thousand-gallon rainwater tanks and cisterns. Rainwater harvesting at school sites are excellent tools to teach the value of water within the local watershed.

MARISA RODRIGUEZ

▲ *EXAMPLE: This 5,000-gallon rainwater harvesting system at the education building of the World Birding Center in Edinburg provides irrigation for nearby flowering plants and shrubs.*

WATERSTORAGETANKSINC.COM

▲ *EXAMPLE: A large 15,000 gallon cistern at Lake Travis Middle School near Austin, Texas is used for landscape irrigation.*

NEPONSET.ORG

▲ *EXAMPLE: The 2018 Canton High School Rain Barrel Project allows students to creatively paint rain barrels used to capture roof runoff.*

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


URBAN RAIN DESIGN

▲ *EXISTING: A park lawn area with an existing inlet in San Mateo County.*


URBAN RAIN DESIGN

▲ *EXAMPLE: An example park space rain garden captures site and sidewalk runoff and features low-water plant communities.*

Park Rain Garden Example

Existing park spaces are full of opportunities to convert under-used grass areas into stormwater landscapes. Simply look for inlet locations where the is not a lot of active use of the space to allow for larger rain gardens to capture and collect stormwater runoff.


QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same park landscape converts a portion of high water use lawn area into a rain garden with drought-tolerant landscaping.*

Park Vegetated Swale Example

Existing spaces alongside pedestrian walkways in parks are great opportunities to introduce vegetated swales. These vegetated swales can help buffer active play zones with pedestrian pathways and can accept runoff from vast lawn spaces or adjacent impervious pathways.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same park and walkway condition with a vegetated swale replacing a portion of the lawn space.*

URBAN RAIN DESIGN

▲ *EXISTING: A typical park lawn area alongside a walkway in San Mateo County.*

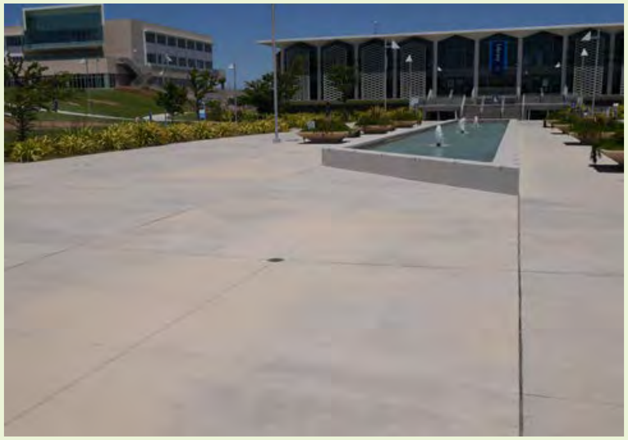
URBAN RAIN DESIGN

▲ *EXAMPLE: An example vegetated swale in San Mateo County captures site and sidewalk runoff.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County



URBAN RAIN DESIGN

▲ *EXISTING: A typical plaza space in San Mateo County.*

URBAN RAIN DESIGN

▲ *EXAMPLE: An example plaza rain garden captures sidewalk runoff and features low-water plant communities.*

Urban Plaza Rain Garden Example

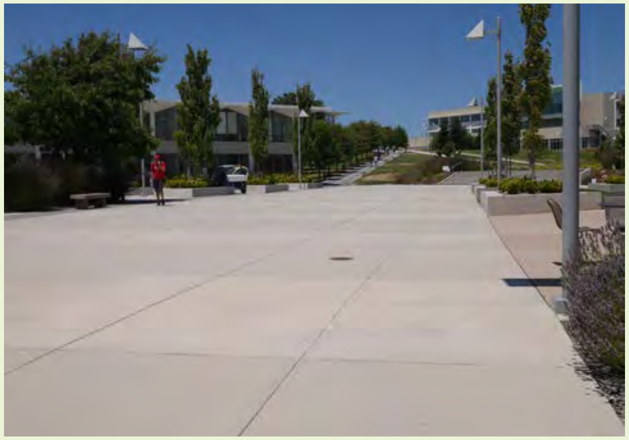
Plaza spaces within public and private developments are great opportunities for retrofitting with green infrastructure as they often have excessive impervious area Many plazas have "dead zones" that do not need to be paved and can be replaced with stormwater landscape without compromising the programming of the space.

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same plaza space converts under-used concrete areas into a rain garden with drought-tolerant landscaping.*

Urban Plaza Stormwater Planter Example

Even narrower plazas/walkways can fit small-width stormwater planters instead of a sea of concrete. This helps soften the look of the space, and if trees are added, it can help shade plaza spaces. As with most plaza conditions, care should be taken to accommodate adequate pedestrian circulation through the space



URBAN RAIN DESIGN

▲ *EXISTING: A typical plaza/walkway site in San Mateo County.*

QUADRIGA INC./URBAN RAIN DESIGN

▲ *RETROFIT OPPORTUNITY: The same plaza space converts a portion of the space into a new stormwater planter. These stormwater planters can help add much-needed trees into barren plaza sites.*

KEVIN ROBERT PERRY

▲ *EXAMPLE: An example plaza/walkway with a stormwater planter and street trees.*

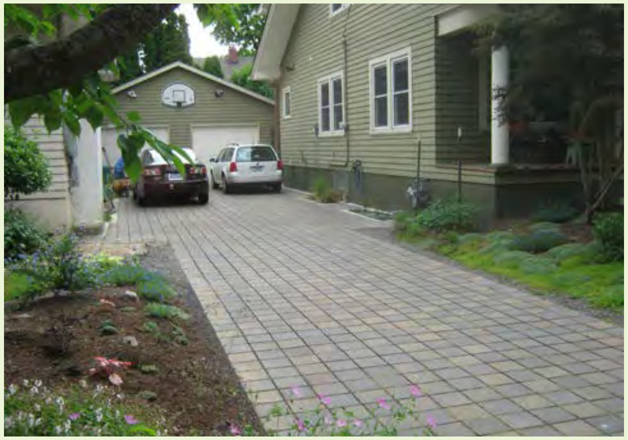
CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

NEVUE NGAN ASSOCIATES

▲ *EXAMPLE: Pervious pavers in a common shared driveway in San Mateo County.*



URBAN RAIN DESIGN

▲ *EXAMPLE: Pervious pavers in a common shared driveway in a low-density condition.*

Full Residential Driveway Pervious Pavement Example

Residential driveways account for a large portion of area that are typically paved with impervious material. New and existing driveways can instead use pervious pavement materials such as pervious pavers or pervious concrete.

URBAN RAIN DESIGN

▲ *EXAMPLE: A pervious concrete driveway in a low-density residential setting.*

Residential Driveway Landscape Strip/Pervious Pavement Example

In many cases, the driveways can be partially paved to allow for just the wheels of vehicles to be on concrete and the remaining driveway to be an extension of the yard landscape or reinforced gravel or grass.


URBAN RAIN DESIGN

▲ *EXAMPLE: A partial concrete/landscape strip driveway in a low-density residential setting.*


URBAN RAIN DESIGN

▲ *EXAMPLE: A partial concrete/reinforced gravel driveway in a low-density residential setting.*


KEVIN ROBERT PERRY

▲ *EXAMPLE: A partial concrete/reinforced grass driveway in a low-density residential setting.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

NEVUE NGAN ASSOCIATES

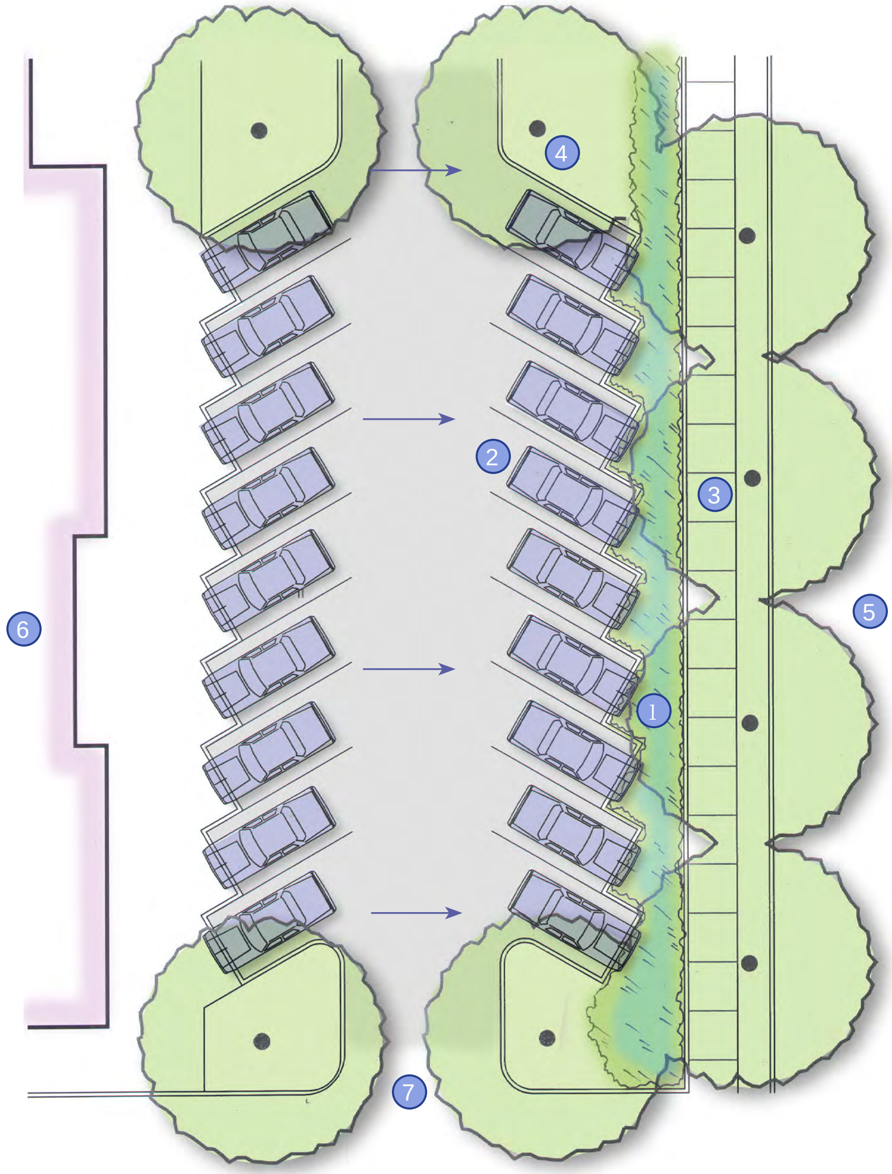
▲ *EXISTING: An angled parking lot example.*

Angled Parking with Vegetated Swales/Rain Gardens

In this example, angled parking leaves unused space between the wheel stop and edge of an existing non-landscaped planter strip. Consolidating this left-over paved space into new landscaping can yield enough room for a vegetated swale or rain garden. Under-utilized paved or landscape space may also exist in front of 90-degree, head-in parking. Sometimes shortening parking stall lengths by 1′ to 2′ can provide enough combined room to introduce a vegetated swale or rain garden.

NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same parking lot retrofitted with a vegetated swale/rain garden.*



Key Design Elements

1. Stormwater planters, rain gardens, or vegetated swale within parking islands accept parking lot runoff.
2. 45-degree angled parking.
3. Sidewalk zone.
4. Conventional landscape island with trees.
5. Street frontage.
6. Building frontage.
7. Parking lot entry/egress.

KEVIN ROBERT PERRY

▲ *EXAMPLE: This parking lot treats its stormwater runoff within multiple stormwater swales throughout the site.*

CHAPTER

3.3 Design Strategies and Guidelines

Buildings and Sites Design Examples for San Mateo County

NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical parking lot in San Mateo County.*

Parking Lot with Stormwater Planter Islands

This example shows a parking lot with stormwater planters replacing under-used parking stalls. This is one of the simplest parking lot retrofit actions to implement. The best approach is to convert the parking stalls immediately adjacent to a drain inlet. Depending upon the size and parking demand of a particular parking lot, a series of parking stalls may be consolidated into stormwater planters.

NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same parking lot retrofitted with a stormwater planter. Notice that this stormwater planter is located near the existing drainage inlet.*

Key Design Elements

1. Vegetated swale/planter accepts runoff from parking lot area.
2. 90-degree head-in parking.
3. Sidewalk zone.
4. Conventional landscape island with trees.
5. Street frontage.
6. Building frontage.
7. Parking lot entry/egress.

KEVIN ROBERT PERRY

▲ *EXAMPLE: This parking lot treats its stormwater runoff within multiple stormwater swales throughout the site.*

CHAPTER

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County

Pervious Pavement for Internally Drained Parking Lots

This example shows a parking lot where stormwater drains inward towards the center of the parking drive aisles as opposed to sheet flow to the periphery of the site. This is a common condition and very common with small-scale parking lots. Without redesigning the drainage system, the best, and most practical option is to utilize pervious pavement. The illustrated example below employs pervious pavement within the parking stalls and allows any excess stormwater runoff to drain into the existing storm inlet. By effectively using pervious pavement in parking stalls, there can be up to a 50% reduction of impervious area that generates stormwater runoff. A parking lot can be retrofitted entirely with pervious pavement, however, it may be more cost effective to only use it in the parking stalls, especially in larger parking lot applications. In addition to parking lots directing stormwater runoff inwards, pervious pavement can also be used in parking lots that drain runoff to the periphery of the site.


NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical parking lot in San Mateo County that directs stormwater runoff inward towards an area drain.*


NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same parking lot retrofitted with pervious pavement in the parking stalls.*

Key Design Elements

1. Pervious pavement within parking stall zone.
2. Concrete band separates paving material.
3. Sidewalk zone.
4. Conventional landscape with trees.
5. Street frontage.
6. Building frontage.
7. Parking lot entry/egress.
8. Drain inlet.

KEVIN ROBERT PERRY

▲ *EXAMPLE: This new parking lot utilizes pervious concrete within the parking lot's parking stalls.*

3.3 Design Strategies and Guidelines

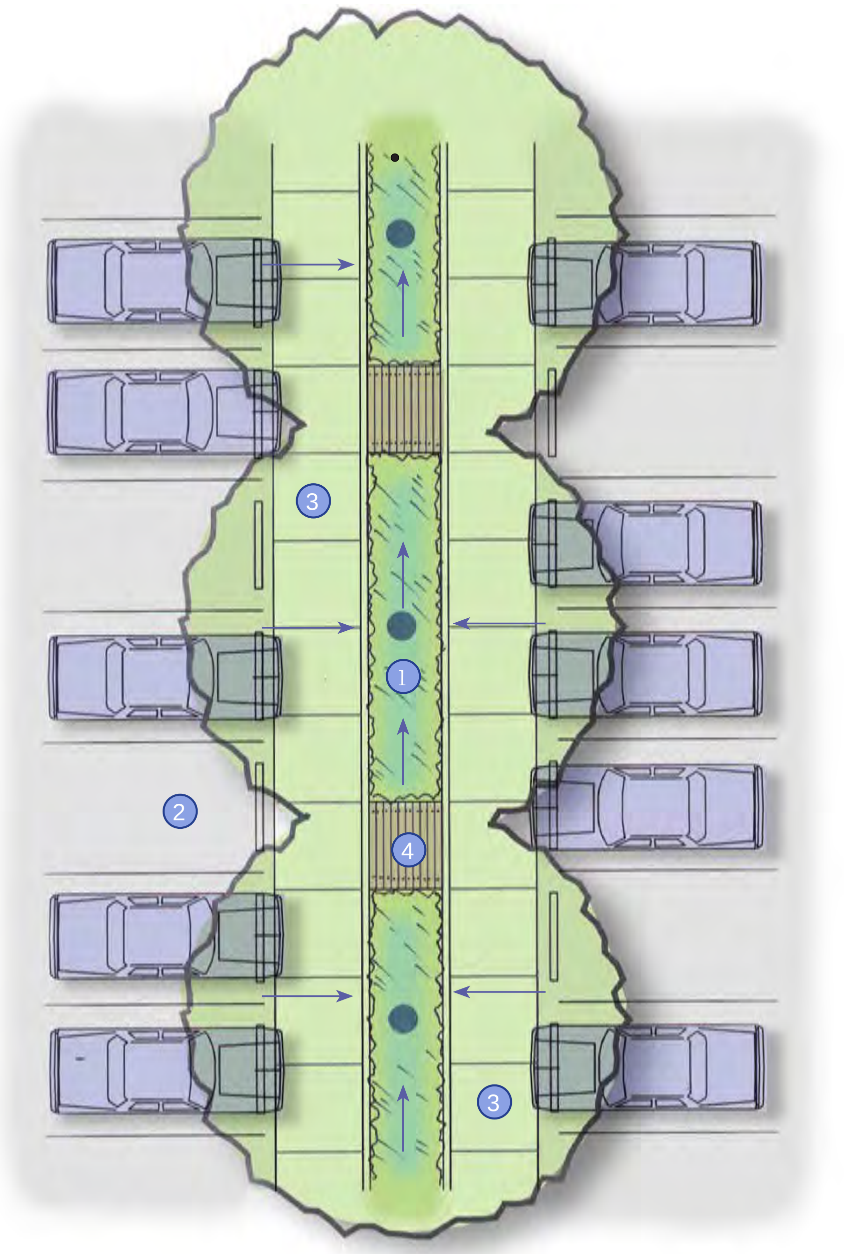
Buildings and Sites Design Examples for San Mateo County

▲ *EXISTING: A typical large shopping mall parking lot in San Mateo County.*

Parking Lot with Center Median Vegetated Swale/Stormwater Planter

The example below shows the length of the parking stalls shortened in order to provide space for a vegetated swale or stormwater planter. This example also illustrates walkways in front of the parked cars and bridges that cross over the stormwater facility to connect these walkways. This design element allows people a refuge to walk to and from their destination without having to walk through a stormwater facility. More detailed design information on this is described in **Chapter 5**. Introducing more landscaping and trees within large urban parking lots also keeps asphalt surfaces cooler and helps reduce the urban heat island effect.

▲ *RETROFIT OPPORTUNITY: The same parking lot retrofitted with a stormwater planter/vegetated swale. Notice the sidewalk zones and dedicated crossings to allow for adequate pedestrian circulation.*



Key Design Elements

1. Vegetated swale/planter accepts runoff from parking lot area.
2. 90-degree head-in parking.
3. Pedestrian egress walkways
4. Stormwater bridges allow pedestrians to access their vehicles. These can be made of a variety of materials.

KEVIN ROBERT PERRY

▲ *EXAMPLE: This parking lot was retrofitted with a stormwater planter with several pedestrian crossings and ample space at the front of the parking zone to access the pedestrian crossings.*

CHAPTER

3.3 Design Strategies and Guidelines
Buildings and Sites Design Examples for San Mateo County


NEVUE NGAN ASSOCIATES

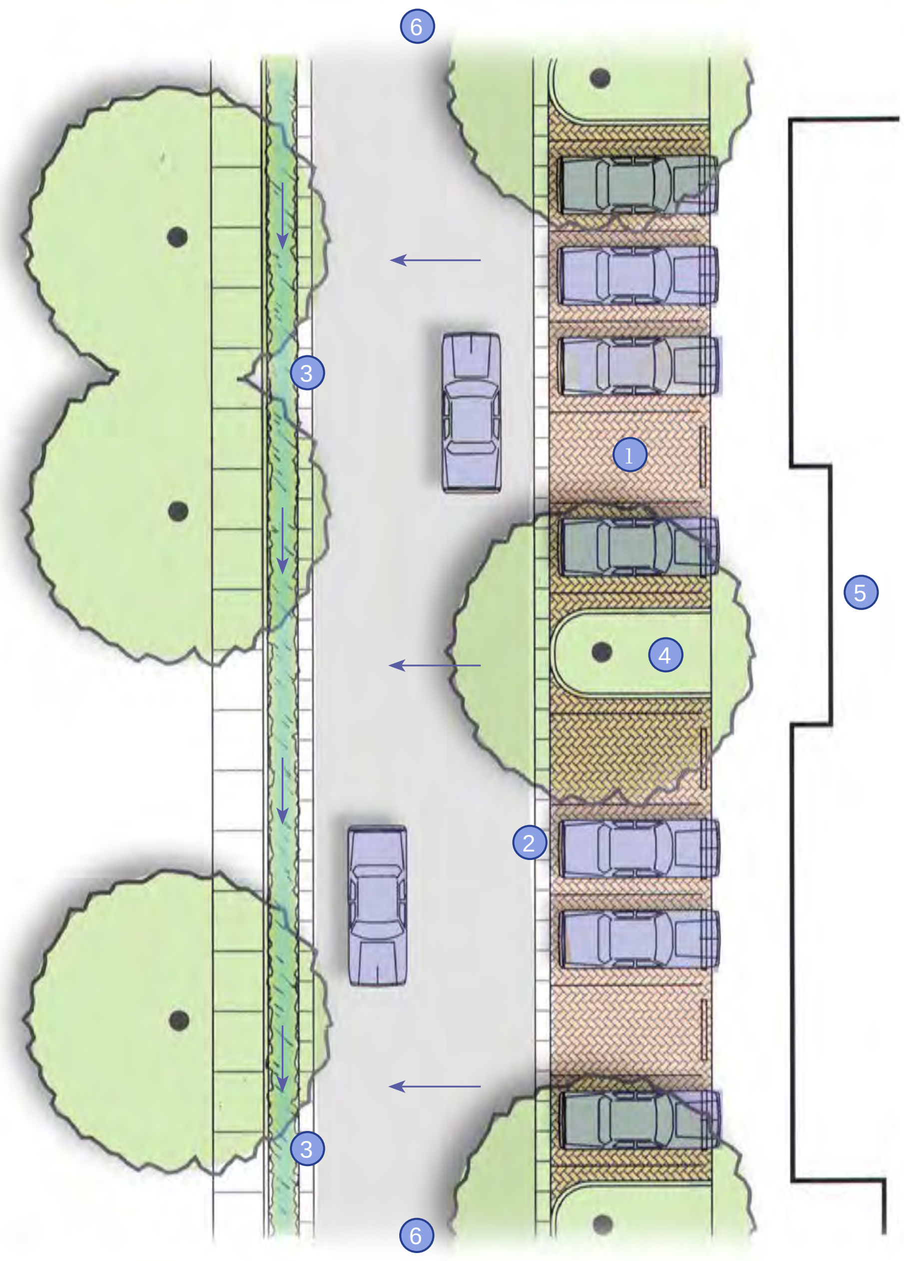
▲ *EXISTING: A typical one-sided loaded parking lot in San Mateo County.*

Parking Lot with Green Gutters

In some situations, a parking lot is only loaded with parking stalls on one side. This scenario lends itself to retrofitting a green gutter along the drive aisle side of the parking lot if the drainage flows in that direction. Often drive aisles are oversized and can be reduced by a couple of feet in order to accommodate a green gutter. To better manage stormwater on-site, pervious pavement and a green gutter system are combined in the illustrated scenario below.


NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same parking lot retrofitted with a green gutter and pervious paving in the parking stalls.*



Key Design Elements

1. Pervious pavement within parking stall zone.
2. Concrete band separates paving material.
3. Green gutter system.
4. Conventional landscape islands with trees.
5. Building frontage.
6. Parking lot entry/egress.

KEVIN ROBERT PERRY

▲ *EXAMPLE: A shallow green gutter accepts runoff from the adjacent parking lot surface.*

3.4 Sustainable Streets Design Elements and Process

What is a Sustainable Street?

MATT FABRY

▲ *An on demand pedestrian flashing crossing, high visibility sidewalk, buffered bike lane, and stormwater curb extensions were implemented as part of this sustainable street retrofit project.*

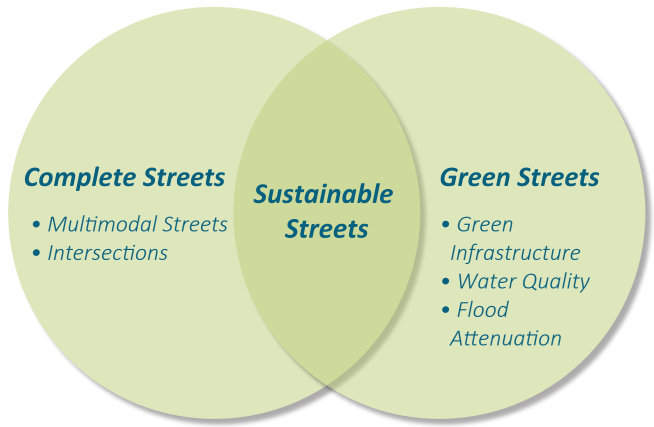
CD+A

▲ *Stormwater planters provide a landscaped buffer between pedestrians and the roadway. Bike lanes provide a designated space for bicyclists, providing a more comfortable cycling experience.*

A sustainable street combines the ideas of mobility and access for all users and other aspects of complete street design with the stormwater and other environmental benefits of green streets which integrate green stormwater infrastructure into streets. The goal of sustainable streets design is to create streets that are comprehensively sustainable in terms of environmental, social, and economic impacts. The resulting streets will help communities address the stormwater requirements of the MRP while providing multiple benefits.

The Countywide Program is promoting sustainable streets in San Mateo County, and has widely and actively supported local projects including Safe Routes to Schools integrated with green infrastructure projects and the Caltrans funded San Mateo County **Sustainable Streets Master Plan**.

This master plan builds upon local and regional watershed, streets, transportation facilities, climate change adaptation, modeled anticipated future changes in rainfall, and other parameters to help identify where and how to develop sustainable streets in San Mateo County. For more information about the Sustainable Streets Master Plan, see: **flowstobay.org/SSMP**.



Interaction will help:

- Better manage street runoff and flooding issues
- Result in consistent approach and appearance
- Improve city and neighborhood character
- Foster climate resiliency and adaptation
- Create more comfortable and safe streets

What are Complete Streets?

Complete Streets are streets for everyone. They are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. Complete Streets make it easy to cross the street, walk to shops, and bicycle to work. They allow buses to run on time and make it safe for people to walk to and from train stations.

Creating Complete Streets means transportation agencies must change their approach to community roads. By adopting a Complete Streets policy, communities direct their transportation planners and engineers to routinely design and operate the entire right of way to enable safe access for all users. This means that every transportation project will make the street network better and safer for drivers, transit users, pedestrians, and bicyclists—making your community a better place to live.[5]

What is a Green Street?

A green street is a stormwater management approach that incorporates vegetation (perennials, shrubs, trees), soil, and engineered systems (e.g., pervious pavements) to slow, filter, and cleanse stormwater runoff from impervious surfaces (e.g., streets, sidewalks). Green streets are designed to capture rainwater at its source, where rain falls, whereas a traditional street is designed to direct stormwater runoff from impervious surfaces into storm sewer systems (e.g., gutters, drains, pipes) that discharge directly into surface waters, rivers, and streams.[6]

---

[5] Source: Smart Growth America, the National Complete Streets Coalition: https://smartgrowthamerica.org/program/national-complete-streets-coalition/what-are-complete-streets/
[6] Source: U.S. EPA: https://www.epa.gov/G3/learn-about-green-streets

CD+A

▲ *Green striped bike lanes, protective islands, and crosswalks aid in providing a more comfortable place for people of all ages to walk and ride.*

CD+A

▲ *Stormwater planters along this major arterial pick up runoff from the street through trench drains and curb cuts along the sidewalk.*

3.4 Sustainable Streets Design Elements and Process

Complete Street Types

CD+A

▲ *Corner and mid-block curb extensions create a safer and more attractive pedestrian crossing. On-demand flashing lights and a high visibility crosswalk provide additional complete street techniques, while stormwater curb extensions add a green infrastructure component.*

CD+A

▲ *Stormwater planters integrated into diagonal parking planter bays. Step out areas along planter bay edges allow comfortable access to enter and exit vehicles.*

Following is a discussion of the different complete streets types and context – land use and character – found in the communities throughout San Mateo County. Discussion and summary tables describing the methodology for selecting appropriate green infrastructure measures and complete street techniques is provided based on the goals and needs of the project, applicability for use in different street and context types, and other considerations. In addition, two example projects are described as they might proceed from planning through to implementation to demonstrate how to use the Design Guide for treatment measures in relation to street and context types, and to illustrate the strategies and techniques for developing sustainable streets.

This section has been developed to provide design guidance to a wide audience. The primary intended audience is the planners, designers, and engineers who conceive of and implement future improvements to streets. While the style is intended to be simple, street design is not always as simple as we might like. Street designs must respond to varied local conditions, specific needs, and site conditions. The designs must balance available standards, guidance, engineering judgment, and new innovations in street design.

The concept of creating complete streets is relatively new and has included the need to develop a new set of street types. In the past, streets have been defined, designed, and operated with a primary focus on vehicular traffic and defined three basic types of streets – arterials, collectors, and local streets. This has been the way streets have been designed since the 1930s and 1940s. These street types do not address the other ways people use streets nor does it address the characteristics of adjacent land use beyond two types – urban and rural. Hence, using this traditional system of arterial, collector, and local street types, six basic street and context types are defined. The complete street types that are used in this Design Guide define streets by their mobility and access characteristics and context, both in terms of use and urban character. This results in the definition of 33 basic complete streets types which are combinations of street and context types; see **Table 3.4a**. These complete streets types reflect the diverse characteristics of the variety of neighborhoods, districts, and open spaces that exist in San Mateo County and allows for the ability to customize the design of streets to better meet the needs of the users and context of location.

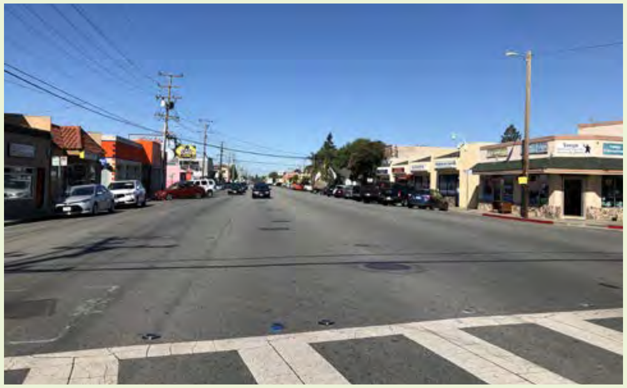
Table 3.4a Complete Street Types – the Combination of Street and Place Types

		Base Street Types				
Context Types		Throughway	Connector	Access	Alley	Path
Use	Character	Complete Street Types				
Mixed Use	Downtown	Downtown Throughway	Downtown Connector	Downtown Access	Downtown Alley	Walkway
Commercial / Mixed Use	Urban	Mixed Use Throughway	Mixed Use Connector	Mixed Use Access	Mixed Use Alley	Walkway
	Suburban	Commercial Throughway	Commercial Connector			
	Rural / Semi-Rural	Parkway	Parkway Connector			
Neighborhood	Urban	Neighborhood Throughway	Neighborhood Connector	Neighborhood Access	Neighborhood Alley	Walkway
	Suburban					
	Rural / Semi-Rural	Parkway	Parkway Connector			Shared Use Path
Industrial	Urban	Industrial Throughway	Urban Industrial Connector	Industrial Access	Industrial Alley	Walkway
	Suburban		Industrial Connector			
	Rural /Semi-Rural					Shared Use Path
Park / Open Space	Urban	Parkway	Parkway Con-nector	Park Access	—	Shared Use Path
	Suburban					
	Rural / Semi-Rural					

Grand Boulevard Initiative Green Infrastructure Opportunities

Communities along El Camino Real (State Route 82) and regional planning, transportation, and economic agencies and organizations have participated in the Grand Boulevard Initiative to revitalize El Camino Real into a vibrant, people-friendly place that is a comfortable place to walk, bike, and take transit. Guiding principles have been developed and endorsed by each community along the corridor to support the vision for El Camino Real.

The integration of green infrastructure along with complete street improvements should be considered with future improvement plans. More major streets and other corridor projects similar to the Grand Boulevard Initiative offer opportunities for obtaining Caltrans and other funding for green infrastructure and climate adaptation projects. For more information, see **Appendix 7** of this guide and https://grandboulevard.net.



CD+A

▲ *Middlefield Road in Redwood City, prior to its redesign, is a wide street with fast moving traffic. It is not a comfortable place for people to walk or bike.*

REDWOOD CITY

▲ *Preliminary redesign of a typical block of Middlefield Road as a sustainable street with green and complete streets elements. This design reduces vehicle lanes and changes the parking configuration to widen sidewalks; add street trees, furnishings, and corner stormwater curb extensions; and designates bike lanes.*

3.4 Sustainable Streets Design Elements and Process

Complete Street Types

The complete streets approach emphasizes identifying and designing for how people use a street, both in traveling along a street and how people access uses along it. For example, an industrial throughway would emphasize trucks over other users, and particularly emphasizing truck traffic traveling through the area. But a downtown access street would emphasize people walking to the uses along it. In addition to the base street types, different ways that people travel can be emphasized. So, the presence of a high-frequency bus route would increase the use of design treatments for movement of buses along the street, and to conveniently serve transit riders walking or cycling to bus stops. But in a downtown area, people walking would have more emphasis, and buses and other traffic might travel slower, to improve pedestrian safety and comfort.

Base Street Types

The base street types describe the primary transportation function of the complete street.

- **Throughway Streets** primarily focus on moving people through an area to their destination, including moving goods by truck, riders in a bus, people in vehicles, or people on bicycles. These streets can also provide access to uses along them, but when possible, vehicles should access uses from side streets rather than the throughway so as not to impede traffic flow. Sidewalks and a comfortable pedestrian environment are still needed, but vary in importance depending upon the context along the throughway and the type of transit using the street. A well-known throughway in San Mateo County is El Camino Real.
- **Connector Streets** are primarily used by people connecting between places over a moderate distance. Connector streets are often important for bus transit and for people who are bicycling, because these streets often connect important destinations. These streets are usually designed for moderate speeds – about 25 mph. Given this speed and importance for transit, uses can front directly onto and be accessible from the street. Examples in San Mateo County include Delaware Street in City of San Mateo and Roosevelt Avenue in Redwood City.
- **Access Streets** primarily provide access to adjacent uses or nearby destinations. In some cases they provide for longer, but more “family-friendly”, trips by bicycle. Pedestrian comfort and safety are important for access streets.
- **Alleys** are streets that are typically located in the middle of a block. Not all, but several, communities in San Mateo County have alleys which provide access to parking, space for utilities and refuse collection, and provide alternative “short cuts” for people walking and bicycling. In some cases, alleys provide primary access to some employment uses and to accessory dwelling units.
- **Paths** are part of the multimodal network, and so are included as a street type. Paths are typically used by people walking, bicycling, or using other “rolling” modes – skateboards, scooters, roller blades, etc. They can be used both for transportation and for recreation, and they can also be active social and commercial spaces, such as Main Street in Downtown San Mateo, which is an alley that has been repurposed as an urban path.

Green Infrastructure in Sustainable Alleys

Older alleys often have drainage issues and can provide unique challenges (e.g., lack of space for landscape) and opportunities (e.g., relatively low traffic levels) for green infrastructure. Many communities around the country have utilized pervious paving in alleyways. Chicago has a program and a handbook specifically focused on Green Alleys[7] and Santa Monica has an Alley Renewal Program that includes installation of pervious concrete center ‘valley’ gutters.[8]

[7] Information about Chicago’s Green Alley program can be found at: https://www.cityofchicago.org/city/en/depts/cdot/provdrs/street/svcs/green_alleys.html
[8] Information about Santa Monica’s Alley Renewal Program can be found at: https://www.smgov.net/streets/alleyprogram/

Some San Mateo County communities may further refine these base street types to more closely fit their community's transportation priorities and character of the built environment. For example, some communities have a downtown and other mixed use commercial districts with streets that could be a walkable "Main Street". The county has some streets that might be called "Rural Highways", where places people are going to are so far apart that walking is not a viable method of moving around, plus the street might only have a gravel shoulder. Communities will also need to have a table that defines the relationship between their complete street types and the "traditional" arterial-collector-local classifications because this is the "functional classification" system required by the Federal Highway Administration (FHWA) for federally funded projects.

See the case study below about the way that the City of San Mateo defined their community-specific street type system and how it relates to the FHWA traditional arterial-collector-local classification system.

City of San Mateo Sustainable Streets Plan and Guidelines Street and Context Types

Table 3.4b: Street and Context Categories (City of San Mateo)

CONTEXT	STREET TYPE: EL CAMINO REAL[5]	MAJOR CONNECTOR	MINOR CONNECTOR	ACCESS	ALLEY	PATH
Downtown	Downtown El Camino Real	Downtown Connector		--	Downtown Alley	Walkway
Commercial/ Mixed-Use[6]	Mixed-Use El Camino Real	Mixed-Use Connector		Mixed-Use Access	Mixed-Use Alley	Walkway
Neighborhood	Neighborhood El Camino Real	Neighborhood Major Connector	Neighborhood Minor Connector	Neighborhood Access	Neighborhood Alley	Walkway
Industrial	--	Industrial Connector		Industrial Access	--	Walkway
Park	--	Parkway Connector	--	Park Access	--	Shared-Use Path

Table 3.4c: Relationship between Street Types and Existing FHWA Classifications (City of San Mateo)

	ARTERIAL	COLLECTOR	LOCAL
EL CAMINO REAL	●		
MAJOR CONNECTOR	●	●	
MINOR CONNECTOR		●	
ACCESS			●

The City of San Mateo has developed a city-specific Sustainable Streets Plan and Guidelines which established a set of street and context categories. It is similar to the street and use types described in this guide with the exception that it distinguishes the most significant arterial street in the city, El Camino Real, as a singular street type. Also, the remaining arterial streets are deemphasized in terms of their through traffic function and are called Major Connectors.

3.4 Sustainable Streets Design Elements and Process

Complete Street Types

▲ *Mid-block stormwater curb extension along this suburban neighborhood connector street with on-demand flashing pedestrian crossing provides a more comfortable and welcoming place to cross.*

▲ *A narrow landscape planter buffers two-way cycle track and a sidewalk from vehicle traffic in this retrofit project along a suburban mixed use throughway corridor.*

Context Types

The use and character of the properties adjacent to a street has a strong relationship to how the street should be designed for transportation – its multimodal function, the allocation of space to different modes, and the character and aesthetic of its streetscape, including the design of green infrastructure along it. For example, a parkway connector street in a rural neighborhood of the unincorporated county or semi-rural Portola Valley might collect street run-off in a grassy swale between a multiuse path and the pavement of the street with the stormwater then flowing to a rain garden where it is treated and has an opportunity to infiltrate. While a mixed use access street in downtown Millbrae may have stormwater flow into a curb inlet and pass through a parking step out area in a trench drain, and into a stormwater planter where it is treated has an opportunity for some infiltration. However, the treated water mainly flows through an underdrain into the municipal storm drain system. The need for more pedestrian circulation and the urban character of downtown Millbrae will result in a street and green infrastructure design that is significantly different from what is appropriate in Portola Valley.

Taking into consideration the complete streets components of a transportation project with regards to street type and context, designers and engineers can effectively integrate green infrastructure elements to create sustainable streets. A set of land use types and character types for the design of sustainable streets are defined below. These reflect the varied uses and character of places throughout San Mateo County. Member agencies may choose to refine these types to reflect their specific local conditions and needs.

Land Use Types

The list of use types is simplified to include categories that distinguish the likely mix and emphasis of transportation modes, and that have a strong influence on streetscape design (e.g., does the use generate higher levels of pedestrian activity and therefore need a wider clear space within the sidewalk for people walking along the street; are there commercial uses that create a need for seating and other amenities on the sidewalk; does the type and intensity of use result in a high demand for on-street parking).

Mixed Use: These are the areas of communities with a mix of retail, employment, public, residential, and open space. These areas typically need more emphasis on people walking and accessing transit, and strong consideration of access and parking for deliveries to commercial uses. These are the most active and urban areas of communities. Streets in mixed use areas will typically have less area that can be devoted to landscape, given the transportation demands on space within the right of way. This affects the types of green infrastructure measures that can be integrated into these streets and the need to design them with stormwater capacity under pavement, such as infiltration trenches and modular suspended pavement systems.


CD+A

▲ *Middlefield Road, Redwood City*

Commercial: These are places with primarily retail and entertainment or employment uses, and little or no residential uses. In commercial areas that have a more suburban or rural character, it is likely that there are existing landscaped areas within the street right of way or adjacent to it that could be converted to green infrastructure or that there is enough space within the existing right of way that could be converted to green infrastructure with curb extensions or other measures.


CD+A

▲ *W 25th Avenue, City of San Mateo*

3.4 Sustainable Streets Design Elements and Process

Complete Street Types

CD+A

▲ *Acacia Avenue, San Bruno*

Neighborhood: These are primarily residential areas that can have a varied mix of single and multi-family housing, a variety of parcel sizes, and a range in the amount of landscaped (i.e., permeable) land area within private lots and within neighborhood streets. Typically, most neighborhood streets in urban and suburban areas have relatively narrow rights of way which can make the addition of green infrastructure challenging. So, the landscaped character of a residential neighborhood has a significant relationship to the potential for streets to be retrofitted to include green infrastructure.

CD+A

▲ *Starlite Street, South San Francisco*

Industrial: Traditionally, these are the areas of communities where manufacturing, utility facilities, warehousing, storage, and generally messier uses have been allowed. As a result, concentrations of different pollutants, including PCBs, which is one of the pollutants that is required to be addressed through the MRP, are often found in older industrial areas. But, older industrial areas can be challenging to retrofit with green infrastructure because of other pollutants in the soil, and given the relatively narrow width of streets and high frequency of larger truck traffic. But many industrial areas in San Mateo County, and other parts of the Bay Area, are experiencing conversion of use, without a change in building or site design. Some locations, such as Menlo Park near the Facebook campus, are experiencing major reconstruction of industrial areas which can make it more feasible to include green infrastructure in the streets of former industrial areas.

CD+A

▲ *San Francisco Avenue, Brisbane*

Park / Open Space: These are the landscaped recreational, civic, and natural spaces within San Mateo County. For parks that are integrated into urban and suburban areas, they may provide landscaped areas adjacent to streets that can be used for green infrastructure to treat and manage street runoff that is not feasible to accommodate within the street right of way.

Character Types

The character of development along a street should have a direct relationship to the design of the street, including things such as posted speed, presence of on-street parking, and design of the pedestrian environment including landscaping, presence of seating, and other elements. In particular, how adjacent development interfaces with the street – storefront and other active uses at the sidewalk, a landscaped yard, a parking lot, a fence, rural farm land, or natural open space – should strongly influence the design of the street and its pedestrian environment. The character of the context along the street also affects the type, size, and design detail of green infrastructure within the street.

Downtown: Given the varied mix of uses and intensity of development in most San Mateo County downtowns, the character of these areas puts high demand on the limited space within the street. This includes space for all modes of transportation, transit stops, parking, and landscape and other streetscape elements such as outdoor seating. In these locations, green infrastructure needs to be efficiently designed to minimize or mitigate impacts to competing interests like on-street parking. Elements such as infiltration trenches or modular suspended pavement systems can be used to increase stormwater treatment and volume reduction while minimizing the surface area of the green infrastructure that is landscaped. In some cases, it may also be feasible to design treatment measures that do not provide full regulated projects levels of treatment, with the goal of building more infrastructure in public projects while receiving some credit towards achieving treatment targets.

CD+A

▲ *Middlefield Rd, Redwood City*

Urban: This character type includes areas of communities with some vertical mix use, but also more single use areas with a moderate intensity of development. Urban areas tend to have a higher percentage of impervious surfaces, compared with suburban areas in the same community. They can include older residential neighborhoods, commercial districts, and industrial areas which can have higher levels of the pollutants of concern in the environment. Many urban areas in San Mateo County communities are experiencing reuse and redevelopment of parcels and public investment in transit and complete streets projects, all of which create opportunities for implementing green infrastructure.

CD+A

▲ *South Delaware Street, San Mateo*

3.4 Sustainable Streets Design Elements and Process

Complete Street Types

CD+A

▲ *Whipple Ave, Redwood City*

Suburban: Suburban areas are more likely to be single use and are generally developed at lower densities which may allow for more landscape in the built environment. But suburban development also tends to have surface parking areas, that when combined with larger retail and employment buildings, can result in large extents of impervious surfaces. The streets in suburban areas tend to focus on vehicular facilities and many communities are investing in making suburban streets more multimodal. So, similar to urban areas, suburban areas do present opportunities for green infrastructure and can provide significant area for development of green infrastructure within and adjacent to the public right of way.

CD+A

▲ *Fair Oaks Lane, Atherton*

Rural / Semi-Rural: These areas exist in communities within the coastal hills, along the coast, and on the San Francisco Bay side of the hills of San Mateo County. There are communities, such as Atherton and Hillsborough, that have a predominantly semi-rural character. Development in these communities and open space areas of San Mateo County is generally low or very low density with larger areas of landscape. Implementation of green infrastructure as part of streets in these areas can be challenging, because existing streets often do not have curbs that can direct water to green infrastructure treatment measures or have narrow rights of way. Sidewalks and storm drain infrastructure may or may not be present. Swales or other surface drainage ways might be used to direct flows to larger rain gardens or other measures; or pervious paving may be an appropriate measure in places with this character type. See **Section 4.14 Specialized Design Considerations for San Mateo County** for design considerations to integrate green infrastructure into rural and semi-rural areas.

Community and Multimodal Specific Refinements

As mentioned earlier, communities in San Mateo County may decide that additional refinements to the complete street types, as defined in this Design Guide, is necessary to address specific community conditions or modal priorities. This can be done by defining overlays that indicate the geographic area in the community's street network where special conditions apply. For example, a Transit-Access Overlay might be applied to streets within the half-mile transit access shed of a Caltrain Station (defined as the area, based on distance, in which people will walk to a station to ride the train), so communities may want to provide extra emphasis for people walking or cycling. This emphasis could be achieved through an overlay around a station. Schools, senior centers, or other special uses might also have overlays applied to the area around them.

A community's bicycle plan defines the existing and future bicycle network, and this could be used to identify streets needing a bicycle emphasis overlay. **Table 3.d** is an excerpt from a table in the City of San Mateo's *Sustainable Streets Plan* that describes a series of overlays, summarizes the purpose of the overlay, and gives examples of design modifications that apply to streets with the overlays.

Table 3.d: Complete Street Design Guidelines Overlays (City of San Mateo)

OVERLAY	PURPOSE	EXAMPLE DESIGN MODIFICATIONS
Pedestrian Greenway Streets	Prioritize pedestrian safety and comfort	Reduced crossing distances and emphasis on pedestrian crossing enhancements Street trees and plantings Maximum sidewalk widths
Suggested Routes to Schools	Prioritize pedestrian and bicycle safety along designated pedestrian and bicycle routes	Reduced crossing distances and emphasis on pedestrian crossing enhancements Bicycle lanes Cycletracks
Transit Streets	Prioritize transit speed and schedule reliability	Lane width guidance Reduced crossing distances Transit speed improvement projects (transit lanes and intersection treatments) Bus stop placement priority
Bicycle Priority Streets	Prioritize bicycle safety and comfort	On-street bicycle treatments Intersection bicycle treatments (See Flexible Zone, Intersections)

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

This section describes the process for selecting complementary green infrastructure measures and complete street techniques, and advancing a sustainable street from planning to design and engineering, construction administration, and ultimately developing an on-going operations and maintenance plan. Each phase of this process includes a general discussion of the strategies for addressing issues that will likely arise during that phase, and uses two hypothetical projects to more specifically illustrate the process. One of the hypothetical projects is a relatively small project, the installation of curb extensions at an intersection, and the other is a larger corridor project, a road-diet with protected bikeways and other complete streets improvements.

An overarching theme to this methodology is an iterative process of developing complete streets and green streets infrastructure components of a project while also maximizing the ability to create an integrated sustainable street where the complete and green streets investments complement one another. The process includes the following phases:

1. Understand Site Considerations and Project Goals and Needs
2. Develop and Assess Sustainable Streets Concepts
3. Prepare Construction Documents
4. Construction Administration
5. Operations and Maintenance

CD+A

▲ *Pervious pavement and linked tree well filters at Bay Meadows in the City of San Mateo.*

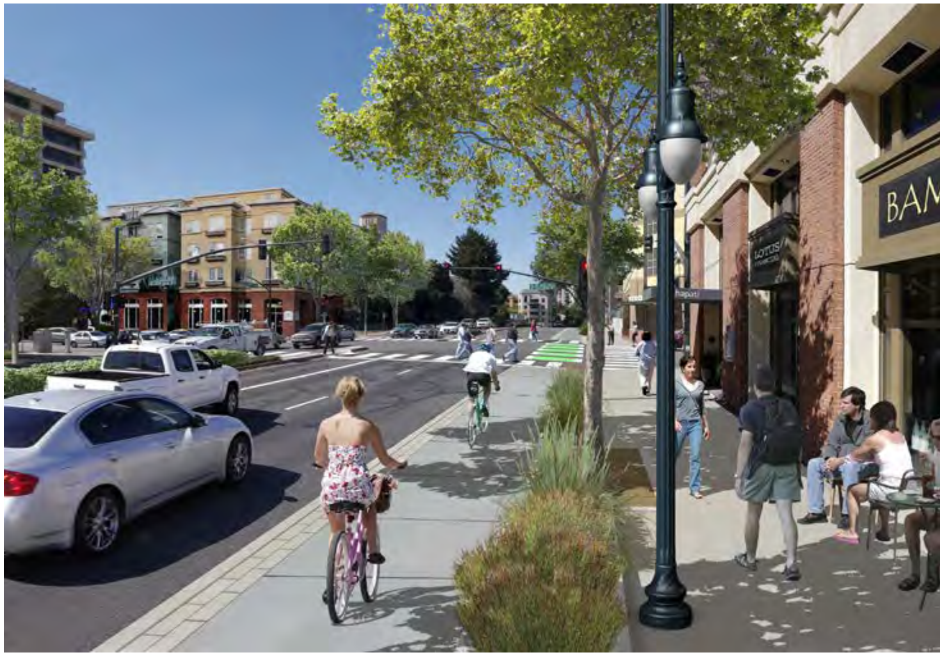
Phase 1 – Understand Site Considerations and Project Goals and Needs

Defining the goals and needs of the project from a complete streets and green infrastructure standpoint is the start of the process. Here are some initial questions and issues to address at project start-up:

- What is the condition of the existing transportation and drainage system?
- What street and context types are part of the project area, and are the existing types being transformed by the project and surrounding development into new types?
- What are the needs of existing and future users of the street?
- What is the funding source for the project, and does it have specific requirements or present multi-benefit opportunities? For example, some transportation funds may limit investment in green infrastructure and vice versa. So, multiple funding sources may be necessary, and this can affect design options for the project.

Depending upon the scale of the project, and community interest, this phase could include a stakeholder input process.

SAN MATEO SUSTAINABLE STREETS PLAN



SAN MATEO SUSTAINABLE STREETS PLAN

▲ *Before and after simulation of how a mixed use throughway street, El Camino Real in City of San Mateo, can be turned into a sustainable street.*

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

Complete Streets – balance design for all users

Complete streets projects are, for the most part, focused on making improvements for the various users of a street – commercial and personal vehicle drivers, transit drivers and riders, cyclists, people walking, and people using wheelchairs. There are a variety of ways to address these needs, and in some cases, the design solutions addressing one user's needs will conflict with those for another user. At the planning level, needs of different users should be identified and the priority for various users should be established. For example, if the street is a designated truck route or is in a commercial district where truck deliveries are important, this can affect the needed width for travel lanes and the corner radius of curbs at intersections, which in turn could affect the potential for curb extensions and influence the selection of green infrastructure treatment measures.

Intersection Design Example Project – This project is an intersection of a neighborhood access street and a connector street; there are stop signs on the access street. Vehicles on the connector street often travel over the speed limit. Improving the safety and comfort for people walking across the connector street is therefore a priority. But, it is decided that the flow of traffic on the connector is also important, and adding stop signs for that traffic is not feasible. The local jurisdiction does a transportation assessment of the intersection and finds that enough people walk across the intersection and enough drivers on the connector street do not yield to them that a rapid flashing beacon should be installed and that curb extensions should be installed to improve visibility between drivers and pedestrians. The community has known of the issues at the intersection for several years and has programmed improvements in their Capital Improvements Plan (CIP) Program. So, the complete street improvements are self-funded.

Corridor Design Example Project – This project is a connector street in an old industrial area that is within a Priority Development Area.[9] The community has designated the area for future mixed use development. The existing street is narrow with four lanes of traffic. The community's bicycle plan designates the street for Class II buffered bike lanes. Future development of the area will increase the number of people walking and cycling, and given the street network in the area, only two of the four existing lanes will be needed for future traffic. There is local funding that can contribute to the reconstruction of the street because it is in a specific plan's area. But, current best practices in bike facility design lead to a recommendation for a Class IV protected bikeway which is more expensive to build than the specific plan's Class II improvements. So, it is decided that the community should pursue a Caltrans Active Transportation Program (ATP) Grant for the project.

[9] Priority Development Areas are places that have been identified by communities that are within walking distance to transit and planned for mixed use redevelopment.

Green Infrastructure – both a stormwater management and broader community asset

There are a number of factors that play into the ability of a street to effectively include green infrastructure. C/CAG's **Stormwater Resource Plan (SRP)** utilized a range of high-level factors to screen-out and prioritize streets in San Mateo County that have some potential for the inclusion of green infrastructure. For instance, if streets have a slope of greater than 5% they were excluded. Communities may wish to include other factors not accounted for in the **SRP** such as complete streets modal priorities, economic development, public health, environmental justice, and other community values and priorities for the built environment. The key factors considered in the **SRP** and additional community benefit factors that may be considered in prioritizing streets that should include green infrastructure are listed in **Figure 3.4a.** Other factors may be included based on each community's specific conditions and goals.

Figure 3.4a: Stormwater Resource Plan Key Factors and Community Benefits

Stormwater Resource Plan Key Factors

- How impervious is the right of way?
- What is the slope of the street, less than 5%?
- Is the street in proximity to flood-prone channels?
- Is the street in an area with potential for higher levels of PCBs?
- Is the street already identified for an improvement project?
- Is the street part of a Safe Routes to School project?
- Does the street drain to a TMDL water (Total Maximum Daily Load of the regulated pollutants)?

Additional Community Benefit Factor to consider

- Is the street in a Specific Plan or other focused planning area that defines street improvements and potential funding?
- Is the street in a Priority Development Area (PDA)[10]?
- Is the street in a Priority Conservation Area (PCA)[11]?
- Is the street located in an area that is a focus for economic development by the community?
- Is the street located in a Community of Concern[12] as identified by the community and (Metropolitan Transportation Commission) MTC?
- Is the street identified by the community for bicycle or pedestrian plan improvements or other complete streets improvements?
- Is the street in an area of concern that has been identified in relation to climate adaptation and community resilience?

[10] PDAs are places identified by Bay Area communities as areas for investment, new homes, and job growth. PDAs are the foundation for sustainable regional growth and Plan Bay Area. To become a PDA, an area must be: 1) within an existing community; 2) within walking distance of frequent transit service; 3) designated for more housing in a locally adopted plan or identified by a local government for future planning and potential growth; and 4) nominated through a resolution adopted by a City Council or County Board of Supervisors. See https://abag.ca.gov/priority/development/ for more information.

[11] PCAs are open spaces that provide agricultural, natural resource, scenic, recreational, and/or ecological values and ecosystem functions. These areas are identified through consensus by local jurisdictions and park/open space districts as lands in need of protection due to pressure from urban development or other factors. PCAs are categorized by four designations: Natural Landscapes, Agricultural Lands, Urban Greening, and Regional Recreation. Refer to https://abag.ca.gov/priority/conservation/ for greater detail.

[12] A "community of concern" is intended to represent a diverse cross-section of populations and a community that could be considered disadvantaged or vulnerable in terms of both current conditions and potential impacts of future growth. Plan Bay Area, and other land use and transportation policy documents, give consideration to increasing transportation and other public investment in communities of concern, because of historic disinvestment in these communities. For more information, see https://www.planbayarea.org/2040-plan/plan-details/equity-analysis.

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

In addition, where green street infrastructure is being considered, the community should evaluate existing storm drain infrastructure, such as the presence of storm drain inlets and storm drain pipes, and surface drainage patterns. Another condition to assess is whether adjacent properties or nearby streets contribute stormwater runoff to the project area. Other hydrologic and soil conditions should also be assessed to identify any issues that could affect green infrastructure feasibility or design, such as high ground water, inability to infiltrate stormwater, and contaminated soils.

Intersection Design Example Project – Both streets are identified as opportunities for green infrastructure in the **Reasonable Assurance Analysis (RAA)** and the local GI Plan. The GI Plan did not identify either street as high priority. Existing street drainage patterns flow to inlets that are at or near to the corners of the intersection. Like much of the bayside of San Mateo County, the soils have high clay content and do not infiltrate well. Surrounding properties do not add much runoff to the street, given the extent of on-site landscaping; existing streets have a landscape strip between sidewalk and the roadway.

CD+A

▲ *Typical intersection between a collector and local street.*

Corridor Design Example Project – This corridor was identified as a green infrastructure opportunity in the **RAA**, and the local GI Plan gives it a high priority, because it is within a specific plan and old industrial area. The area has some flooding issues brought about by the high percentage of impervious surface within the existing industrial development and deficiencies in the existing older stormwater drainage system. These were identified in the specific plan and storm drain improvements are included in the financing plan. However, the public works department is interested in reducing investment in the underground system by including green infrastructure in the area to spread peak stormwater flows. Future redevelopment is required to manage their stormwater on-site given C.3 regulations, therefore they will not contribute significant stormwater flows into the street. There are some contaminated soils in the project area.

CD+A

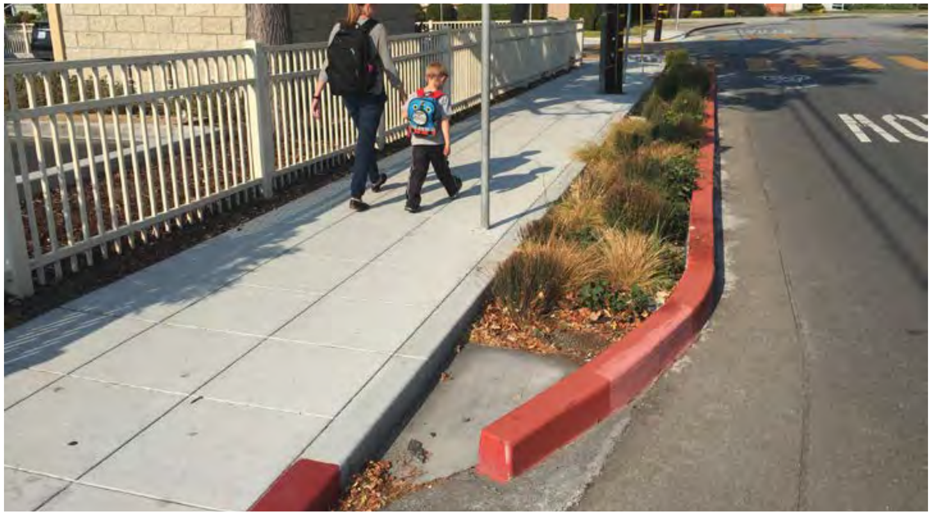
▲ *Typical four-lane industrial corridor in Burlingame.*

Context-Sensitive Design – Enhance Quality of Place

The character of existing streets and adjacent properties should influence both sustainable streets design. Also, some areas of the county and its communities will have the character of their existing context change, as areas that were industrial or older commercial are redeveloped into new mixed use districts. Therefore, an understanding of a street's context must take into consideration the jurisdiction's land use policies and the potential for future reuse and redevelopment. The combination of surrounding context, and the area needed for transportation and other space within the street right of way, has a significant effect on the amount of space for landscape and this will affect the area and type of green infrastructure that can be used.

Intersection Design Example Project – The intersection is in a Suburban Neighborhood context that is not expected to see extensive change for the foreseeable future. Adjacent properties have well landscaped yards and the streets include a landscape strip with trees between the sidewalk and curb. On-street parking is used, but properties all have off-street parking as well. The public works department's traffic and stormwater staff have begun to have meetings with stakeholders in the neighborhood to discuss the complete and green streets goals for the project.

Corridor Design Example Project – While the area is currently an Urban Industrial context, the adopted specific plan foresees the area becoming an Urban Mixed Use district. There are no active development proposals in the project area. The public works department has hired a consultant team to develop a design concept for use in the Active Transportation Program (ATP) Grant. The planning and design process has begun with a needs assessment for the corridor and a review of the specific plan's goals and guidelines for the street redesign with project stakeholders.


EOA

▲ *Street retrofit in the City of San Mateo added numerous stormwater curb extensions near a school and neighborhood.*

EOA

▲ *This industrial street, Bransten Road in San Carlos, also underwent a street retrofit to integrate stormwater curb extensions.*

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

Phase 2 – Develop and Assess Sustainable Streets Concepts

This phase is a multistep process of developing and evaluating design options, refining them to achieve project goals for sustainable streets, and finally selecting the preferred design based on multiple criteria. Depending upon the scale of the project, a stakeholder input process and review and approval by community committees and commissions, and ultimately the community's council or supervisors, may be needed.

Develop and Assess Feasibility of Initial Design Concepts

The key issue that must be addressed in the development of design concepts for a sustainable street project is to achieve a balance between space requirements for complete streets and green streets improvements within the constraints of a project's street right of way. From a complete streets perspective, Phase 1 determined priorities for improvements to address the needs for the range of users of the street. The initial design concepts will identify the range of physical improvements that can be accommodated within the right of way. Typically, the improvements will all be made within the existing right of way given the amount of time and expense for right of way acquisition. Initial design concepts are typically developed to test basic spatial feasibility of design options with the goal of identifying a smaller set of options for more detailed concept design and evaluation. For some smaller projects it may be possible to move directly into selection of a preferred concept following assessment of initial design concepts. **Tables 3.4e** and **3.4f** show the potential for various types of green infrastructure in relation to different street types and land use context types. Different green infrastructure measures are best suited to particular locations within the street, which affects the viability of green infrastructure opportunities with complete streets improvements, see **Table 3.4g**.

CD+A

▲ *A sustainable street retrofit project along Humboldt Street in the City of San Mateo includes bike lanes and stormwater planters along a commercial and residential corridor.*

Table 3.4e - Green Infrastructure Measure Applicability by Street Type

Street Types		Green Infrastructure Measures: Bioretention/Bioinfiltration Area/Planter – Stormwater Planter	Bioretention/Bioinfiltration Area/Planter – Stormwater Curb Extension	Bioretention/Bioinfiltration Area/Planter – Rain Garden	Tree Well Filter	Infiltration Systems [1]	Pervious Pavement	Vegetated Swale	Green Gutter	Stormwater Tree
Throughway	Downtown, Commercial or Mixed Use Throughway						2			
Throughway	Neighborhood or Industrial Throughway						2			
Throughway	Parkway					3	2		4	
Connector	Downtown, Mixed Use, Commercial, or Urban Industrial Connector						2			
Connector	Neighborhood or Industrial Connector					3	2		4	
Connector	Parkway Connector					3	2		4	
Access	Downtown Access									
Access	Mixed Use Access					3			4	
Access	Neighborhood Access					3			4	
Access	Industrial Access					3	2		4	
Access	Park Access					3			4	
Alley	Downtown Alley									
Alley	Mixed Use Alley					3			4	
Alley	Neighborhood Alley					3			4	
Alley	Industrial Alley					3			4	
Path	Walkway									
Path	Shared Use Path					3			4	

Table Notes

1. An infiltration system can be installed adjacent to other treatment measures to allow for secondary “storage” of treated stormwater to facilitate infiltration where native soils are slow to percolate.
2. Use pervious pavement only in parking lanes, shoulders, and medians.
3. Possible to use in Park, Semi-Rural or Rural contexts, but there are likely more cost-effective alternatives.
4. Possible to use in Park, Semi-Rural or Rural contexts, but narrowing the street right of way in these lower intensity and open space oriented contexts is more desirable in relation to complete streets and green infrastructure goals.

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

Table 3.4f - Green Infrastructure Measure Applicability by Context Types

Context Types		Green Infrastructure Measures								
		Bioretention/Bioinfiltration Area/Planter								
Use	Character	Stormwater Planter	Stormwater Curb Extension	Rain Garden	Tree Well Filter	Infiltration System [1]	Pervious Pavement	Vegetated Swale	Green Gutter	Stormwater Tree
Mixed Use	Downtown								2	
Commercial / Mixed Use	Urban								2	
	Suburban									
	Rural/Semi-Rural		3		3,4	4			5	
Neighborhood	Urban									
	Suburban									
	Rural / Semi-Rural		3		3,4	4	4		5	
Industrial	Urban						6			
	Suburban					4	6		5	
	Rural /Semi-Rural		3		3,4	4	4,6		5	
Park / Open Space	Urban		3		3	4			5	
	Suburban					4			5	
	Rural / Semi-Rural		3		3,4	4	4		5	

Table Notes

1. An infiltration system can be installed adjacent to other treatment measures to allow for secondary "storage" of treated stormwater to facilitate infiltration where native soils are slow to percolate.
2. Limited applicability given land area needed for measure, more area efficient measures will allow space for complete streets and public open space features within urban street rights of way.
3. On streets with curbs.
4. Possible to use in Park, Semi-Rural or Rural contexts, but there are likely more cost-effective alternatives.
5. Possible to use in Park, Semi-Rural or Rural contexts, but narrowing the street right of way in these lower intensity and open space oriented contexts is more desirable in relation to complete streets and green infrastructure goals.
6. Use pervious pavement only in parking lanes, shoulders, and medians.

Table 3.4g Possible Green Infrastructure Locations within the Street

Street Zone	Green Infrastructure Measures								
	Bioretention/Bioinfiltration Area/Planter								
	Stormwater Planter	Stormwater Curb Extension	Rain Garden	Tree Well Filter	Infiltration System [1]	Pervious Pavement	Vegetated Swale	Green Gutter	Stormwater Tree
Sidewalk									
Curb Lane									
Roadway									
Median	2		2	2	2		2		2
Intersection									

Table Notes

1. Depending upon the type of infiltration system, it can be installed adjacent to other treatment measures to allow for secondary "storage" of treated stormwater to facilitate infiltration where native soils are slow to percolate.
2. Typical center crowned streets do not support this treatment measure in a median.

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

Sizing of Green Infrastructure in Sustainable Streets

Most communities' GI Plans will identify the need to implement green infrastructure in street redesign/reconstruction projects to achieve the treatment targets. But, most street retrofit projects are not regulated projects. Therefore, there is some flexibility in sizing the project to either achieve the treatment sizing requirements of the MRP (C.3.d), and if that is not possible, to meet the alternative sizing requirements that are allowed if there are constraints in the right of way. (Refer to **Section 4.12 General Sizing of Green Infrastructure Facilities** for more information.) It is best at this point in the planning process to determine which method should be used in developing a project's design concepts. Achieving or exceeding the treatment requirements of the MRP can provide additional community benefits, even if the project is not a regulated project, because this will do more to achieve a jurisdiction's treatment targets. Further, designing and sizing green infrastructure facilities to adequately manage the tributary flow will aid in the longevity and proper functionality of these facilities.

Intersection Design Example Project – This project is not a regulated project. Given the funding constraints of the project, the most cost effective and reasonable green infrastructure treatment measures to include in the project are stormwater curb extensions and stormwater trees. Other options that were considered but eliminated for cost efficiency reasons include pervious pavement and tree well filters.

Initial design concepts were developed exploring which corners have drainage patterns and systems that can allow for curb extensions, and the length of curb extensions and resulting area for associated stormwater planters. Stormwater trees were eliminated from consideration because of cost and the extent that they would impact the existing landscape strips.

CD+A

▲ *Conceptual options to evaluate different designs to select the preferred project design that best meets a project's goals and balances the different competing spatial requirements.*

Corridor Design Example Project – Initial concept design, feasibility assessment, and discussions with project stakeholders indicate that two complete streets concepts should be developed further to explore potential for green infrastructure performance in relation to complete streets, green streets, and other community goals, as well as cost effectiveness. One concept includes two traffic lanes, a center turn lane, buffered bike lanes, on-street parking, widened sidewalks and corner curb extensions. The second concept has two traffic lanes, on-street parking, a concrete median separating a protected bikeway from parked cars and providing space for passengers to step out, and a sidewalk. This concept can also include curb extensions.

Green infrastructure measures that will be explored further include: stormwater curb extensions, stormwater planters, and tree well filters. Linked tree well filters and pervious pavement will also be considered, but would likely only be included if the green infrastructure is treating stormwater runoff from the street and adjacent private redevelopment sites.

Refine and Evaluate Design Concepts and Select Preferred Concept

This step in the design process includes more detailed evaluation of the most favored initial design concepts. This includes developing more detailed plans, grading concepts, and the additional consideration of street design elements such as pedestrian lighting, tree grates and tree guards, low railings around some green infrastructure measures, etc. This step allows for more detailed feasibility assessment and development of cost estimates. Opportunities for stakeholder input can be included, as well as further discussions with potential private development partners. This is also the point at which any environmental assessment and certification should take place.

Intersection Design Example Project – More detailed design of the stormwater curb extensions concept establishes the viability of curb extensions into the connector street, but not into the crossing access street. It was not possible to maintain flow along the gutter line of extensions into the access street. Assessment of parking impacts and cost effectiveness of connections to storm drains indicates that three of the four stormwater curb extensions can have underdrains and overflows connected to the storm drain system. The fourth curb extension will be designed for rain water interception with trees, and limited treatment of stormwater runoff with an additional curb cut allowing stormwater to flow back out of the planter. The public works and planning departments prepare a categorical exemption for the project which is approved by city council.

Corridor Design Example Project – More detailed design studies, cost estimates, complete streets assessments, and green infrastructure evaluations were done for the two concepts identified by the initial design and feasibility assessment. The evaluations and discussions with stakeholders resulted in a decision that the center turn lane is not necessary for providing site access, rather, sites can be accessed primarily from side streets. This makes space available to include Class IV protected bikeways. The design constrains the sidewalk width so that stormwater planters would be undersized. Instead, a series of stormwater curb extensions and tree well filters within the parking lane will be designed and interconnected with an underdrain. This design approach will also create opportunities for pervious pavement in the parking lane in locations where adjacent redevelopment projects are permitted to allow for shared public and private stormwater management. One developer has indicated an interest in pursuing this approach. The public works and planning departments prepare a mitigated negative declaration for the project California Environmental Quality Analysis (CEQA) assessment, tiering off of the environmental document for the specific plan. The city council accepts the environmental document. If the project receives an ATP grant it will likely include federal funding and a National Environmental Policy Act (NEPA) process will be necessary.

The preferred concept design is then packaged for an ATP Grant application which seeks funding for the NEPA assessment, construction documents preparation, and for a significant portion of the construction costs of the project.

3.4 Sustainable Streets Design Elements and Process

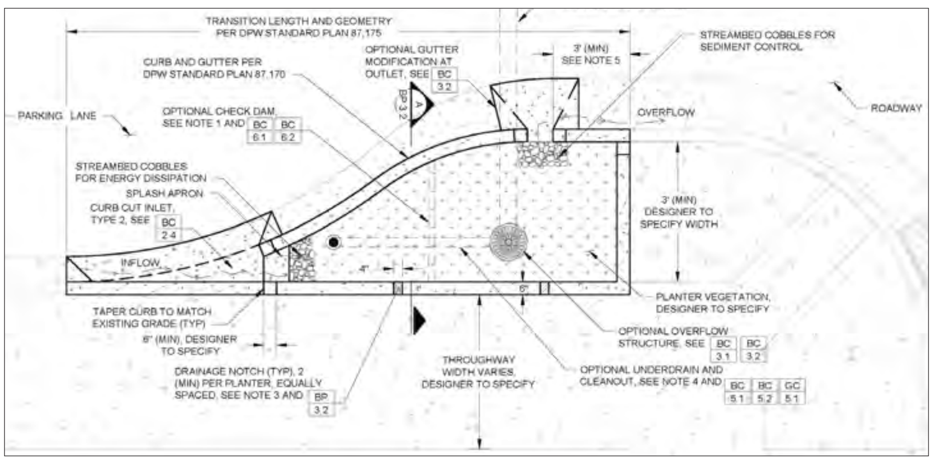
Sustainable Street Design Process and Strategies

Phase 3 – Prepare Construction Documents

In this phase of the project, any remaining environmental assessments should be completed, construction documents are prepared, and any agreements with partner agencies or private partners should be finalized. Any final approvals from agency administrators, commission, and elected officials should be in place for the project to enter construction or go out to bid.

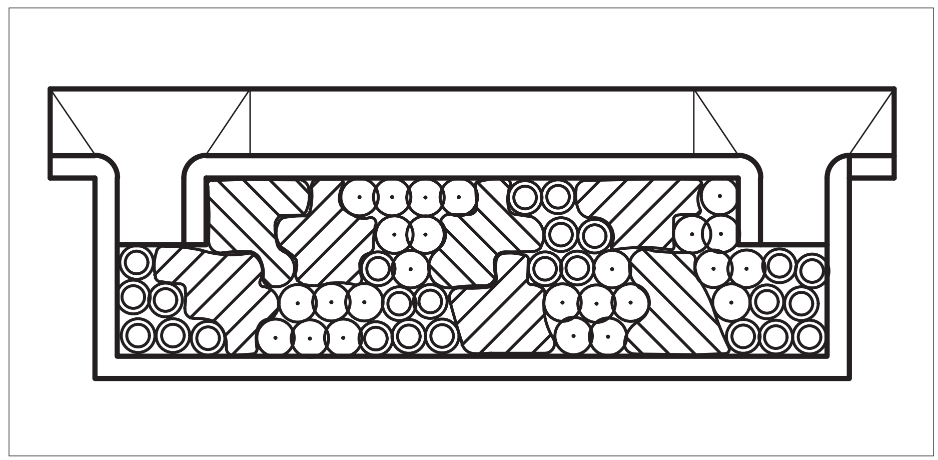
Intersection Design Example Project – The public works department prepares construction and bid documents, and discussions take place with adjacent property owners regarding selection of tree species for the trees that will be planted in the landscape strip.

Corridor Design Example Project – The project receives an ATP Grant, and there is a year before the funding will be available. During this time, the developer that expressed interest in joint green infrastructure development finishes their development approvals, including a memorandum of understanding (MOU) for the shared green infrastructure. The MOU includes funding of construction documents, construction costs, and operations and maintenance costs by property owners for the improvements along their property frontage. Once initial ATP funding is available, the project goes through a NEPA environmental review process and additional preliminary engineering. With certification of the NEPA document, the community authorizes the consultant team to prepare construction documents.



SFPUC

▲ *Develop details and plans specific to the project goals and design.*



CITY OF PORTLAND, OREGON

▲ *Prototypical landscape plan for a stormwater planter.*

Phase 4 – Construction Administration

Once the construction documents are finalized the project can be put out to bid, or in some cases, smaller projects may be constructed by jurisdiction staff. In most cases, the project will be put out to bid, a contractor is selected, and once an agreement is in place construction begins. During construction, the jurisdiction's engineering staff reviews and approves the work of the contractor. If there was a design and engineering consultant team, they will typically provide construction administration assistance to jurisdiction staff. Once construction is complete and approved, the contractor will likely continue to have responsibility for establishment of landscape within the street, including the green infrastructure.

Intersection Design Example Project – The bidding and contractor agreement process goes smoothly. Minimal change orders are needed during construction, and construction is complete within a few months of the projected schedule.

Corridor Design Example Project – The bidding and contractor agreement process goes relatively smoothly. But during construction, it becomes clear that the general contractor and the landscape subcontractor are not as experienced with green infrastructure construction as they indicated in the bid documents. The consultant team and city engineer reject multiple submittals and shop drawings. After some delays, the general contractor replaces the landscape subcontractor and construction proceeds more smoothly. As with many street reconstruction projects in older areas, there are some major change orders because underground infrastructure is different than indicated from record documents and the site survey. Despite the complexities the project is completed within a few months of schedule. Construction of the private development has begun and over the next couple of years the on-site stormwater system is connected to the shared green infrastructure within the street as planned and designed.

J LEE

▲ *Construction administration is important to ensure that the project is built according to the plans.*

3.4 Sustainable Streets Design Elements and Process

Sustainable Street Design Process and Strategies

Phase 5 – Operations and Maintenance

This phase of the project will primarily involve jurisdiction staff unless the project is a shared public-private project or a multi-agency project. In some cases, in residential neighborhoods or mixed use and commercial districts, some operations and maintenance responsibilities may be undertaken on a voluntary basis with neighbors or a Business Improvement District, or a major adjacent property owner may take on some maintenance responsibilities. The **C.3 Regulated Projects Guide** and **Chapter 6 Operations and Maintenance** of this Design Guide provide further information regarding on-going monitoring, operations, and maintenance of green infrastructure.

Intersection Design Example Project – The landscape establishment period goes smoothly with only one tree needing to be replaced. During the construction phase the local neighborhood group and senior center expressed interest in being involved with on-going maintenance of the green infrastructure landscaping. Training sessions are held with public works staff and the two groups provide quarterly assistance in landscape maintenance.

Corridor Design Example Project – The landscape establishment period goes smoothly, and with completion of the private development, the developer/owner of the project takes on their responsibilities in relation to on-going operations and maintenance of the shared green infrastructure with city parks and recreation staff and public works staff undertaking their operations and maintenance responsibilities.

CD+A

▲ *Remove sediment and debris as needed to maintain the function of the green infrastructure.*

CD+A

▲ *All aspects of a project should be inspected, including that irrigation is working properly.*

CD+A

▲ *A sustainable street in San Francisco that integrates stormwater planters and stormwater curb extensions with improved pedestrian and bicycle facilities.*

3.5 Sustainable Streets Design Strategies and Guidelines

Introduction

The integration of green infrastructure into complete streets to form sustainable streets is an emerging and rapidly evolving practice. Design guidance specific to sustainable streets is currently not common and has generally been developed for more urban cities in the United States. Designing and implementing green infrastructure within streets is different from providing green infrastructure within a development site or associated with a building. Many factors need to be considered and evaluated in the design and implementation of a sustainable street to achieve a final project that balances the needs and safety of different transportation modes and otherwise meets the goals of a community. This section builds upon the key considerations described in **Chapter 2** and the general guidance discussed in **Section 3.1** and provides more detailed design strategies and guidelines that are specifically tailored for the different types and locations of green infrastructure measures that typically occur within sustainable streets. This emphasis allows designers and civil and transportation engineers to better understand the complexities and needs of sustainable streets. It also complements the guidance the **C.3 Regulated Projects Guide** provides that is more oriented toward building and site projects.

Some redundancy exists between the different treatment measures discussed within this section. However, this allows a designer or engineer to focus upon the specific green infrastructure type they are interested in learning about or integrating into their project. As with **Section 3.1**, the guidance in the following pages is organized into general, green street, and complete street categories for each green infrastructure measure.

▲ *A sustainable street retrofit in Oakland that integrates stormwater planters with improved pedestrian and bicycle (cycle track) facilities. Two-way vehicle traffic is located to (and off) the photograph to the left. Stormwater runoff flows from vehicle lanes through notches in a landscape buffer across the cycle track and into the stormwater planters on the opposite side of the street.*

CD+A

CHAPTER 3

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Planters

CD+A

General Guidance

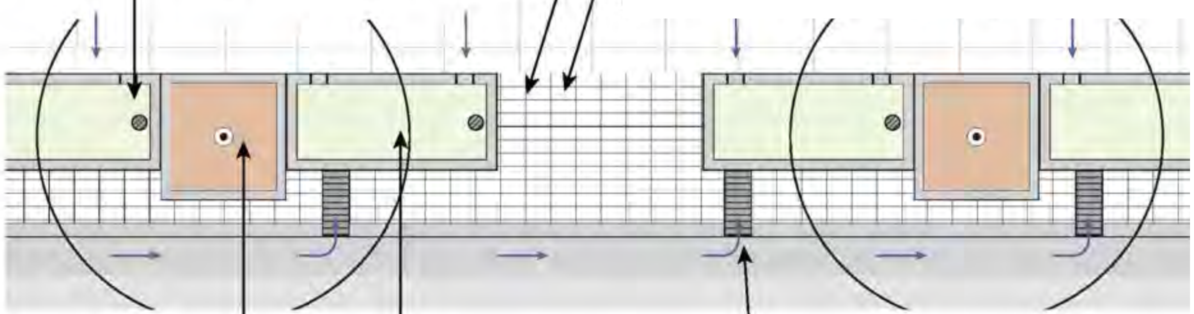
- Existing sidewalks can often be redesigned to manage stormwater with the use of stormwater planters.
- Permeable paving placed within the parking lane of the street or sidewalk can complement the stormwater planter and allow improved management of the street's stormwater runoff.
- Stormwater planters can also be used in medians and other islands including dividers between vehicle and bicycle lanes, roundabouts, and intersection "porkchop" islands.
- In shared streets, stormwater planters can be placed between the vehicle drive area and the primary pedestrian zone, as well as between vehicle travel lanes for traffic calming purposes.
- Stormwater planters within the right of way are typically located between the curb and sidewalk or vehicle lane and primary pedestrian zone in shared streets and take the place of the landscape strip or parkway.
- Can be used on streets with or without parking.

CD+A

▲ *Stormwater planters can effectively be located in street medians.*

Green Streets Guidance

- Locating stormwater planters near and just upstream of drainage inlets will help ensure that street run-off flows to the green infrastructure, because the grade of the street and gutter should already flow to the inlet.



▲ *Typical plan of stormwater planter set back from the roadway curb and trees planted outside of the stormwater planters.*

Locations for Stormwater Planters

	Street Types	Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●
	Parkway Connector	
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	●
	Industrial Access	●
	Park Access	
Alley	Downtown Alley	
	Mixed Use Alley	
	Neighborhood Alley	●
	Industrial Alley	
Path	Walkway	●
	Shared Use Path	●

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Planters

CD+A

▲ *Detail of trench drain directing runoff from the street to the stormwater planter set back from the on-street parking lane.*

CITY OF MENLO PARK

▲ *This stormwater planter is flanked by trees which can help reduce heat island effect.*

Complete Streets Guidance

- Stormwater planters shall be designed to accommodate pedestrian access between parallel parking stalls and the uses at the back of sidewalk.
- Where soil volume and other design parameters allow, street trees can be planted within the stormwater planting creating opportunities for passive rainwater harvesting.
- The minimum sidewalk width between the stormwater planter and the edge of the street right of way, the back of the sidewalk, should generally be 6 feet in urban areas and 5 feet minimum. In areas with higher pedestrian activity this area should be wider than 6 feet, particularly if there are active storefronts along the street or outdoor seating. In areas with lower pedestrian activity, the sidewalk must at least meet the width and maneuvering requirements of ADA.
- Where on-street parking occurs, provide breaks between stormwater planters to allow pedestrian access between the parked vehicle and sidewalk. Breaks should be provided a maximum of every 45 feet. Pedestrian access width shall be a minimum of 5 feet wide, and preferably 6 feet. Note that sizing and frequency of pedestrian circulation across and around the stormwater planter should be verified with the jurisdiction's ADA Coordinator or Public Works Department.
- In shared street applications, where pedestrians are allowed and encouraged to walk in the area typically reserved for vehicle traffic, pedestrian access widths between stormwater planters shall be a minimum of 8 feet wide, and wider widths should be considered given the context and level of pedestrian activity.
- If used at an intersection, consideration should be given to using a stormwater curb extension. But if parking is not present, then a stormwater planter could be used.
- When used at an intersection, minimize curb radii on stormwater planters as much as possible while designing the project for the standard design vehicle type, turning buses on transit routes, and emergency vehicles on primary emergency routes. Generally, the corner radii should be no more than 15 feet; in downtowns or main streets, a radius of 5 to 10 feet may be appropriate.

Special Conditions Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on edge treatments and other conditions.

Roadway locations

- Where stormwater planters are set back from the street and trench drains are used to channel the runoff to the planter, trench drain grates must meet ADA requirements, and be designed to avoid catching shoe heels.

Diagonal parking locations

- May be located within the ends of or in interior spaces within a row of diagonal parking stalls. Stormwater planters can frame and buffer seating spaces and pedestrian amenities from vehicles.

Bicycle lane or route and cycle track locations

- On streets with protected bikeways or cycle tracks, the stormwater planter can be located between the bicycle lane and the travel lane as part of the buffer between cyclists and vehicles.


CD+A

▲ *Stormwater planter design, configuration, and location can vary depending upon the context and need for pedestrian circulation.*


CD+A

▲ *Stormwater planters within shared streets can manage stormwater while also providing a buffer between primary pedestrian access areas and shared spaces.*


CITY OF DALY CITY

▲ *Stormwater planters can be retrofitted into street projects to meet multiple community goals including climate resiliency and adaptation, and integration of multimodal facilities.*


CITY OF MENLO PARK

▲ *Stormwater planters located between the vehicle travel lane and cycle track provide a buffer between the different transportation models, enhancing bicyclist safety and riding comfort.*

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Curb Extensions

CD+A

General Guidance

- Where curb extensions are desired for crossings at intersections, a landscape area for stormwater treatment can be provided by extending the curb extension further along the curb line away from the intersection.
- Evaluate existing utilities during the conceptual phase as presence of existing utilities may alter the location and design of the stormwater curb extension.
- Delineate the planter edge: given that the green infrastructure area of the curb extension is typically directly adjacent to a sidewalk and/or pedestrian crossing, a curb edge or low railing can be provided to keep people from entering the planter. If a low curb edging is used, provide gaps for runoff to flow from the adjacent sidewalk or other pavement into the curb extension; refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on curb, railing, and other edge treatments.
- For corner applications, stormwater curb extension sizing must consider the turning clearance needs of the largest design vehicle and space requirements for adjacent parking and loading spaces.
- In addition to individual jurisdiction and fire department requirements, existing utility locations may also limit curb extension locations and width. It may be necessary to reduce the width of a curb extension to avoid a utility conflict.
- Generally, a minimum length of 30 feet, between inner curb radii connections, is required to accommodate a mid-block stormwater curb extension that is integrated with a mid-block pedestrian crossing. This allows for a 10-12 foot wide ramp and adequate areas for stormwater planters on both sides.

Green Streets Guidance

- If it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and cost implications of making the connection.
- Design side slopes, when used, ideally at a 4:1 slope with a maximum slope of 3:1, with a flat shelf transitioning between the curb or pavement, especially the walkway or sidewalk, and the slope. In lieu of a shelf and side slopes, a flat bottom facility can be used with an edging curb or low fence. Refer to **Section 3.1 General Design Strategies and Guidelines** for additional information regarding design of edge conditions, railings, etc.
- The preferred retention depth is 6 inches of stormwater. More depth may be needed if there are high volumes of stormwater that cannot be directed to other treatment measures, up to 8 inches deep, and in extreme cases where space within the right of way is constrained by other needs a depth of up to 12 inches can be acceptable, if approved by the jurisdiction.
- Locate inlets into curb extensions so that water does not back up and pond in the street or along the gutter.
- Curb extensions can be used as a "backstop" for capturing runoff from upstream flow along steep slope conditions with the use of check dams. When street slopes are over 2%, stormwater curb extensions need check dams. For street slopes over 5%, the interior of the curb extensions needs to be terraced and designed as a series of planters.

Locations for Stormwater Curb Extensions

Street Types		Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	●
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●
	Parkway Connector	●
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	●
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	
	Mixed Use Alley	
	Neighborhood Alley	
	Industrial Alley	
Path	Walkway	●
	Shared Use Path	●

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Curb Extensions

CD+A

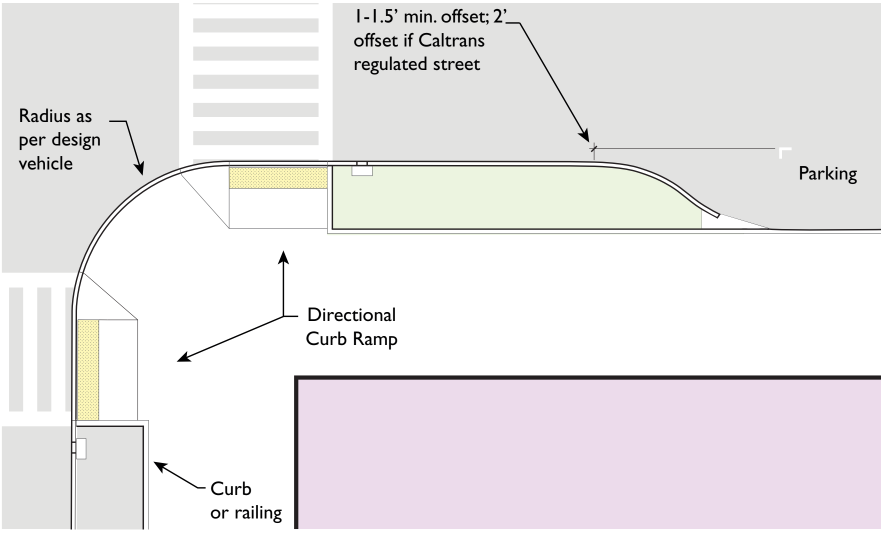
▲ *Low curb edge with gaps to allow runoff to enter bioretention area.*

CD+A

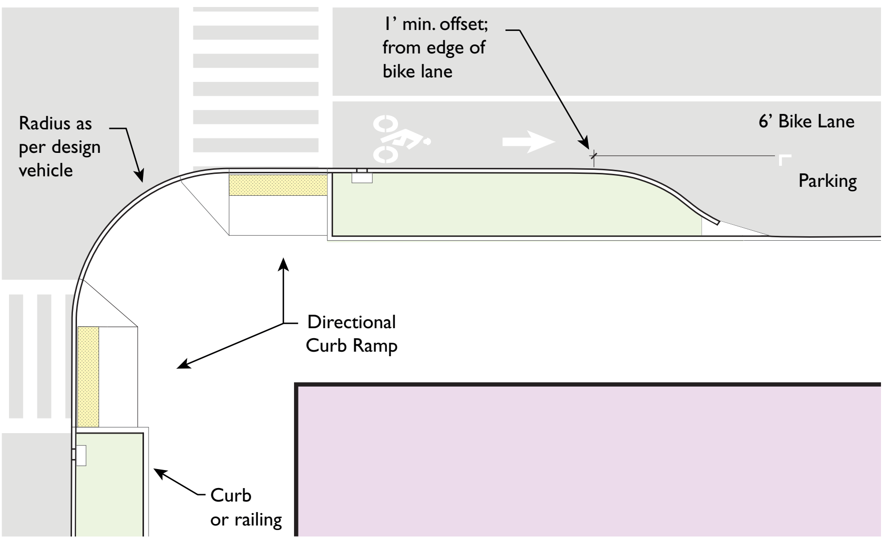
▲ *A stormwater curb extension provides attractive green space at this location between on-street parking stalls. A 2-3" rock gravel mulch helps to dissipate runoff flows on this sloping street condition.*

Complete Streets Guidance

- Curb extensions should provide at least 18 inches of additional width between the travel lane and the curb extension's curb face, resulting in a typical curb extension width of 6.5 feet; Caltrans regulated streets require 2 feet of additional width, see upper figure to the right.
- Evaluate curb extension geometry to accommodate vehicle traffic, dual curb ramps (for directional circulation of pedestrians), as illustrated in the figures to the right.
- If used at an intersection, the corner radii should typically be no more than 15 feet, in downtowns or main streets a radius of 5 to 10 feet may be appropriate. Size the radius for an appropriate design vehicle so that vehicle tires do not traverse over and into the stormwater curb extension.
- Utilize reversing curves with radii at least 15 feet inner and 10 feet outer for the transition of the curb line from the existing curb to the curb extension and paint the curb red. This design allows street sweeping machinery to collect trash and debris that accumulates in transition areas; the designer needs to verify the specific street sweeping requirements of the local jurisdiction.
- Evaluate existing driveways and on-street parking configurations during the conceptual phase, and incorporate sight distances and driveway ingress and egress, as appropriate, into the stormwater curb extension feasibility assessment.
- Minimize curb radii on stormwater curb extensions as much as possible while designing curb extensions for each jurisdiction's standard design vehicle type, turning buses on transit routes, and emergency vehicles on primary emergency routes.
- Curb extensions on designated truck routes must accommodate tractor-trailer trucks at the size designated by the local jurisdiction.
- Consider median pedestrian refuge areas where curb extensions are too constrained and cannot be used to shorten pedestrians' crossing distance.
- Curb extensions can be bridged with grates, boardwalk, or pedestrian bridges to increase space provided for pedestrian travel, seating, or other pedestrian or transit infrastructure.



Corner stormwater curb extension



Corner stormwater curb extension with bicycle lane

▲ *Curb extentions with gaps allows stormwater runoff to enter the treatment measure.*

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Curb Extensions

CD+A

▲ *Stormwater curb extensions and a median stormwater planter along with striped bike lanes have been retrofitted into this semi-rural neighborhood.*

CD+A

▲ *The stormwater curb extension adds additional landscaping for this multi-family development.*

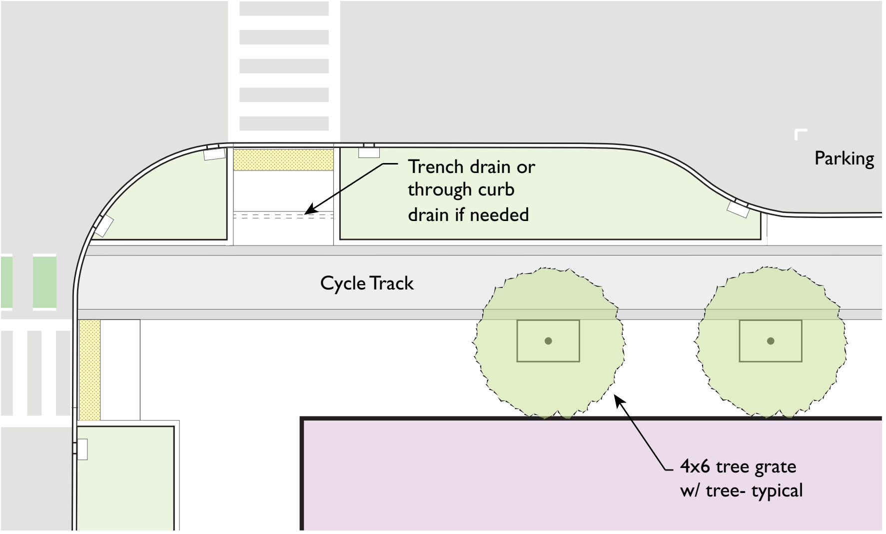
Special Conditions Guidance

Intersection locations

- Consider steel faced curbs at locations with high truck and/or bus turning traffic.
- Plants used at intersections, crossings, and cycle track buffers must meet local requirements for corner visibility regulations, sometimes referred to as sight triangle visibility.

Mid-block locations

- Curb extensions can be consolidated with landscape areas located within the landscape strip, or parkway, behind the curb to increase the area available for stormwater attenuation.
- Where on-street parking is highly utilized, small planters may be added between parking spaces to provide some stormwater treatment and complete street benefits of shading sidewalks with trees and visually narrowing the street.



Corner stormwater curb extension with raised cycle track

Mid-block locations

- Consider consolidating curb extensions with landscape areas located in the landscape strip, or parkway, behind the curb, and behind the sidewalk to increase the area available for stormwater attenuation and treatment.

Diagonal parking locations

- Curb extensions with diagonal parking need to provide a paved or otherwise walkable material step out area of a minimum of 3 feet within or next to the curb extension when the curb extension is immediately adjacent to a parking stall.
- Carefully locate any trees and other tall landscape within a curb extension to maintain needed sight lines for drivers who are pulling out of diagonal parking spaces.

Bicycle lane or route and cycle track locations

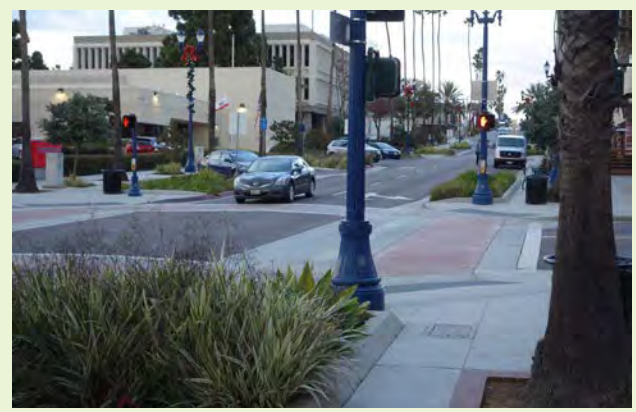
- On streets with protected bikeways or cycle tracks, the green infrastructure can be between the bicycle lane and the travel lane, see lower figure opposite page.
- Do not specify plants or place plants too close to curbs or routes that have the potential to encroach into bicycle lanes or cycle tracks.

CD+A

▲ *A stormwater curb extension with weirs was added to this sloped residential street.*

CD+A

▲ *Stormwater curb extensions are used at corners next to diagonal back-in street parking in this complete and green street retrofit project.*



CD+A

▲ *Curb extensions provide green buffer zones at this intersection and also break up parking pavement along the street.*

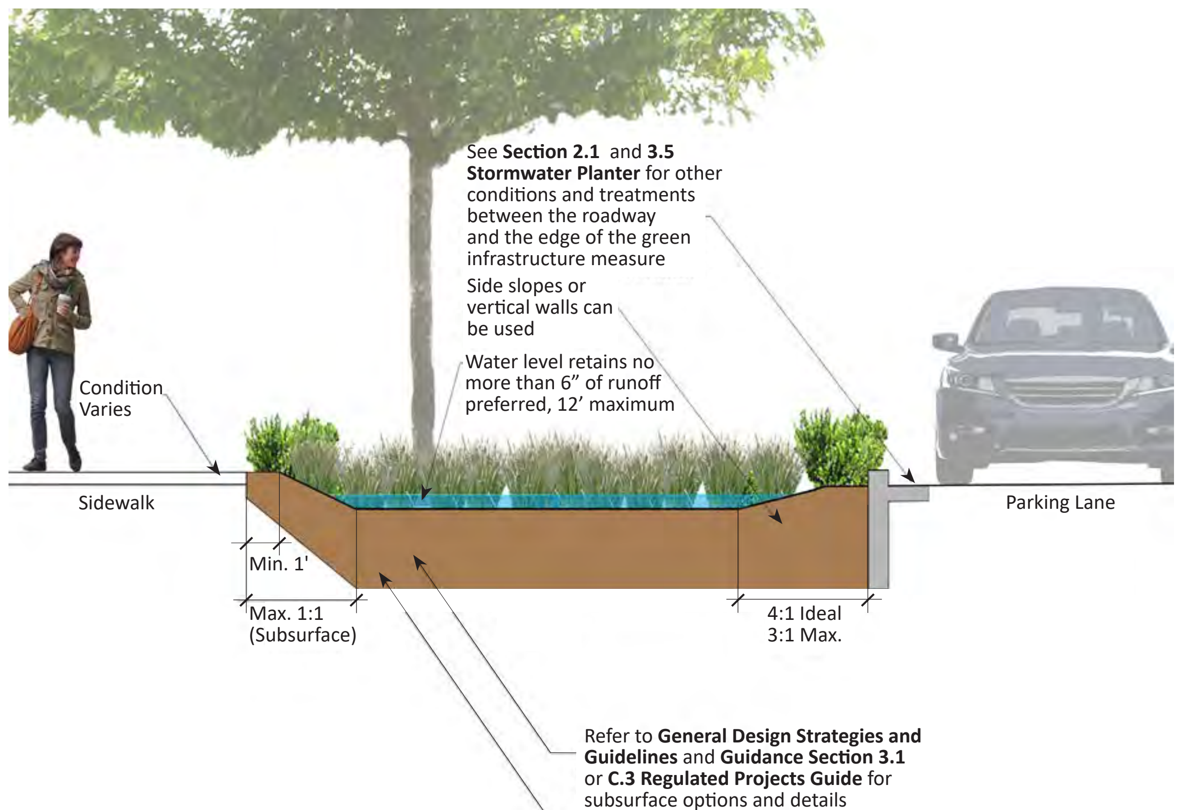
3.5 Sustainable Streets Design Strategies and Guidelines

Rain Gardens

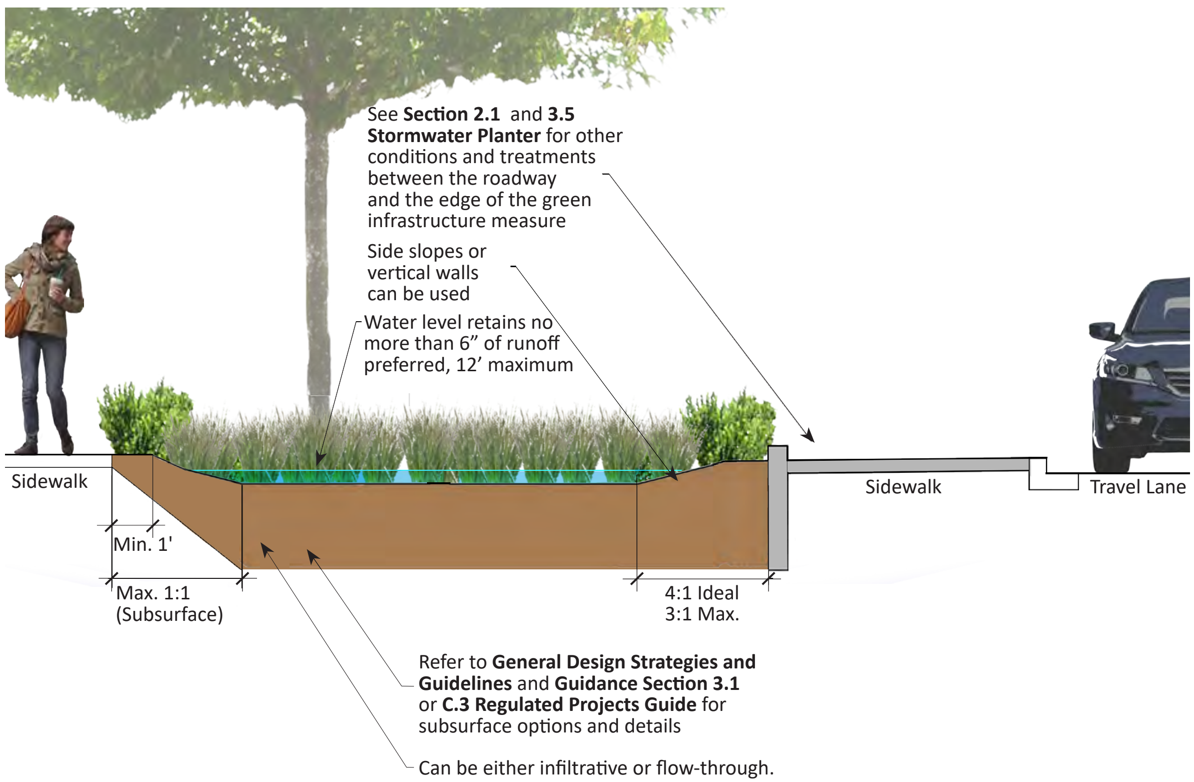
General Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on edge treatments and other considerations. Also see the general guidance from **3.5 Stormwater Planter**.

- Consider building rain gardens in the public right of way in areas that are "left over," where streets intersect at odd angles or street grids are offset from one another.
- Rain gardens can be bridged with grates, boardwalk, or pedestrian bridges to increase space provided for pedestrian travel, seating, or other pedestrian or transit infrastructure.



▲ *Typical section of rain garden*



▲ *Typical section of rain garden*

Locations for Rain Gardens

	Street Types	Viable Locations
Throughways	Downtown, Commercial or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	●
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●
	Parkway Connector	●
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	●
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	
	Mixed Use Alley	
	Neighborhood Alley	
	Industrial Alley	
Path	Walkway	●
	Shared Use Path	●

3.5 Sustainable Streets Design Strategies and Guidelines

Rain Gardens

CD+A

▲ *This street retrofit features a rain garden, a bulbout for a protected pedestrian crossing area, and two streetlights that form a gateway feature.*

CD+A

▲ *This rain garden within a street separates a "free right" turn bike lane from through bike and vehicle lanes. The rain garden could have been extended toward the viewer to provide greater runoff treatment.*

Complete Streets Guidance

- Rain garden facilities within roadways should provide at least 18 inches of additional width between the travel lane and the rain garden's curb face or planter edge if curbless; Caltrans regulated streets require 2 feet of additional width, see figure in **Section 3.5 Stormwater Curb Extension**.
- Evaluate rain garden geometry to accommodate vehicle traffic, dual curb ramps (for directional circulation of pedestrians), and other considerations as illustrated in **Section 3.5 Stormwater Curb Extension**.
- If used at an intersection, the adjacent corner radii that a vehicle will turn from should typically be no more than 15 feet, in downtowns or main streets a radius of 5 to 10 feet may be appropriate. Size the radius for an appropriate design vehicle so that vehicle tires do not traverse over and into the rain garden. Corner radii may be reduced if a bike lane is present, which allows a vehicle a wider turning area.
- Utilize reversing curves with radii at least 15 feet inner and 10 feet outer for the transition of the curb line from the existing curb to the curb extension and paint the curb red. This design allows street sweeping machinery to collect trash and debris that accumulates in transition areas; the designer needs to verify the specific street sweeping requirements of the local jurisdiction.
- Minimize curb radii on rain gardens as much as possible while designing elements within the roadway for each jurisdiction's standard design vehicle type, turning buses on transit routes, and emergency vehicles on primary emergency routes.
- Rain gardens on designated truck routes must accommodate tractor-trailer trucks at the size designated by the local jurisdiction.

Special Conditions Guidance

Roadway locations

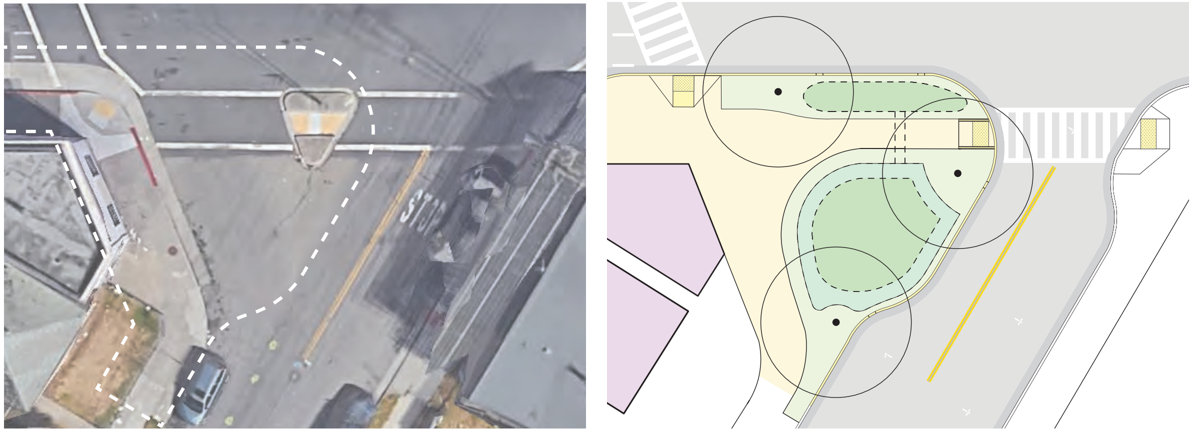
- Where rain gardens are present in features such as mini-roundabouts, islands, etc., directional signage, low fences, and any other vertical elements should set back 18 inches from the face of curb, and/or vegetation planted that is at least 6 to 12 inches taller than the curb edge should be used to provide additional visual clues to drivers to drive around the features.
- Consider consolidating rain gardens with landscape areas located within the median and other islands.

Mid-block locations

- Consider consolidating rain gardens with landscape areas located in the landscape strip, or parkway, behind the curb, and behind the sidewalk to increase the area available for stormwater attenuation and treatment.

Diagonal parking locations

- Corner curb extensions on streets with diagonal parking may provide an opportunity for a large area of green infrastructure, a hybrid rain garden curb extension. See also design guidance in **Section 3.5 Stormwater Curb Extensions.**



▲ *Diagram of how a rain garden and pedestrian space can be part of a large angled intersection retrofit project to provide green infrastructure in parallel with creating a more comfortable place for people to walk and bike.*

▲ *A variety of utilities are integrated into this rain garden.*

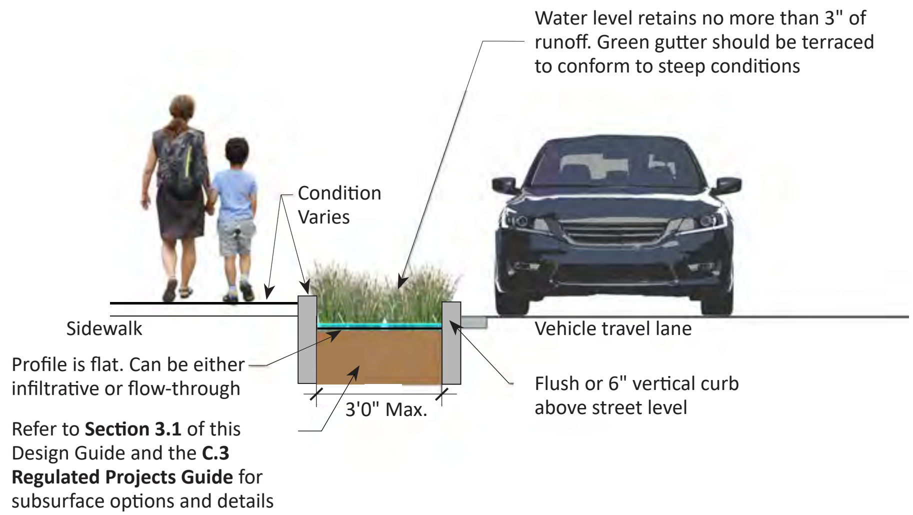
▲ *Rain gardens can provide community identity and act as a buffer for pedestrians from vehicle traffic.*

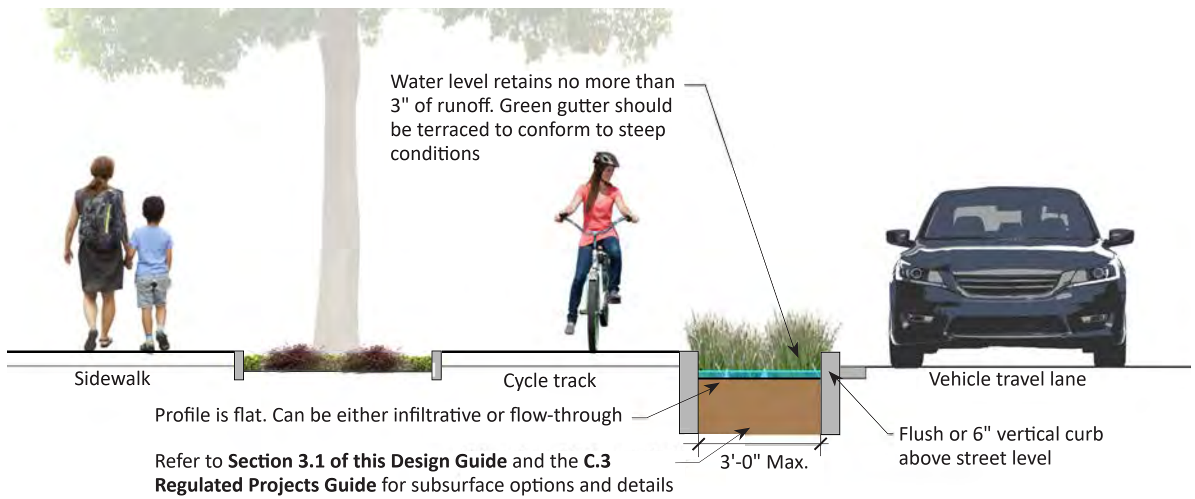
▲ *Rain gardens allow for the collection and treatment of larger runoff quantities of stormwater runoff. Runoff from a commercial parking lot and a nieghborhood multi-use path flow into this rain garden.*

3.5 Sustainable Streets Design Strategies and Guidelines

Green Gutters

Green gutters can be used in combination with different multimodal and streetscape designs, such as between a protected bikeway or a sidewalk and a vehicle lane.

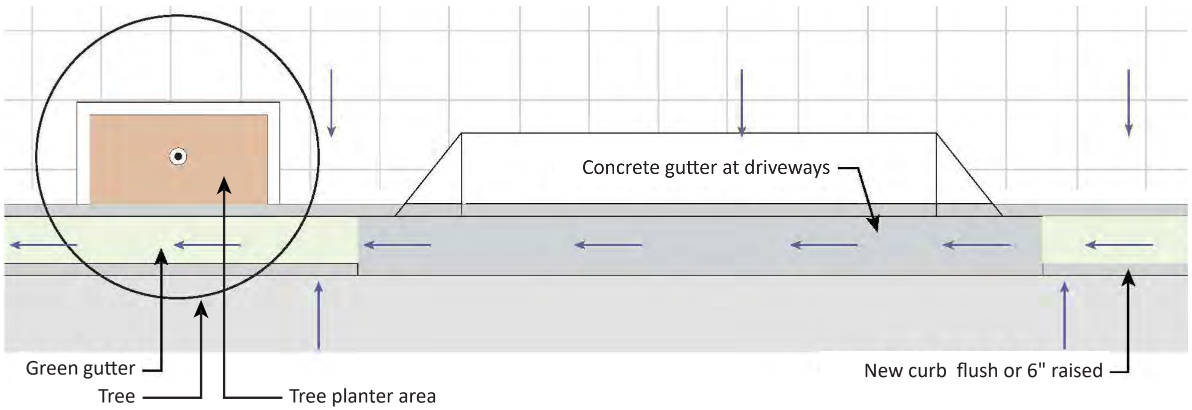




▲ *These typical sections demonstrate a range of how green gutters can be integrated into street projects.*

General Guidance

- Existing streets can often be redesigned to integrate green gutters to manage stormwater. Even where on-street parking is highly utilized there may be opportunities for green gutters.
- Travel lanes need to be wide enough to accommodate a green gutter or a parking lane may need to be removed.
- When the street includes protected bikeways, where the bicycles pass between a raised buffer and the green gutter along the sidewalk curb, designing for stormwater function is more challenging.
- Evaluate existing utilities and vehicle access and parking needs during the conceptual phase as presence of existing utilities and vehicle circulation and parking may alter the location and design of green gutters.
- Determine if the vehicle lane side of a green gutter should be raised or flush (curbless). Flush curb designs allow for sheet flow into the green gutter. A standard curb and gutter, however, can also be built with frequent curb cuts if there is a concern about vehicular traffic volumes or speeds.
- Given that green gutters are directly adjacent to a sidewalk and potentially a bicycle lane, a curb edge can be provided to keep people and bicyclist from entering it. If a low curb or raised curb edging is used, provide gaps for runoff to flow from the adjacent sidewalk or other pavement into the green gutter. Refer to **Section 3.1 General Design Strategies and Guidelines** for additional guidance on curbs and other edge treatments.



Locations for Green Gutters

Street Types		Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	●[13]
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●[13]
	Parkway Connector	●[13]
Access	Downtown Access	●
	Mixed Use Access	●[13]
	Neighborhood Access	●[13]
	Industrial Access	●[13]
	Park Access	●[13]
Alley	Downtown Alley	●
	Mixed Use Alley	●[13]
	Neighborhood Alley	●[13]
	Industrial Alley	●[13]
Path	Walkway	●
	Shared Use Path	●[13]

[13] Possible to use in Park, Semi-Rural or Rural contexts, but narrowing the street right of way in these lower intensity and open space oriented contexts is more desirable in relation to complete streets and green infrastructure goals.

3.5 Sustainable Streets Design Strategies and Guidelines

Green Gutters


NEVUE NGAN ASSOCIATES

▲ *Green gutter with weirs retrofitted into a residential street.*

- Overflow runoff can overflow into the existing storm system or is conveyed back into the street.
- Many older urban streets have a "high crown" cross section profile resulting from years of repavement with asphalt overlays, which increases the cross slope of the roadway and can make it challenging to integrate green gutters. Removal of old asphalt may be needed to install green gutters as well as may limit typical jurisdictional procedures for roadway improvements/overlays, which adds to construction cost and may limit the ability to install green gutters.
- Low vegetation is needed to maintain sight lines between vehicles and people walking or bicycling. Green gutters can be planted with a variety of low grasses and groundcovers, depending on site context and conditions. Select plants that do not need to be mown regularly.

Green Streets Guidance

- If it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and cost implications of making the connection.
- Where curbs edge a green gutter, locate curb inlets so that runoff can easily enter the green gutter.
- Locating green gutters near to and upstream of drainage inlets will help ensure that street runoff flows to the green infrastructure, because the grade of the street and gutter should already flow to the inlet.
- Permeable paving placed within the parking lane of the street or across driveway cuts could complement the green gutter and allow better management of the street's stormwater runoff.

Complete Streets Guidance

- Oversized shoulder areas may be repurposed as a bicycle lane and a green gutter.
- A green gutter along the curb line helps provide a buffer between high speed traffic and pedestrians using the sidewalk.
- Evaluate green gutter placement to accommodate vehicle traffic, circulation, and parking needs.
- Evaluate existing on-street parking configurations during the conceptual phase.

Special Conditions Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance applicable to aspects of green gutter design.

Roadway locations

- When used in areas of uncontrolled pedestrian activity, such as along a neighborhood street with few driveways, provide periodic paved or bridge crossings to allow pedestrians to cross without having to step into or over the green gutter.
- In some cases when grades allow, green gutters can be used along the median curb edge. Even when runoff does not flow towards the median, a green gutter will reduce the impervious area within the right of way.

Bicycle lane or route and cycle track locations

- On streets with protected bikeways or cycle tracks, a green gutter can be between the bicycle facility and the travel lane.


CD+A

▲ *Green gutter buffers pedestrians and cyclists from vehicles.*


CD+A

▲ *Green gutter with notched curb edging collects and treats runoff from multi-use trail and street.*

3.5 Sustainable Streets Design Strategies and Guidelines
Tree Well Filters

KEVIN ROBERT PERRY

General Guidance

- The stormwater volume of an individual or series of tree well filters can be increased with the use of infiltration trenches, structural soils, or a structural pavement support system. Structural soils and structural support systems support the sidewalk and/or adjacent curb lane and allow the soil to be compacted at a low enough level so that it can provide a biotreatment function. The lower compaction of the soil can also support improved tree health. The designer should select a soil mix and design approach to support long-term tree health.
- Delineate the planter edge:
    - When in the sidewalk – given that the green infrastructure area of the tree well filter is typically directly adjacent to a sidewalk and/or pedestrian crossing, a tree grate, curb edge or low railing can be provided to keep people from entering the planter. If a low curb edging is used, provide gaps for runoff to flow from the adjacent sidewalk or other pavement into the tree well filter.
    - When in the parking lane – given that the green infrastructure area of the stormwater tree may be in the roadway, a tree grate, curb edge or low railing can be provided to keep people from entering the planter.
    - Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on curb, railing, and other edge treatments.
- Current best practices suggest that tree root volume for new trees should be 400 - 600 cubic feet for small trees (6-inch diameter trunk), 800 - 1,000 cubic feet for medium sized trees (16-inch diameter trunk), and 1,200 - 1,500 cubic feet for large trees (24-inch diameter trunk). These are general sizing and volume recommendations that will be affected by different climatic and environmental conditions found in various parts of the county. In situations where landscape areas connect, or are shared by, two or more tree root areas, the root volume area per tree may be reduced. Tree root volumes are based on a three-foot depth planter area.

  However, in reality, these root volume areas are difficult to achieve in urban, suburban, and constrained sites. In these cases, there may be the ability to use root "channels" under pavement (small trenches or conduits of planting soil placed under pavement and connecting to larger landscaped areas), modular pavement support cells, and other techniques can be used to expand the tree root volume. It is better to base tree root volume from trunk size rather than canopy width, as many trees planted along streets are narrow in form, yet their root systems are still wide reaching.

Green Streets Guidance

- The preferred size for a tree well filter is 6-feet wide and 6-feet long, for a planter area of 36 square feet. Where sidewalk width is constrained and functional space for people walking is in high demand, the width may be 4 feet minimum and a desired length of 8 feet with a minimum of 5 feet.
- Refer to current accessibility regulations for treatment of vertical drop between the tree well filter and the adjacent accessible path of travel. Refer to **Section 3.1 General Design Strategies and Guidelines** for additional information regarding design of edge conditions, railings, etc.
- Tree well filters can be planted with a variety of trees, shrubs, grasses and groundcovers, depending on site context and conditions. Provide minimum 2-foot clearance between tree trunk and understory plants to reduce competition for water, nutrients, and root space with trees.

Complete Streets Guidance

- When a tree well filter is behind a street curb, vertical elements of the tree well filter that are more than 12 inches above the road surface shall be setback back 18 inches from the face of curb.
- In shared street applications, pedestrian access widths between stormwater planters shall be a minimum of 8 feet wide, and wider widths should be considered given the context and level of pedestrian activity.
- Evaluate existing driveways and on-street parking configurations during the conceptual phase, and incorporate sight distances, and driveway and parked vehicle ingress and egress, as appropriate.
- Tree well filters can be bridged with grates, boardwalk, or similar features to increase space for pedestrian travel, seating, or other pedestrian or transit infrastructure. Tree trunk holes of grates need to be periodically inspected and cut wider to prohibit the grate from impeding trunk growth and having the trunk grow into and around the grate.

Locations for Tree Well Filters

	Street Types	Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●
	Parkway Connector	
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	●
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	
	Mixed Use Alley	
	Neighborhood Alley	
	Industrial Alley	
Path	Walkway	●
	Shared Use Path	●

3.5 Sustainable Streets Design Strategies and Guidelines
Tree Well Filters


WWW.NACTO.ORG

▲ *Tree well filters linked by trench drain to can be edged with low curbs or railing and used with or without a tree grate.*


KEVIN ROBERT PERRY

▲ *Tree well filters within parallel parking lane enhance streetscape character while keeping the sidewalk clear for pedestrian travel.*

Special Conditions Guidance

Roadway locations

- Trees should be protected from vehicle damage with the use of a raised curb, tree guard, bollards, and/or tree grates, and adequate bumper/overhang clearances when tree well filters are used in adjacency to vehicles.

Intersection locations

- While acceptable, other green infrastructure features provide more treatment benefits and amenities. See **3.5 Stormwater Curb Extension**, for instance.

Mid-block locations

- When used adjacent to parking or loading areas, use a cast iron capped curb cut inlet to guard against vehicle tires from entering the facility and provide a place for pedestrians to step.
- Tree well filters within the right of way are typically located between the curb and sidewalk, or vehicle lane and primary pedestrian zone in shared streets, and take the place of the landscape strip, or parkway.

Diagonal parking locations

- Tree well filters with diagonal parking need to provide a paved or otherwise walkable step out area of a minimum of 3 feet within or next to the tree well filter when it is immediately adjacent to a parking stall; this dimension should be verified with jurisdiction's ADA Coordinator, see also **Section 4.2 Designing for Pedestrian Circulation**.
- When used adjacent to parking or loading areas, install cast iron capped curb cut inlet to guard against vehicle tires and provide a place to step for pedestrians.
- Carefully locate any trees and other tall landscape within the tree well filter to maintain needed sight line for drivers who are pulling out of parking spaces.

Bicycle facility locations

- On streets with protected bikeways or cycle tracks, the tree well filter can be between the bicycle lane and the travel lane.
- Do not specify plants or place plants too close to curbs or routes that have the potential to encroach into bicycle lanes or cycle tracks.

GOOGLE

▲ *These tree wells are surrounded by a low fence to prevent people from entering the planter. Planters or pavement can be used between the tree wells.*

CORALVILLE.ORG

▲ *Tree well filters with pervious paver sidewalk. Note how tree well filters transition from street adjacent to within sidewalk easily.*

3.5 Sustainable Streets Design Strategies and Guidelines

Stormwater Trees

CD+A

General Guidance

- Current best practices suggest that tree root volume for new trees should be 400 - 600 cubic feet for small trees (6-inch diameter trunk), 800 - 1,000 cubic feet for medium sized trees (16-inch diameter trunk), and 1,200 - 1,500 cubic feet for large trees (24-inch diameter trunk). These are general sizing and volume recommendations that will be affected by different climatic and environmental conditions found in various parts of the county. In situations where landscape areas connect, or are shared by, two or more tree root areas, the root volume area per tree may be reduced. Tree root volumes are based on a three-foot depth planter area.

  However, in reality, these root volume areas are difficult to achieve in urban, suburban, and constrained sites. In these cases, there may be the ability to use root "channels" under pavement (small trenches or conduits of planting soil placed under pavement and connecting to larger landscaped areas), modular pavement support cells, and other techniques to expand the tree root volume. It is better to base tree root volume from trunk size rather than canopy width, as many trees planted along streets are narrow in form, yet their root systems are still wide reaching.

- Delineate the planter edge:
  - Given that the green infrastructure area of the stormwater tree is typically directly adjacent to a sidewalk and/or pedestrian crossing, a tree grate, curb edge or low railing can be provided to keep people from entering the stormwater tree planter. If a low curb edging is used, provide gaps for runoff to flow from the adjacent sidewalk or other pavement into the curb extension.
  - Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on curb, railing, and other edge treatments.

Green Streets Guidance

- Consider placement of stormwater trees in relation to existing drainage inlets and catch basins.
- The preferred size for a tree planter is 6 feet by 6 feet providing a total of 36 square feet, and the minimum sized tree planter is 24 square feet with a minimum width perpendicular to the curb of 4 feet, and a preferred length along the curb of 6 feet.
- In retrofit situations, stormwater tree planting areas can be saw cut into existing sidewalks. In these conditions, the sidewalk width shall not be less than 4 feet wide and the stormwater tree planter width not less than 2.5 feet. Small trees shall be used when tree stormwater planting areas are sized this minimally. When 2.5 foot stormwater tree planter areas are used, the length of the planting area should be as long as possible to provide greater soil access to oxygen and water.
- Refer to current accessibility regulations for treatment of vertical drop between the stormwater tree planter and the adjacent accessible path of travel. Refer to **Section 3.1 General Design Strategies and Guidelines** for additional information regarding design of edge conditions, railings, etc.
- If turning existing street tree plantings into stormwater trees, work with an arborist to confirm the trees can tolerate proposed grading and the addition of new and/or larger amounts of water inundation.
- If higher levels of stormwater treatment are desired, the Tree Well Filter treatment measure should be used.

Locations for Stormwater Trees

	Street Types	Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	●
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●
	Parkway Connector	●
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	●
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	●
	Mixed Use Alley	●
	Neighborhood Alley	●
	Industrial Alley	●
Path	Walkway	●
	Shared Use Path	●

3.5 Sustainable Streets Design Strategies and Guidelines
Stormwater Trees


NEW YORK CITY DEPARTMENT OF ENGINEERING

▲ *Stormwater trees can have one or two inlets/outlets depending upon the amount of runoff to be captured and the grading and drainage design.*


NEW YORK CITY DEPARTMENT OF ENGINEERING

▲ *This stormwater tree has two inlet/outlets which allows excess runoff to flow out of the planter and down the gutter to drop into an inlet.*

Complete Streets Guidance

- When used in a parking lane, stormwater trees should provide at least 18 inches of additional width between the travel lane and the stormwater tree planter curb face, resulting in a typical stormwater tree planter area width of 6.5 feet in an 8 foot wide parking lane; Caltrans regulated streets require 2 feet of additional width, see figure in **3.5 Stormwater Curb Extensions**.
- Evaluate existing driveways and on-street parking configurations during the conceptual phase, and incorporate sight distances and driveway ingress and egress, as appropriate, into the stormwater tree feasibility assessment.


NYC WATER/FLICKR

▲ *Stormwater trees increase a community's urban forest while also achieving stormwater management goals.*

Special Conditions Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance applicable to aspects of stormwater tree design.

Roadway locations

- Provide protection from vehicle damage such as adequate bumper/overhang clearances; and use of curbs, bollards, tree grates, or tree guards.

Mid-block locations

- When located adjacent to parking or loading areas, use a cast iron capped curb cut inlet to guard against vehicle tires and provide a place to step for pedestrians.

Diagonal parking locations

- Stormwater trees used with diagonal parking need to provide a paved or otherwise walkable material step out area of a minimum of 2 feet within or next to the tree planter area when it is immediately adjacent to a parking stall.
- When placed adjacent to parking or loading areas, use a cast iron capped curb cut inlet to guard against vehicle tires and provide a place to step for pedestrians.
- Carefully locate any trees and other tall landscape within the stormwater tree planting area to maintain needed sight lines for drivers who are pulling out of parking spaces.
- Provide protection from vehicle damage such as adequate bumper/overhang clearances; and use of curbs, bollards, tree grates, or tree guards.

ACTREES.ORG

▲ *Stormwater tree planters can vary in length, but are typically shorter than this example. Note that this example uses metal capped inlets to keep vehicle tires from entering the planter.*

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

▲ *A variety of plants can be used compatibly with the stormwater tree.*

3.5 Sustainable Streets Design Strategies and Guidelines

Infiltration Systems

General Guidance

- Infiltration systems surfaced with gravel or landscape need to be protected from being disturbed or compacted by vehicle traffic and other activities.
- Evaluate existing utilities during conceptual design as presence of existing utilities may alter the location and design of infiltration systems.
- Confirm the type and design of the infiltration system and/or structure, base, and subbase used can support the weight load requirements of vehicle traffic placed above the system.

Green Streets Guidance

- Always use a landscaped green infrastructure measure such as a rain garden or stormwater planters, unless otherwise allowed by local jurisdiction, in combination with infiltration systems. The landscaped green infrastructure removes sediments and debris, and treats pollutants before the stormwater flows into the infiltration system.

Complete Streets Guidance

- Evaluate existing driveways and on-street parking configurations during the conceptual phase, and incorporate vehicle access, pedestrian access, and driveway ingress and egress, as appropriate, into the feasibility assessment.
- Pavement covered infiltration trenches or basins shall be provided where pedestrians are to queue and/or cross a street.

Special Conditions Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance applicable to aspects of infiltration system design.

Roadway locations

- Provide protection from vehicle damage as warranted in rural situations where no raised curb is provided.

Roadway and Sidewalk locations

- When infiltration systems are placed under pedestrian and bicycle improvements, utility covers need to be selected and placed to maintain a safe walking and cycling surface for all users and to meet ADA requirements.

CD+A

▲ *Infiltration trench placed behind sidewalk within the right of way.*

Locations for Infiltration Systems

Street Types		Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	●
	Neighborhood or Industrial Throughway	●
	Parkway	●[14]
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	●
	Neighborhood or Industrial Connector	●[14]
	Parkway Connector	●[14]
Access	Downtown Access	●
	Mixed Use Access	●[14]
	Neighborhood Access	●[14]
	Industrial Access	●[14]
	Park Access	●[14]
Alley	Downtown Alley	●
	Mixed Use Alley	●[14]
	Neighborhood Alley	●[14]
	Industrial Alley	●[14]
Path	Walkway	●
	Shared Use Path	●[14]

[14] *Applicable for infiltration trenches. For subsurface infiltration systems, it is possible to use in Park, Semi-Rural or Rural contexts, but there are likely more cost-effective alternatives.*

CD+A

3.5 Sustainable Streets Design Strategies and Guidelines

Pervious Pavement

Green Streets Guidance

- Complement other green infrastructure measures such as stormwater planters and stormwater tree well filters by linking a series of measures together with pervious pavement as well as expand the area of stormwater management, depending on site context and conditions.
- Consider the use of pervious pavement panels adjacent to or over tree planting areas to increase oxygen/water access to tree roots and infiltrate stormwater runoff.

CD+A

▲ *Porous asphalt panels (outlined in red) placed adjacent to this tree planter creates a walkable surface that also enables oxygen and water/runoff access to the tree's roots. Some of the trees along this street are also supported by a modular suspension pavement system which provides stormwater runoff treatment and management as well as an improved tree planting environment.*

Complete Streets Guidance

- Confirm with responsible jurisdiction that the type of pervious pavement desired is acceptable in the type of use and the jurisdiction's ability to maintain the pavement type.
- If pervious pavers are used, follow ADA requirements related to offsets between paver heights, widths, etc.; and verify approach with local ADA Coordinator.
- Pervious pavement on designated truck routes, in areas of higher traffic volumes, or vehicle weight must be designed for these factors.
- Consider different colors, textures, and materials to aid in traffic calming in street applications.
- Pervious pavements adjacent to and over tree plantings can expand pedestrian walking and loading zones while allowing for stormwater runoff infiltration and enhance tree root growing conditions.

GOOGLE STREET VIEW

▲ *This is a retrofit project in which the street was redesigned to drain to the center permeable paver median and to the curbs with tree wells designed with a modular suspended pavement system.*

Locations for Pervious Pavement

	Street Types	Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	● [15]
	Neighborhood or Industrial Throughway	● [15]
	Parkway	● [15]
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	● [15]
	Neighborhood or Industrial Connector	● [15]
	Parkway Connector	● [15]
Access	Downtown Access	●
	Mixed Use Access	●
	Neighborhood Access	● [15]
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	●
	Mixed Use Alley	●
	Neighborhood Alley	●
	Industrial Alley	
Path	Walkway	●
	Shared Use Path	●

[15] *Use pervious pavement only in parking lanes, shoulders, and medians.*

3.5 Sustainable Streets Design Strategies and Guidelines

Pervious Pavement

Special Conditions Guidance for Pervious Pavement

Refer to **Section 3.1 General Design Strategies and Guidelines** for guidance applicable to aspects of pervious pavement design.

Roadway locations

- When pervious pavers are used, consider how markings and striping for lanes, bicycle facilities, and other features will be delineated.
- Ensure Class 2 Perm base and pervious pavements are placed correctly, especially in utility trenches to limit the amount of settlement and displacement.
- Consider combining deepened aggregate bases, use of subsurface infiltration, and linking to tree well filters and other measures to increase the amount of runoff captured and treated.
- Consider use of pervious pavements in raised medians and other islands to reduce impervious surfaces, even if the elements are undersized to meet regulated projects credits.

CD+A

CD+A

▲ *This is a retrofit project in which a wide street was narrowed to add stormwater planters and permeable pavers for the sidewalk, step out area along the curb, and driveways within the improved right of way area.*

CD+A

▲ *Porous rubber panels over tree planter areas allow for a walking surface, especially in active curb areas, and runoff infiltration and improved tree health.*

CD+A

▲ *Pervious concrete placed over this tree well allows for both a walkable surface and runoff infiltration.*

Intersection locations

- When pervious pavers are used, consider how markings and striping for lanes, bicycle facilities, and other features will be delineated.

Bicycle lane or route and cycle track locations

- Pervious materials can be used in bicycle facilities on- or off-roadways and can be the buffer/divider between the bicycle facility and the vehicle travel or parking lane.

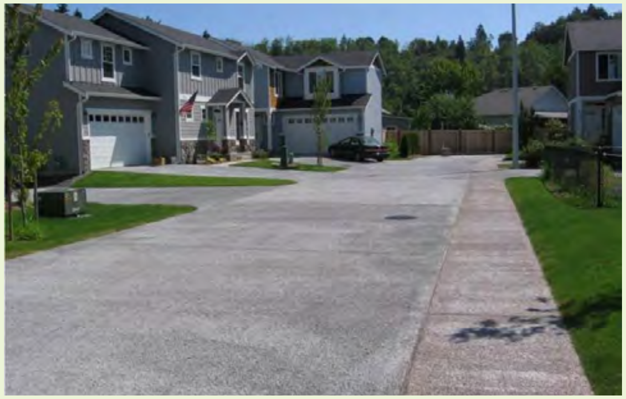
BAY AREA PERVIOUS CONCRETE

▲ *The parking lane in this San Francisco residential street is being retrofitted with pervious concrete.*

BAY AREA PERVIOUS CONCRETE

▲ *This pervious concrete sidewalk is being retrofitted along El Camino Real in South San Francisco.*

GOOGLE STREETVIEW

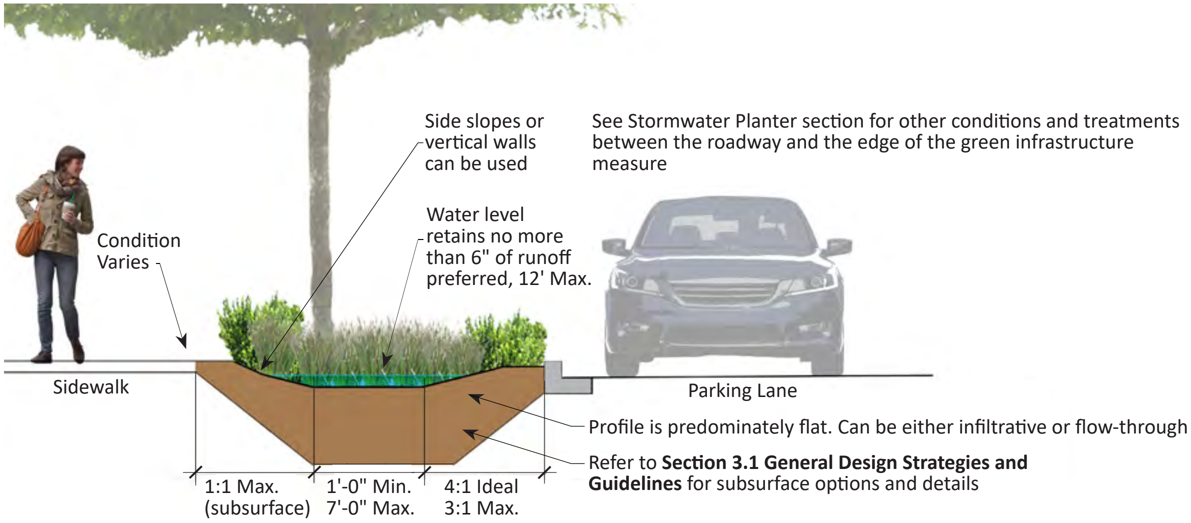


BAY AREA PERVIOUS CONCRETE

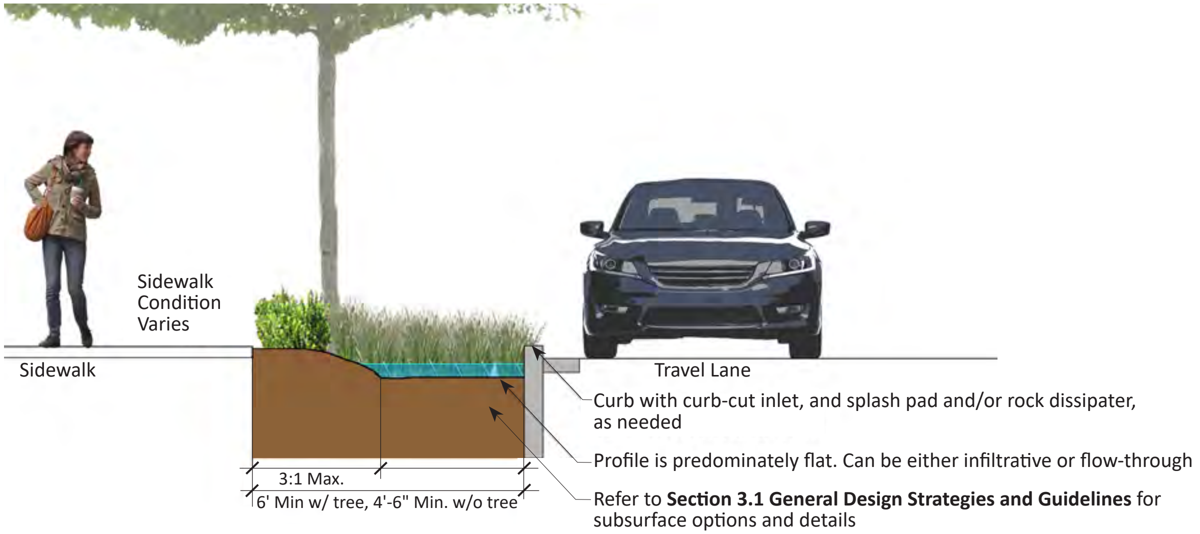
▲ *Pervious pavements such as pervious concrete can be used in different land uses and street types. Different colored pavements can be used to define pedestrian and vehicular spaces.*

3.5 Sustainable Streets Design Strategies and Guidelines

Vegetated Swales



▲ *This vegetated swale illustrates a design option for streets with wider sidewalks and on-street parking where a vegetated swale with two sloping sides and a curbside step-out space along parked cars can be accommodated.*



▲ *Typical vegetated swale in a constrained right of way. This concept shows a design option in locations where less space is available and no step-out space is required.*

General Guidance

- Evaluate existing utilities during the conceptual phase as presence of existing utilities may alter the location and design of the vegetated swale.
- Consider roadway profile and grades to ensure that stormwater will flow into and along vegetated swales. This is especially true for vegetated swales in center medians, which are typically the high point of roadways.
- Use in conjunction with other measures to form a treatment train to achieve compliance with regulated projects regulations.
- Where space permits and in more rural and suburban contexts, consider vegetated swale edges having a short flat bench along the pedestrian or bicycle facility and a low gradient slope leading to the bottom of the vegetated swale.
- Depending upon the location, depth of vegetated swale, and context, vegetated swales can be curbless or have a curb surround. Alternatives for delineation of the vegetated swale edge:
- The vegetated swale edge should generally have a curb to keep people and vehicles from entering the vegetated swale. Provide gaps in the curb for runoff to flow from the adjacent street, sidewalk, or other pavement into the vegetated swale. Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance on curb and other edge treatments.
- At the discretion of the jurisdiction's traffic engineer, the vegetated swale edge can be curbless, with a flat area leading to a low slope gradient planted with low to medium height vegetation when it is adjacent to a travel lane with low volumes of traffic traveling at slower speeds or a sidewalk or bicycle facility with lower levels of activity.
- Side slopes should be designed at a 4:1 slope with a maximum allowed slope of 3:1, with a 12-inch flat shelf transitioning between the curb or pavement and the slope when used adjacent to a parking lane, bicycle facility, or sidewalk.

Locations for Vegetated Swales

	Street Types	Viable Locations
Throughways	Downtown, Commercial, or Mixed Use Throughway	
	Neighborhood or Industrial Throughway	●
	Parkway	●
Connectors	Downtown, Mixed Use, Commercial, or Urban Industrial Connector	
	Neighborhood or Industrial Connector	●
	Parkway Connector	●
Access	Downtown Access	
	Mixed Use Access	
	Neighborhood Access	●
	Industrial Access	●
	Park Access	●
Alley	Downtown Alley	
	Mixed Use Alley	
	Neighborhood Alley	
	Industrial Alley	
Path	Walkway	
	Shared Use Path	●

CHAPTER 3

3.5 Sustainable Streets Design Strategies and Guidelines

Vegetated Swales

CD+A

▲ *The landscape area behind the curb has been designed as a gentle swale to capture, infiltrate low flows, and direct runoff off the street.*

CD+A

▲ *Native grasses and oaks are used along a curbless street and in a vegetated swale to mimic a natural landscape.*

General Guidance

- Vegetated swales can be used in both relatively flat conditions or steeper conditions up to a 5% longitudinal slope. For swales above a 2% slope, check dams or terraces should be used to help slow the flow of water. For street slopes over 5%, the interior of the vegetated swale needs to be terraced and designed as a series of planters.
- Where vegetated swales are immediately adjacent to the roadway, the bottom of the vegetated swale should be kept as high as possible; however, it is recognized that the bottom elevation may need to be designed to accept stormwater runoff from existing storm drain pipe outlet elevations.
- If recognition as a treatment measure is desired, consider using a stormwater planter instead.

Green Streets Guidance

- While vegetated swales are primarily conveyances features, they can detain and infiltrate low flows and can be designed to infiltrate some higher flows.
- If it is not possible to infiltrate given soil or other conditions, verify the ability to connect to a storm drain line and the cost implications of making the connection.
- The preferred retention depth is 6 inches of stormwater. More depth may be needed if there are high volumes of stormwater that cannot be directed to other treatment measures and where space within the right of way is constrained by other needs. A maximum depth of up to 12 inches can be acceptable, if approved by the jurisdiction's engineer.

Complete Streets Guidance

- Evaluate existing roadways, pedestrian and bicycle facilities, and landscape area configurations during the conceptual phase, and incorporate sight distances and driveway ingress and egress, as appropriate, into the vegetated swale feasibility assessment.
- The context and depth of the swale shall be considered in determining the separation of the swale from the travel or parking lanes, and if a curb or curbless edge condition is appropriate. Where parking is located adjacent to a vegetated swale, a minimum 4 foot flat area should be provided before the swale slopes down.

Special Conditions Guidance

Refer to **Section 3.1 General Design Strategies and Guidelines** for detailed guidance applicable to many of the green infrastructure measures.

Roadway locations

- Provide regularly spaced pedestrian access bridges over vegetated swales between car stalls or a street and a sidewalk or pathway. This will limit the amount of people crossing through the green infrastructure measure and causing potential damage to it. Frequency of crossings is dependent upon the level of activity and as needed per the adjacent uses. Vegetated swales can be bridged with grates, boardwalk, or pedestrian bridges to increase space provided for pedestrian travel, seating, or other pedestrian or transit infrastructure.

Bicycle lane or route and cycle track locations

- On streets with buffered bikeways or cycle tracks, vegetate swales can be installed between the bicycle lane and the travel lane, see figure in **Section 3.5 Stormwater Curb Extension**. Vegetated swales have limited application in narrow and/or shorter locations.


GRANDRAPIDSMI.GOV

▲ *This example uses stormwater planters instead of vegetated swales to gain treatment credits. The planters step down a gradual slope with check dams and are installed along the shoulder of a road, maintaining the rural character of the area.*


LAND8.COM/CANNON

▲ *Rocks and rail track are used to slow runoff while adding character. Periodic pedestrian bridges and culverts at intersections are provided to allow crossing of the vegetated swale.*


HARRISON DESIGN

▲ *Vegetated swale provides a buffer to pedestrians walking along the street from vehicle traffic. Periodic pedestrian bridge crossings could be provided to improve this design.*

3.6 Sustainable Streets Design Examples

Introduction

The sustainable streets design scenarios presented in this chapter illustrate different ways that stormwater planters, rain gardens, pervious paving, and stormwater curb extensions can be applied to the variety of street types, land uses, complete street elements, and other conditions found in San Mateo County. The examples are just a sampling of the many opportunities that exist. Designers, engineers, and developers are encouraged to adapt these examples to best fit the needs and conditions of their own projects.

Several “before and after” sketches show the potential for sustainable streets retrofit opportunities in San Mateo County. The goal of illustrating multiple design strategies is to give the user of this guide a broad range of design applications that can be similarly reproduced throughout the county. The examples shown are for reference only and are not actual projects. Whether a particular site is located in a residential neighborhood, a commercial “main street” district, or along a thoroughfare, there are multiple stormwater design options and corresponding complete street elements available.

The table on the following page lists design examples provided in this chapter including their street, land use, and context types, as well as the green infrastructure measure that is being illustrated in the retrofit of the existing street. Other green infrastructure measures may be feasible within these streets given their street, land use, and context types. The combinations of appropriate green infrastructure measures are described in **Chapter 3** of this guide, and specifically in **Tables 3.4 e, f, and g**.

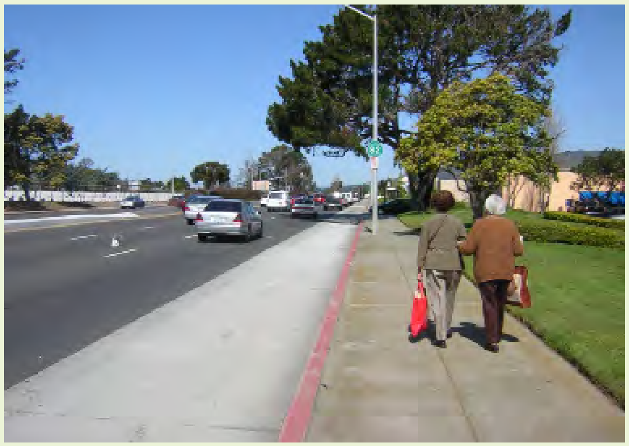
Design Examples

The design examples provided in this chapter are as follows:

No.	Street Type	Land Use Type	Context Type	Green Infrastructure Measure
1	Throughway	Commercial	Suburban	Stormwater Planter
2	Throughway	Commercial	Urban	Stormwater Curb Extension
3	Connector	Mixed Use	Urban	Pervious Pavement/ Stormwater Curb Extension
4	Throughway	Mixed Use	Urban	Tree Well Filter
5	Parkway	Neighborhood	Rural	Terraced Stormwater Planter/ Stormwater Curb Extension
6	Connector	Mixed Use	Urban	Stormwater Curb Extension
7	Connector	Mixed Use	Urban	Stormwater Planter
8	Connector	Neighborhood	Suburban/ Semi-rural	Rain Garden
9	Access	Industrial	Suburban	Stormwater Curb Extension
10	Access	Neighborhood	Suburban	Pervious Pavement
11	Access	Neighborhood	Suburban	Stormwater Curb Extension
12	Access	Neighborhood	Suburban	Stormwater Curb Extension
13	Alley	Commercial/ Mixed Use	Suburban	Stormwater Planter/ Pervious Pavement
14	Alley	Neighborhood	Suburban	Pervious Pavement


CD+A

3.6 Sustainable Streets Design Examples



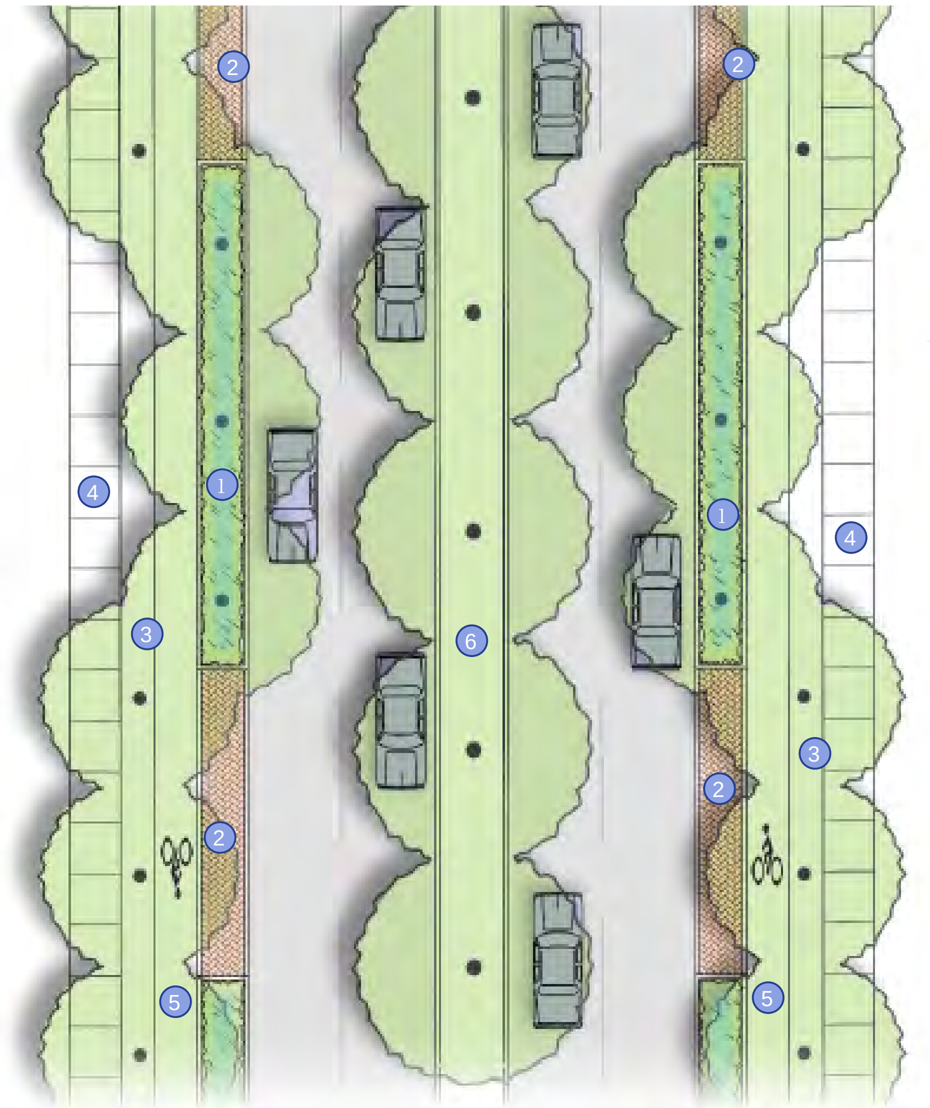
▲ *EXISTING: A typical multi-lane throughway's under-utilized paved shoulder in San Mateo County.*

▲ *EXAMPLE: Pavement materials and colors distinguish raised two-way cycle track and adjacent sidewalk. Landscape buffer from plaza and street.*

Commercial Throughway with Stormwater Planters and Protected Cycle Track

In some conditions along throughways, there is extra paved shoulder space that can be converted into stormwater planters or curb extensions. Depending on how much space there is, it is also possible to introduce a new bike lane or separated cycle track, also known as a protected bike lane, next to the stormwater facilities. Using such an approach helps reinforce the concept of providing more comfortable and family-friendly alternative transportation facilities in concert with managing stormwater runoff treatment. The illustration below showcases this green streets and complete concept.

▲ *RETROFIT OPPORTUNITY: The same street retrofitted with a series of stormwater planters and pervious pavement, a separated cycle track, and additional street trees.*



NEVUE NGAN ASSOCIATES

Key Design Elements

1. Stormwater planters are placed periodically to capture runoff from the roadway.
2. Pervious paving is used in-between stormwater planters.
3. Conventional landscape strip with street trees.
4. Sidewalk.
5. Buffered and protected bike lanes/cycle track.
6. Conventional center landscape median.

CD+A

▲ *EXAMPLE: Raised two-way cycle track and adjacent sidewalk separated from street by landscaping and stormwater attenuation.*

3.6 Sustainable Streets Design Examples

Commercial Throughway with Stormwater Curb Extensions

Along busy throughways, converting some on-street parking into stormwater curb extensions provides room for green space and street trees, and provides a buffer between pedestrians and moving vehicles. This newly introduced landscape area next to the sidewalk can help buffer pedestrians from high-speed traffic, as well as treat stormwater runoff. Green infrastructure measures can be included with curb extensions that provide space for bus stops; these types of facilities are referred to as bus bulbs. Where streets are wide enough, bike lanes can be striped. In other cases, road diets, or lane reductions, can be implemented to provide bicycle and other improvements where none exist or to create a more comfortable experience to walk and cycle on the street.

NEVUE NGAN ASSOCIATES

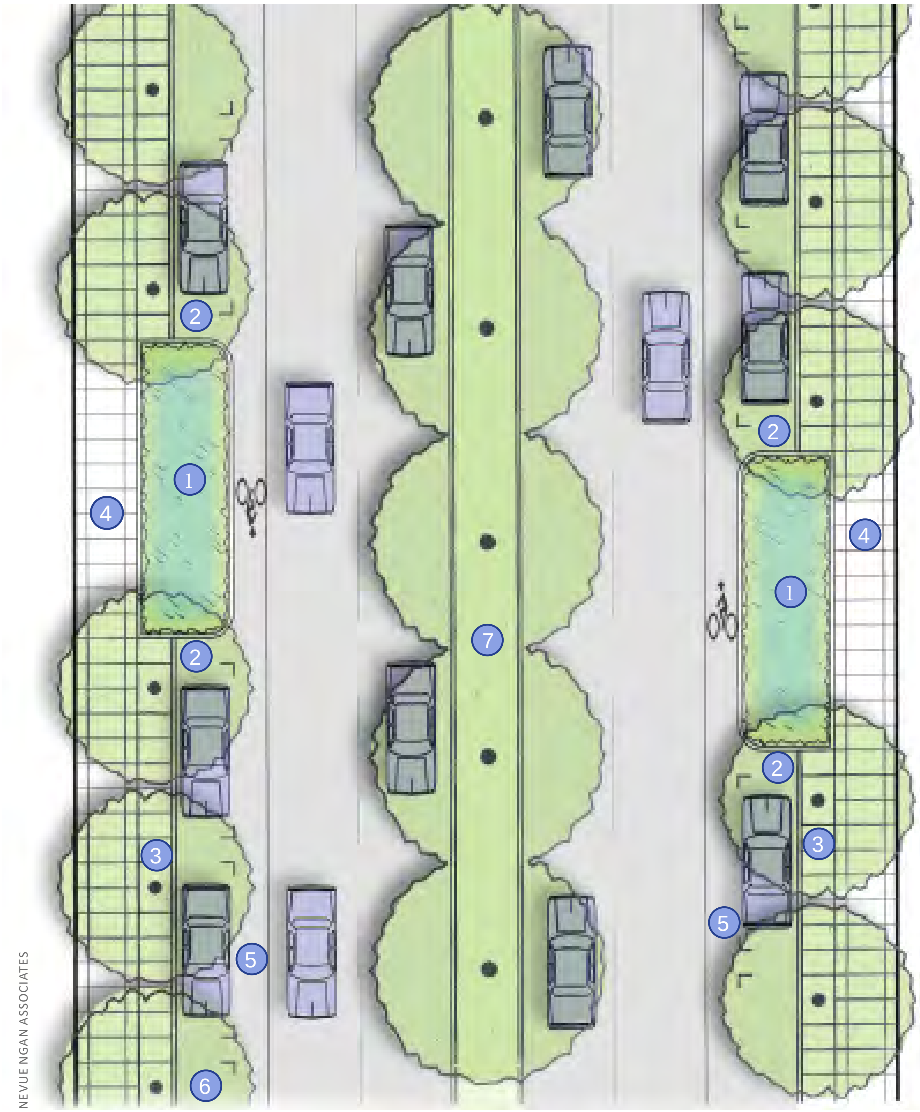
▲ *EXISTING: A typical multi-lane throughway roadway and sidewalk in San Mateo County.*

CD+A

▲ *EXAMPLE: A stormwater curb extension extends along the entirety of the street, treating stormwater and buffering pedestrians from vehicle and bicycle traffic.*

NEVUE NGAN ASSOCIATES; COMPLETE STREETS IMPROVEMENTS CD+A

▲ *RETROFIT OPPORTUNITY: The same street retrofitted with a stormwater curb extension in the parking zone. In this example a low-profile railing has also been added to the streetscape to keep people from entering the planter.*



Key Design Elements

1. Stormwater curb extensions can incorporate the street's planter strip or can be narrower by leaving the existing curb intact.
2. Curb cuts allow runoff to enter/exit the stormwater facility.
3. Conventional landscape strip with street trees.
4. Sidewalk.
5. Bike lane.
6. On-street parking.
7. Conventional center landscape median.

▲ *EXAMPLE: Stormwater curb extensions can aid to calm traffic and reduce pedestrian crossing widths while also accepting stormwater from the street. This stormwater curb extension could have been designed to be wider.*

3.6 Sustainable Streets Design Examples


NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical commercial main street with on-street parking in San Mateo County.*


CD+A

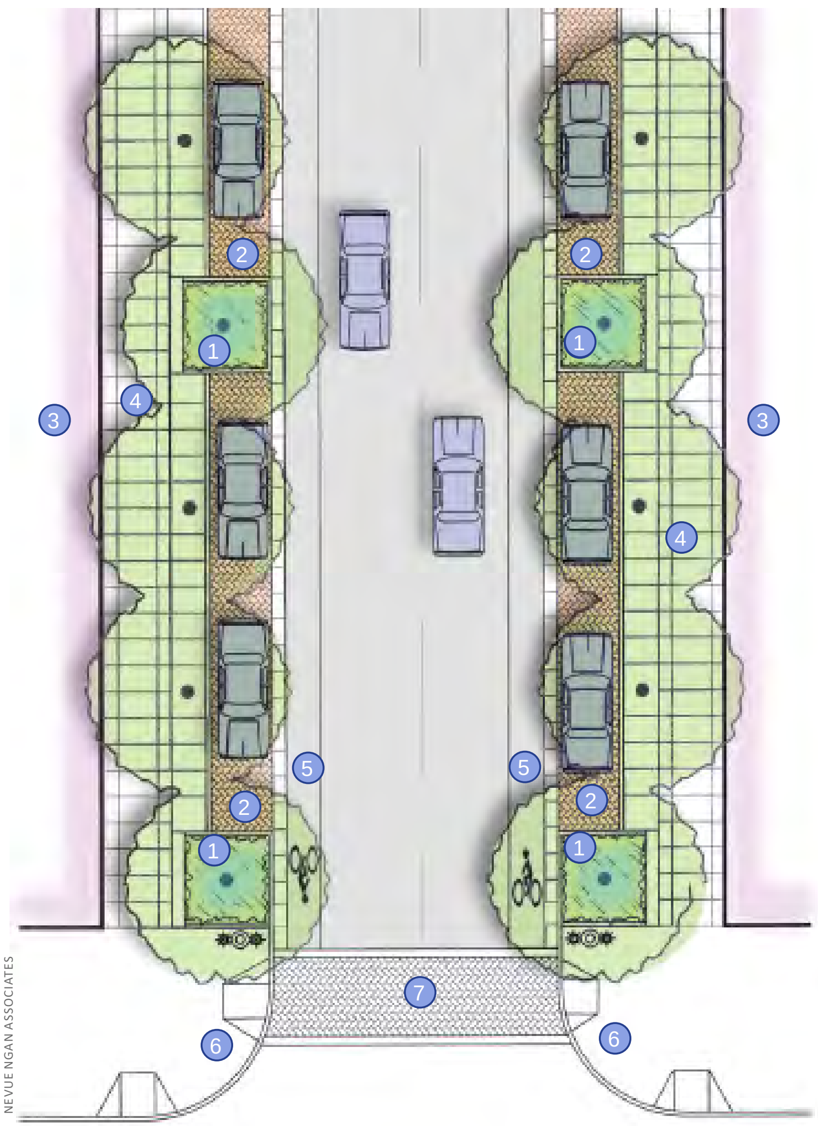
▲ *EXAMPLE: A combination of pervious pavement and stormwater trees adjacent to the parking lane maximize both space efficiency and stormwater management.*

Mixed Use Connector with Pervious Pavement

This example shows pervious paving combined with mid-block and corner stormwater curb extensions in the parking lane. Combining pervious paving with short curb extensions allows for maximum stormwater management with minimal parking loss. For this example, the curb extensions are built as stormwater planters with vertical walls instead of having a defined side slope. It should be noted that the vehicle lane appears wide, and the addition of a bike lane should be considered to help calm traffic and provide a designated bike facility.


NEVUE NGAN ASSOCIATES; COMPLETE STREETS IMPROVEMENTS, CD+A

▲ *RETROFIT OPPORTUNITY: The same commercial street with a combination of stormwater curb extensions and pervious paving in the parking lane.*



Key Design Elements

1. Stormwater curb extensions can incorporate the street's planter strip, be narrower by leaving the existing curb intact, or expand to abut ADA ramp.
2. On-street parking zone with pervious paving.
3. Building frontage.
4. Sidewalk.
5. Bike lane.
6. Accessible ADA ramps at street intersection.
7. Curb extensions narrow the pedestrian crossing distance, but allows bicycle and vehicular traffic.

▲ *EXAMPLE: This urban street uses pervious paving in its parking lane and could have been further refined with stormwater curb extensions.*

3.6 Sustainable Streets Design Examples

NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical multi-lane thoroughfare in San Mateo County.*

GOOGLE

▲ *EXAMPLE: This street uses tree well filters linked with pervious paving or landscape areas.*

Mixed Use Throughway with Tree Well Filters

Street trees can aid in reducing the perceived width of throughway to calm traffic, as well as reduce heat island effect, and buffer pedestrians from fast moving traffic. The use of tree well filters can add a water quality infrastructure component to trees along streets. Tree well filters can be placed where there is space to maintain an adequately sized clear sidewalk space for the amount of people walking along the street. To expand stormwater treatment and storage and provide improved tree root area, the use of modular suspended pavement systems or linked tree well filters should be considered. The addition of bike lanes or road diets should be considered as part of street improvements to improve pedestrian and bicyclist comfort and safety.

CD+A

▲ *RETROFIT OPPORTUNITY: The same commercial street with tree well filters to capture and treat stormwater runoff and bike lanes to define space for cyclists.*

Neighborhood Connector Street with Terraced Stormwater Planters and Stormwater Curb Extensions

Often, rural connectors are designed with no curb or with gutters that double as mini-swales to collect and direct stormwater. Not only do impervious surfaces contribute to the runoff, but rolling hillsides and steep terrain where rainfall cannot fully infiltrate into the soil can also concentrate runoff. Where a street is adjacent to open space is an ideal location for a stormwater planter with check dams to collect both impervious and open space flows. Stormwater curb extensions within parking lanes can also collect and treat stormwater while providing traffic calming and a buffer between pedestrians and motorists and adding to the landscaped character of the surrounding rural open space context.

CD+A

▲ *RETROFIT OPPORTUNITY: The same street with a combination of terraced stormwater planters and stormwater curb extensions.*

CD+A

▲ *EXISTING: A typical rural residential street in San Mateo County.*

NEVUE NGAN ASSOCIATES

▲ *EXAMPLE: This neighborhood connector incorporates a stormwater curb extension with check dams to reduce velocities on a sloping street.*

CHAPTER 3

3.6 Sustainable Streets Design Examples

NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical multi-lane mixed use connector in San Mateo County.*

CD+A

▲ *EXAMPLE: Stormwater curb extensions in middle and at end of diagonal parking row.*

Mixed Use Connector with Stormwater Curb Extension in Angled Parking

Angled parking along mixed use main streets and connectors is very common in San Mateo County. To develop a green street, one or more parking spaces flanking intersections and driveways, and along the block can be retrofitted into a stormwater curb extension. This is a relatively simple retrofit application if parking can be removed. Converting angled parking spaces into curb extensions adds more landscaping to the street, which can also enhance the aesthetics of storefront businesses and entice shoppers to come to and spend time along the street. Curb extensions can also provide space for bus stops, parklets, and other pedestrian oriented spaces. Back in angled parking could be considered prior to implementing permanent stormwater planters as this configuration allows drivers to better see on-coming cyclists.

NEVUE NGAN ASSOCIATES; COMPLETE STREETS IMPROVEMENTS CD+A

▲ *RETROFIT OPPORTUNITY: The same mixed use connector street with two angled parking stalls converted into a stormwater curb extension.*

Key Design Elements

1. Stormwater curb extensions can incorporate the street's planter strip, be narrower by leaving the existing curb intact, or expand to abut the ADA ramp.
2. Curb cuts allow runoff to enter/exit the stormwater facility.
3. Conventional landscape strip with street trees.
4. Sidewalk.
5. Small alcoves for pedestrian seating.
6. Accessible ADA ramps at street intersection.
7. Curb extensions narrow the pedestrian crossing distance, but allow vehicular travel.
8. Step out area can be flush with parking stall or raised on an island.

▲ *EXAMPLE: This main street retrofit consolidated a few parking spaces and incorporated an angled stormwater curb extension.*

CHAPTER 3

3.6 Sustainable Streets Design Examples

Mixed Use Connector with Stormwater Planter along Parking Lane

Stormwater planters can be added between the outside edge of the sidewalk and the curb, while retaining on-street parking. Pedestrian circulation between parked vehicles and frontage uses can be accommodated by creating walkways in between the planters and a pedestrian step out area adjacent to the on-street parking. The retrofit opportunity illustrated below links a series of infiltration planters. As the upstream stormwater planter fills up with runoff, it overflows out onto the street and enters the next downstream planter. In urban areas, using stormwater planters is advantageous because they allow for stormwater treatment in constrained spaces. Stormwater planters provide a buffer to pedestrians from fast moving vehicles. In addition, the inclusion of stormwater corner bulbouts and striped bicycle lanes should be considered to provide improved complete street benefits and additional stormwater management and treatment.

NEVUE NGAN ASSOCIATES

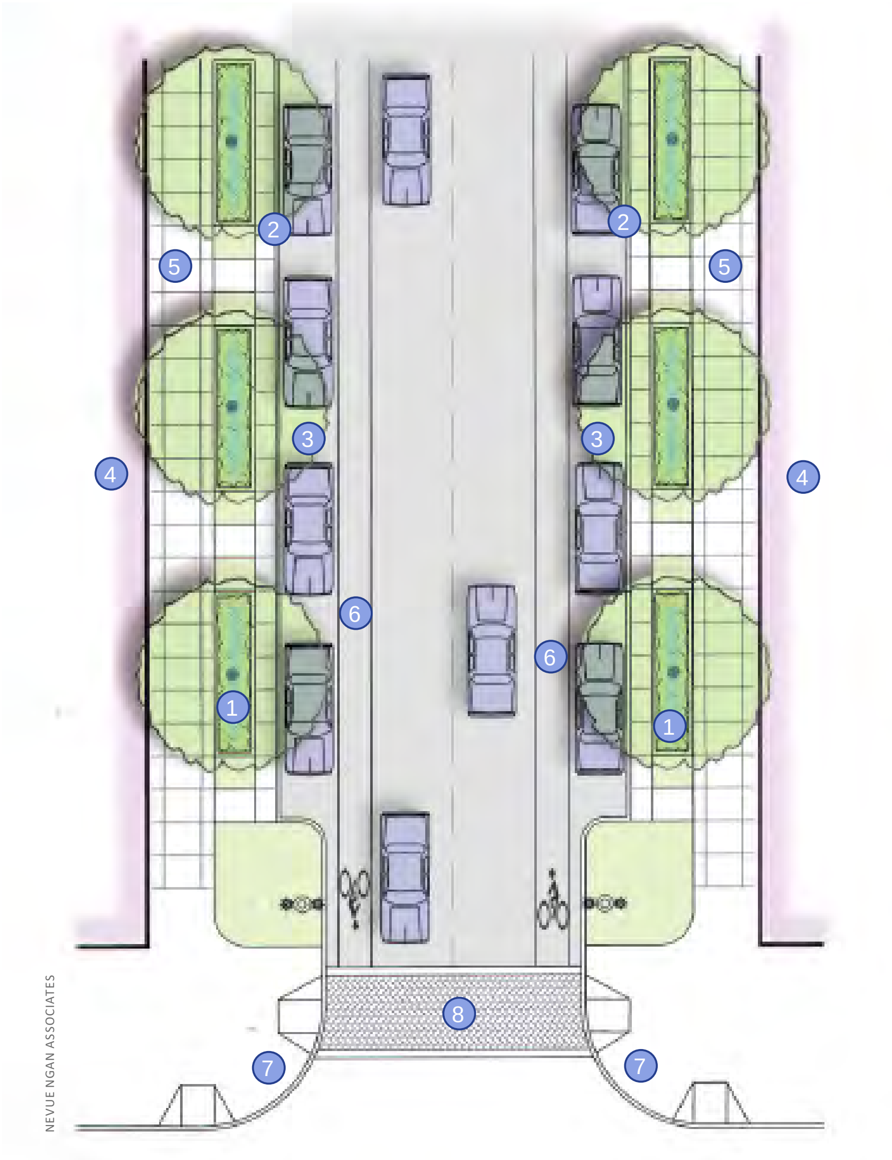
▲ *EXISTING: A mixed use connector street in San Mateo County with on-street parking.*

CD+A

▲ *EXAMPLE: This stormwater planter provides efficient treatment area in a constrained urban downtown. Pedestrian circulation can be improved by locating parking meters out of the path of travel or using a ticket dispensing system that is not reliant upon pole mounted meters.*

NEVUE NGAN ASSOCIATES; COMPLETE STREETS IMPROVEMENTS CD+A

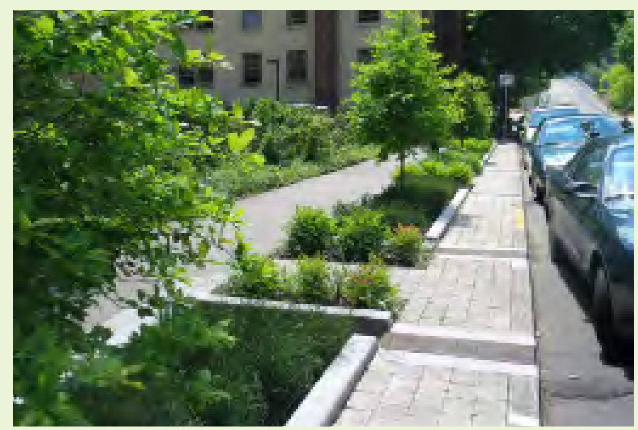
▲ *RETROFIT OPPORTUNITY: The same mixed use connector retrofitted with stormwater planters that still provide on-street parking.*



NEVUE NGAN ASSOCIATES

Key Design Elements

1. Stormwater planters allow for on-street parking with a step out area for people to access their vehicles and the sidewalk.
2. Grated curb cuts allow runoff to enter/exit the stormwater facility.
3. On-street parking lane.
4. Building frontage.
5. Sidewalk.
6. Bike lane.
7. Accessible ADA ramps at street intersection.
8. Curb extensions narrow the pedestrian crossing distance, but allow two-way vehicular traffic



KEVIN ROBERT PERRY – CITY OF PORTLAND

▲ *EXAMPLE: Stormwater planters used along a downtown street. Notice that there is adequate space allocated for people to get in and out of their vehicles and access the sidewalk and frontage uses.*

3.6 Sustainable Streets Design Examples

GOOGLE

▲ EXISTING: A plan view of a typical wide intersection caused by offset street grids or curvilinear streets within an otherwise orthogonal street grid network in San Mateo County.

CD+A

▲ EXAMPLE: The space created between three intersecting streets was designed into a large rain garden to reduce impervious pavement, capture and treat runoff, provide a sidewalk along the connector, and increase neighborhood identify.

Neighborhood Connector Street with Rain Garden Intersections

Street intersections that are wide due to angled intersecting streets present opportunities to use rain gardens either within the center of the intersection as an island or roundabout, or to the side to expand a corner area for stormwater management and increasing public space and character. Street grades need to be considered to allow runoff to flow into the rain garden either from adjacent catch basins or sheet flow. Placing rain gardens within the roadway can aid in calming traffic and making a more comfortable and safer place for people to walk, bicycle, and drive. Where connectors and other streets are multi-lane or have a wide lane width, consider the ability to perform a lane reduction or add bicycle facilities. The illustration below shows rain gardens used to define vehicle circulation and calm traffic, and the addition of bicycle lanes. Corner curb extensions are placed at adjoining corners to increase pedestrian safety and comfort and shorten crossing distances.

GOOGLE/CD+A

▲ RETROFIT OPPORTUNITY: The same street intersection retrofitted with a rain garden to better define and calm vehicle traffic movement. Adjacent corners have corner stormwater curb extensions to shorten pedestrian crossings. Wide streets can be retrofitted to include bike lanes.

Industrial Access Street with Stormwater Curb Extensions

Many industrial access streets are present in San Mateo County. They typically have a wide roadway, driveways set far apart, narrow sidewalks adjacent to the curb, and no street trees. These streets provide opportunities to reduce impervious areas, collect and treat runoff, improve pedestrian and bicyclist comfort, and reduce heat island effect. The retrofit opportunity below shows stormwater curb extensions placed that maintain the turning radius needed for larger trucks to enter driveways. Lane widths can be reduced to allow designated bike lanes to improve bicycling comfort.

CD+A

▲ *RETROFIT OPPORTUNITY: The same industrial street retrofitted with stormwater planters in the parking lane of the street, as well bike lanes added.*

CD+A

▲ *EXISTING: A typical industrial street in San Mateo County.*

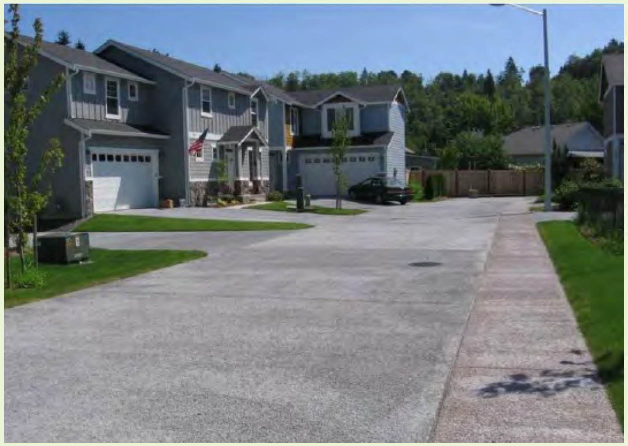
EOA

▲ *EXAMPLE: This industrial street placed stormwater curb extensions in a parking lane to collect and treat runoff.*

3.6 Sustainable Streets Design Examples

NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical narrow neighborhood access street in San Mateo County.*



BAY AREA PERVIOUS CONCRETE

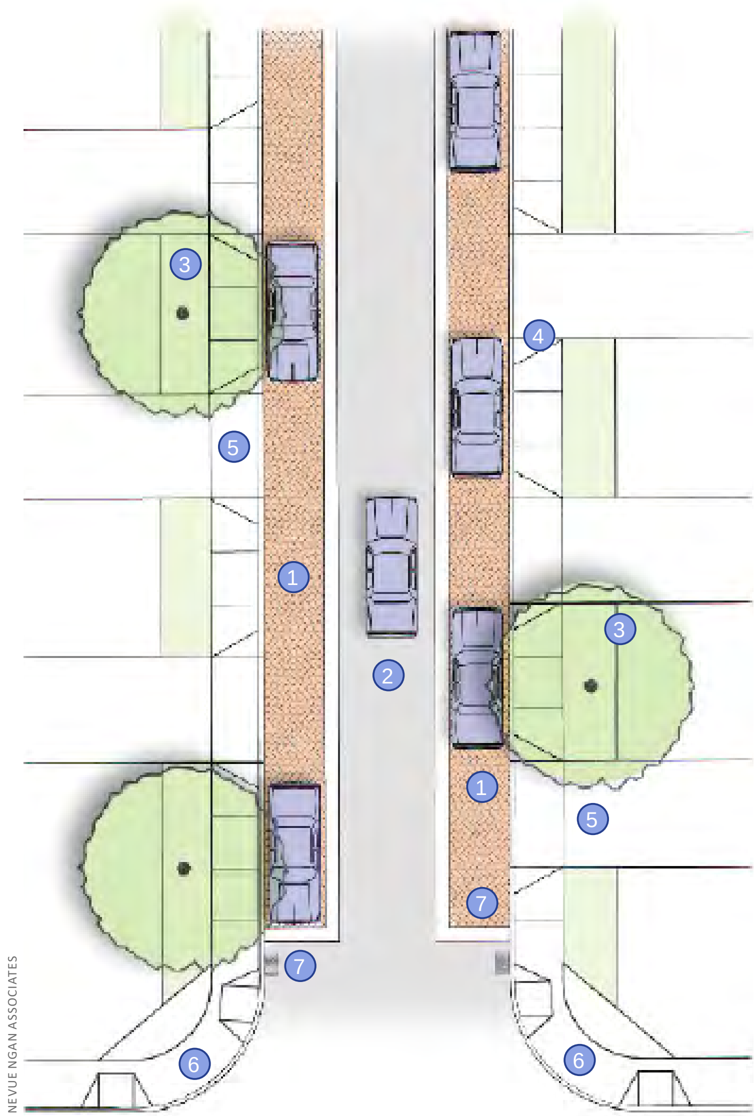
▲ *EXAMPLE: A neighborhood cul de sac installed with curb-to-curb pervious pavement. Sidewalks can further be converted with pervious pavers as well.*

Neighborhood Access Street with Pervious Pavement

Some neighborhood access streets in San Mateo County have narrow residential parcels along them, which can make it difficult to park a car on the street in between driveways. In addition, many neighborhoods have narrow sidewalks placed adjacent to the curb. If the need for on-street parking limits the use of landscape-based stormwater facilities such as curb extensions, then pervious paving may be the best retrofit option. The retrofit opportunity below shows an application of pervious concrete pavers separated by a concrete band from the asphalt roadway. Porous asphalt and pervious concrete are alternative materials. Some residential streets in San Mateo County are narrow enough that the use of pervious paving on the entire street may be cost effective if the native soils and physical conditions are well-suited. The texture of pervious paving can provide audio and physical cues that a driver should slow down, which increases pedestrian and bicyclist safety.

NEVUE NGAN ASSOCIATES; COMPLETE STREETS IMPROVEMENTS, CD+A

▲ *RETROFIT OPPORTUNITY: The same neighborhood access street retrofitted with pervious paving in the parking lanes of the street as well as street trees within front yards.*



Key Design Elements

1. Parking lane is converted to pervious paving.
2. The street is visually narrowed without physically altering the curb-to-curb width.
3. Front yards are planted with street trees.
4. Sidewalk. To provide accessible access, driveway aprons can be steepened and shortend, sidewalks can jog around driveway apron, or by other techniques
5. Driveway locations.
6. Accessible ADA ramps at street intersection.
7. Any overflow that does not infiltrate within the pervious paving section is allowed to enter the storm drain system or flows back into the street.

▲ *EXAMPLE: A residential street is retrofitted with pervious paving.*

3.6 Sustainable Streets Design Examples

NEVUE NGAN ASSOCIATES

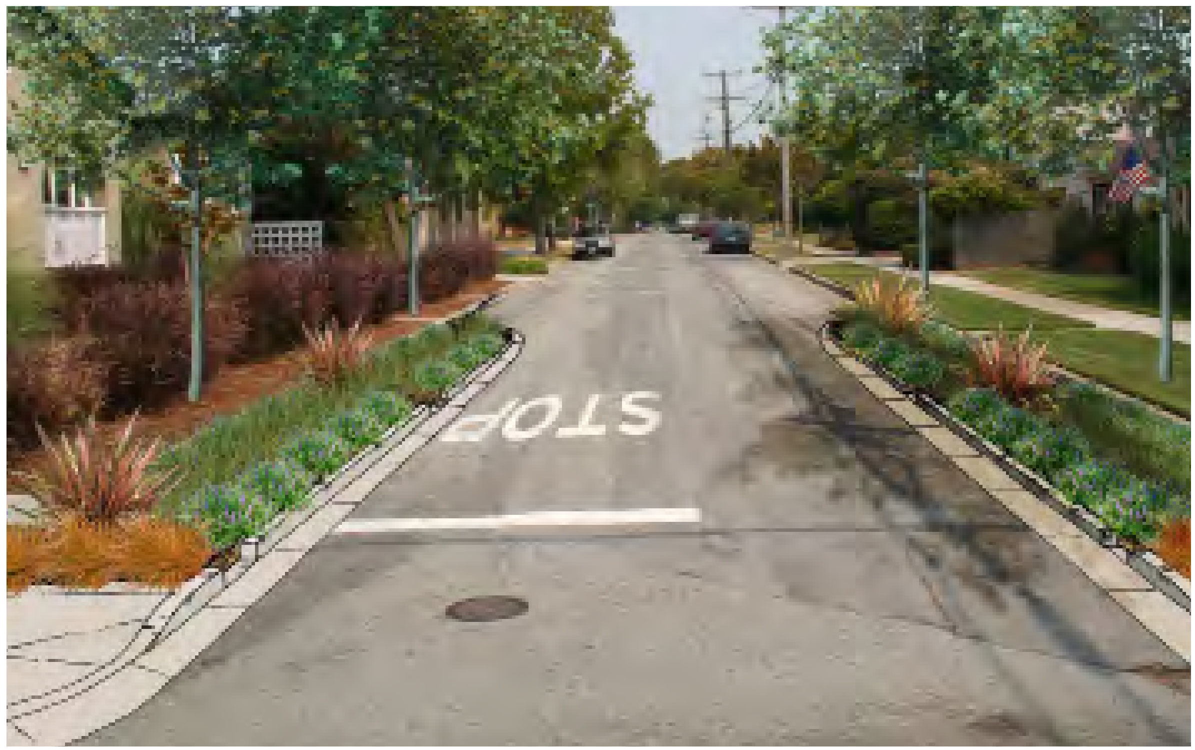
▲ *EXISTING: A typical low-density neighborhood access street in San Mateo County.*

CD+A

▲ *EXAMPLE: A neighborhood T-intersection retrofit with stormwater curb extensions to calm incoming traffic, shorten pedestrian crossing distance, manage stormwater, and revitalize the space.*

Neighborhood Access Street with Stormwater Curb Extensions at Intersections

This neighborhood access street example illustrates how stormwater curb extensions can be easily retrofitted alongside the existing curb line. Runoff from the street can simply enter these landscape areas and overflow into the existing drain inlets. Because this street has a lot of unused on-street parking, installing curb extensions does not adversely impact existing parking. With the new stormwater curb extensions and street trees in place, the narrowed intersection provides a more aesthetically pleasing gateway, calms traffic, and shortens the distance pedestrians need to cross a street.



NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same neighborhood access street retrofitted with stormwater curb extensions, as well as additional street trees. In this example the curb extension, except at the very corner, is off set from the existing curb and "free standing" within the roadway. This reduces capital cost but could increase maintenance costs.*

Key Design Elements

1. Stormwater curb extensions can incorporate the street's planter strip or can be narrower by leaving the existing curb intact.
2. Curb cuts allow runoff to enter/exit the stormwater facility.
3. Conventional landscape strip with street trees.
4. Sidewalk.
5. Accessible ADA ramps at street intersection.
6. Curb extensions narrow the pedestrian crossing distance, but allow two-way vehicular travel.

▲ *EXAMPLE: A pair of stormwater curb extensions used in a residential street's parking zone. Notice that there is still plenty of on-street parking available.*

3.6 Sustainable Streets Design Examples

NEVUE NGAN ASSOCIATES

▲ *EXISTING: A typical low-density neighborhood access street in San Mateo County.*

CD+A

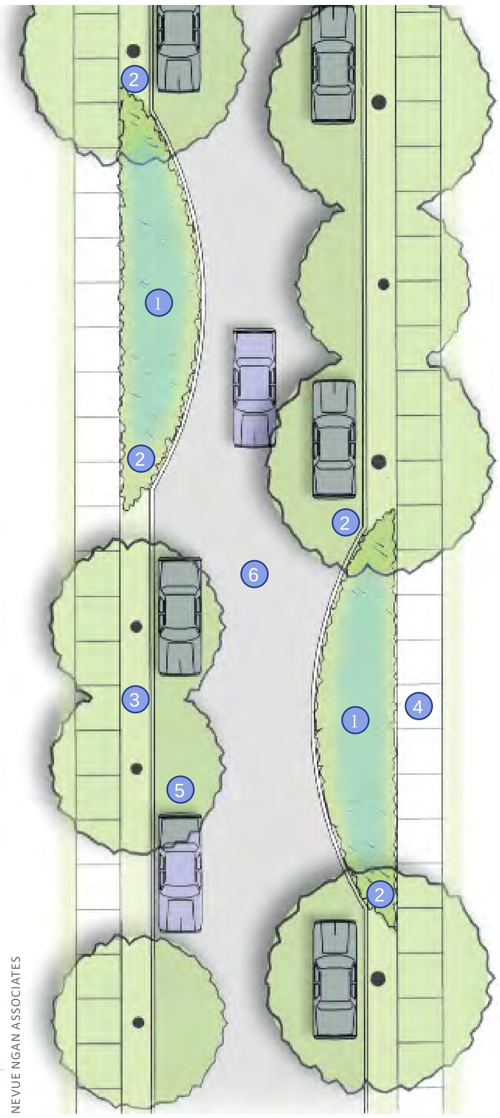
▲ *EXAMPLE: Stormwater curb extensions are paired with a pedestrian crossing at a neighborhood mid-block to calm approaching traffic.*

Neighborhood Access Street with Stormwater Curb Extensions at Mid-block

The sidebar illustrates an existing neighborhood access street's mid-block area that offers an opportunity to use stormwater curb extensions. Mid-block curb extensions can be designed in many shapes and layouts. The illustration on the following page shows stormwater curb extensions in a staggered pattern to create traffic calming features; a symmetrical pattern could also be used. Stormwater curb extensions do not have to be paired on both sides of the street. The illustration below shows a mid-block curb extension used on one side of the street to accommodate existing driveways on the other side of the street. Pervious paving placed within the driveway side of the street could complement the mid-block curb extension and allow better management of the street's stormwater runoff.

NEVUE NGAN ASSOCIATES

▲ *RETROFIT OPPORTUNITY: The same neighborhood street retrofitted with mid-block stormwater curb extension, as well as an additional street tree.*



Key Design Elements

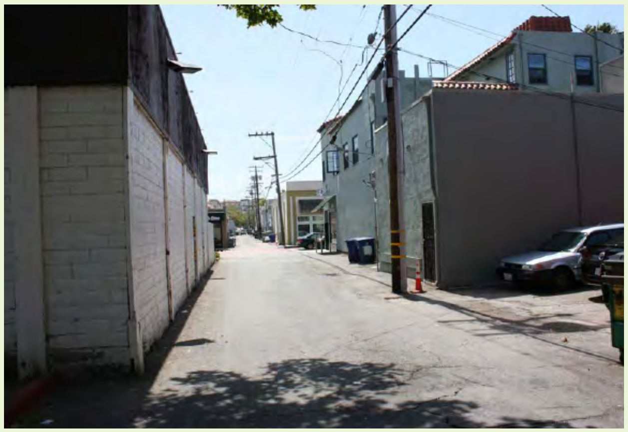
1. Stormwater curb extensions can incorporate the street's planter strip or can be narrower by leaving the existing curb intact.
2. Curb cuts allow runoff to enter/exit the stormwater facility.
3. Conventional landscape strip with street trees.
4. Sidewalk.
5. On-street parking.
6. Curb extensions narrow the curb-to-curb distance at mid-block. This allows for only one car to move through the curb extensions while an opposing vehicle waits. This arrangement of curb extensions provides a traffic calming measure.

▲ *EXAMPLE: This residential street incorporates staggered mid-block curb extensions as well as periodic center medians to help with traffic calming.*

3.6 Sustainable Streets Design Examples

Commercial/Mixed Use Alley with Pervious Paving and Stormwater Planters

Commercial and mixed use areas can have alleys. Alleys provide access for loading, private parking, and public parking lots; space for garbage storage and collection and utilities; and is a shared corridor for pedestrians, bicyclists, and vehicles. The frontages of commercial and mixed use alleys are typically the backs building, parking areas, and utility equipment. While alleys come in different widths, they are typically narrow, which can limit the use of landscape-based stormwater facilities. The retrofit opportunities below and opposite show alleys that are wide enough to accommodate stormwater planters, use colored pervious pavements to define parking areas and vehicle travel ways, and add murals and furnishings.



CD+A

▲ *EXISTING: A typical commercial/mixed use alley in San Mateo County fronted by buildings and intermittent parking areas.*

CD+A

▲ *EXISTING: A typical commercial/mixed use alley in San Mateo County that is adjacent to larger parking lots and some building frontage.*

CD+A

▲ *RETROFIT OPPORTUNITY: The same commercial/mixed use alley retrofitted with stormwater planters and pervious paving. Stormwater planters are shown with flush curbs, but can be designed with raised curbs.*

In addition, existing landscape areas are redesigned to become stormwater planters. Pervious pavement can be used across the entire alleyway for added stormwater management and treatment. Different pavement colors and materials can be used to define the vehicle travel way, parking spaces, and pedestrian areas.

CD+A

▲ *RETROFIT OPPORTUNITY: The same commercial/mixed use alley retrofitted with stormwater planters and pervious paving. Colored bands of pavement can define the vehicle travel way from parking and utility areas, and emphasize pedestrian walkways and spaces. The alley's alignment offset can aid in calming traffic.*

CD+A

▲ *EXAMPLE: This mixed use alley uses planters and stormwater trees to collect runoff. The addition of seating creates a place for neighborhood gathering as well as calms traffic.*

DOWNTOWN LONGMONT

▲ *EXAMPLE: Different types, colors, and textures of pervious pavements can add interest and aid in defining primary vehicle travel ways and other spaces such as primary pedestrian areas and loading.*

3.6 Sustainable Streets Design Examples

CD+A

▲ *EXISTING: A typical neighborhood alley in San Mateo County.*

CITY OF SAN JOSE

▲ *EXAMPLE: The Martha Gardens neighborhood in San Jose was retrofitted with three green alleys. Runoff flows to a central panel of pervious pavers over an infiltration trench to reduce localized flooding and improve water quality.*

Neighborhood Alley with Pervious Paving

Alleys occur in some neighborhood areas, providing access to garages, corridors for utilities, and is a shared space amongst pedestrians, bicyclists, and vehicles. Because back yards are adjacent to the alley, residential alleys are typically lined by fences or walls except at driveways. While alleys come in different widths, they are always narrow and are constrained from being widened. This can limit the use of landscape-based stormwater facilities, so pervious paving is usually the best retrofit option. The retrofit opportunity below shows an application of porous asphalt across the entire alleyway to collect runoff; a deeper aggregate base can provide greater storage. Pervious concrete pavers (in a center band or the entire alley width) and pervious concrete are other options.

CD+A

▲ *RETROFIT OPPORTUNITY: The same residential alley repaved with porous asphalt. Other pervious pavements may be used.*

SAN FRANCISO PUBLIC UTILITIES COMMISSION

▲ *EXAMPLE: Where alleys are wide enough, as with this high density residential alley, they can also be retrofitted with green infrastructure measures such as this stepped stormwater planter.*


NACTO.ORG

▲ *EXAMPLE: This neighborhood alley uses pervious pavers across the entire alley to manage and treat stormwater.*

TRUST FOR PUBLIC LANDS

▲ *EXAMPLE: This neighborhood alley uses pervious pavers in a central band and landscape areas to capture and treat stormwater.*

Chapter 4

Key Design and Construction Considerations

◄ *A stormwater planter at Laurel Elementary School in San Mateo, California.* Photo Credit: Urban Rain|Design

4.1 Key Design and Construction Considerations

Protecting Existing Improvements

Protecting Existing Improvements

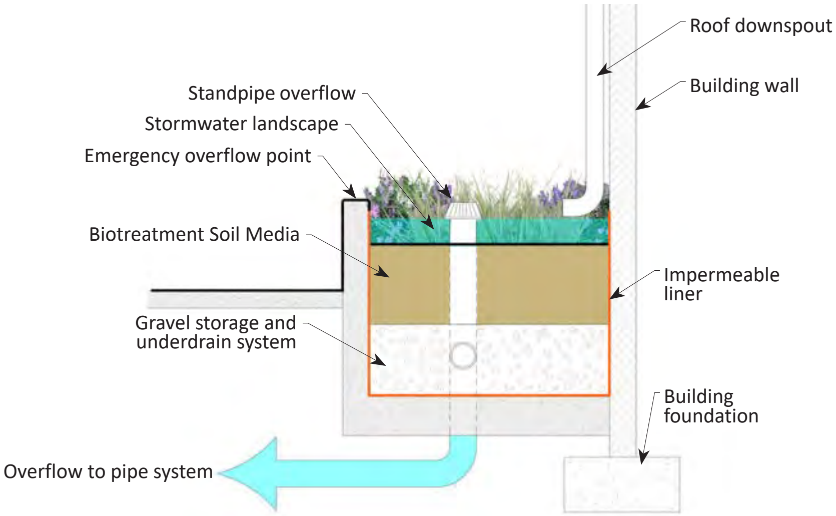
Green infrastructure facilities are often placed in the context of existing site, building, or street improvements to receive stormwater runoff from surrounding impervious surfaces. Designers must take care to protect any existing structures and improvements from detrimental interaction with stormwater. There are three basic methods of preventing water to come in contact with building structures and street improvements:

- Offset the stormwater facility at sufficient distance from the building or other structure so that any infiltrated stormwater will not interact with any foundation or basement.
- Create a flow-through stormwater facility with an underdrain and is sealed with a liner or otherwise does not allow for any infiltration into the native soil.
- For green infrastructure adjacent to a roadway, curbwalls can be designed deep enough to avoid water intrusion into the aggregate layer under the adjacent pavement.

Offsetting stormwater facilities from a structure can still allow for the infiltration of stormwater. A ten-foot distance between a stormwater facility and a building is a general rule-of-thumb for protecting building foundations from infiltrated stormwater with larger building rooftops draining into the stormwater facility. Smaller-scale buildings, such as single-family residential dwellings, should also have some offset distance from the adjacent foundation, but can often be less than ten feet, when approved by a geotechnical engineer. When in doubt, consult a geotechnical engineer for advice on the specific setback recommended for a particular project site.

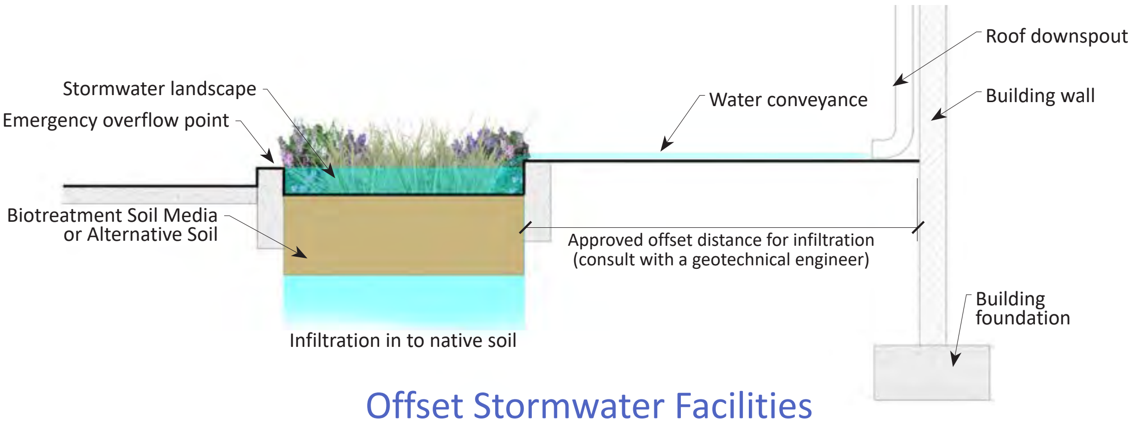
Flow-through stormwater facilities do not allow for direct infiltration of stormwater runoff and hence can be placed immediately adjacent to the building façade or within sidewalks or roadways. These types of stormwater facilities are completely lined with a water protection membrane and often encased with concrete or other durable hardscape material. Any runoff from rooftops, parking lots, or streets is directed into flow-through stormwater facilities and filtered through biotreatment soil media. Ultimately an underdrain will collect water that is not absorbed through plants and soil, as well as a raised overflow standpipe to determine the amount of retained stormwater. They can also be placed above the surrounding grade or recessed into the ground. For both offset and flow-through stormwater facilities, there should also be an overflow escape point designed to allow the water to flow over land and away from the building and sidewalk.

◀ *A large rain garden at a San Mateo County healthcare facility is placed offset from the building.*



Flow-Through Stormwater Facilities

Flow-through facilities are completely lined and do not allow for infiltration against building facades.



Offset Stormwater Facilities

Offset facilities allow for infiltration of stormwater because the water is directed away from the building foundations.

Street Applications

Stormwater facilities in streets that are intended to allow for infiltration of runoff into the underlying native soil and that are located adjacent to or within a roadway should be constructed with adequately designed deepened curb walls between the roadway bed and soil mix that extend below the roadway base course to prevent erosion of the roadbed and its potential subsidence. In addition, the designer should consult with utility providers whose lines may be located under or near a stormwater facility to receive guidance on how to avoid potential conflicts or other design solutions.

KEVIN ROBERT PERRY

▲ *A stormwater curb extension during construction showing deepened curb walls used to help protect the existing road base from lateral migration of infiltrated stormwater.*

KEVIN ROBERT PERRY

▲ *A stormwater planter is offset the building facade by at least 10 feet. This example captures both building and parking lot runoff.*

4.2 Key Design and Construction Considerations

Designing for Pedestrian Circulation

The Importance of Good Pedestrian Circulation Design

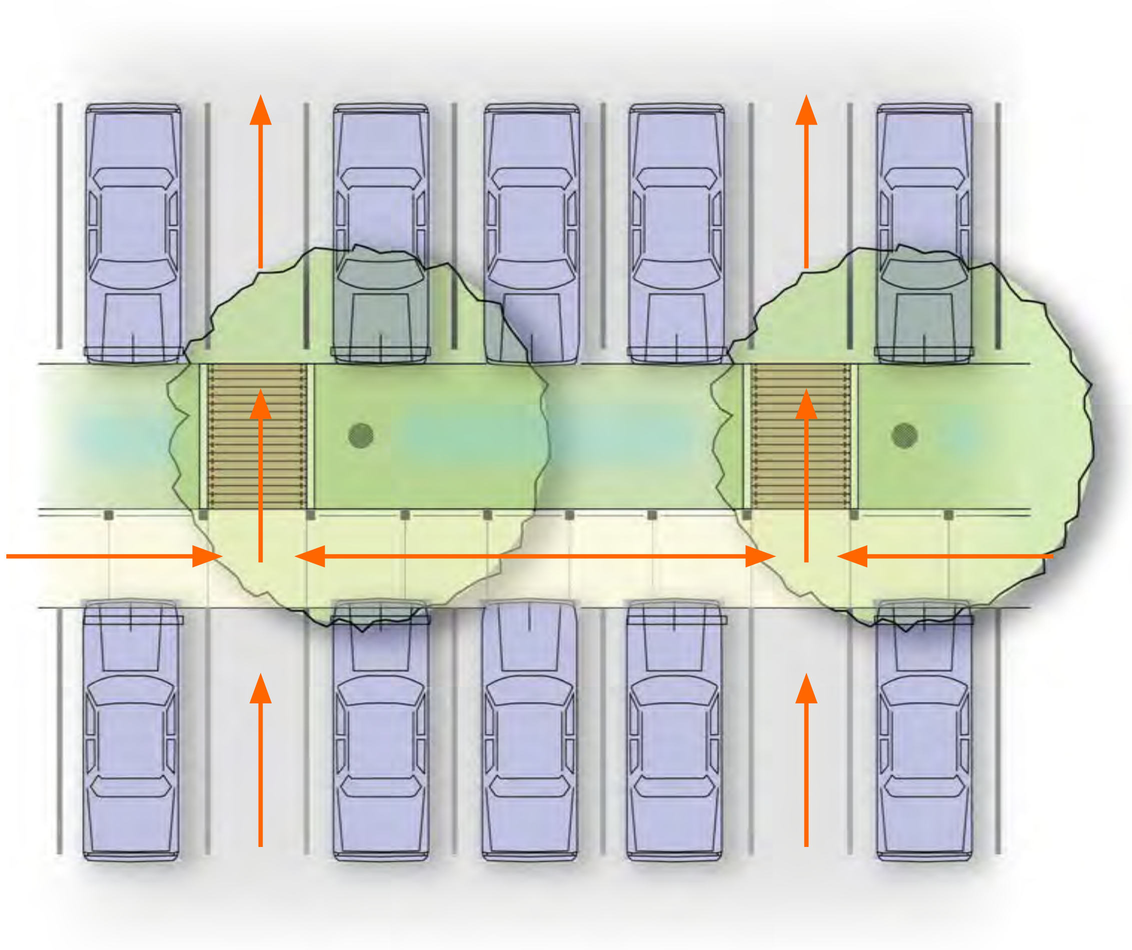
Providing adequate pedestrian circulation near stormwater facilities should always be a priority and should not be compromised during the project design. For all site conditions, a design consideration for pedestrian circulation is assuring that people of all abilities can safely walk. The design of the edge condition between the walkway and the adjacent green infrastructure facility will need to consider grade/elevation differences and how the edge is to be designed. Raised curbs, low fences or railings are often used to visually and/or physically denote vertical drops in grade, create larger grade changes, or protect landscaping due to high levels of pedestrian activity. See **Section 3.1 General Design Strategies and Guidelines** for greater detail on edge conditions and transitions, railings, and curbs. These design elements give people, especially the visually-impaired, a means to safely navigate and avoid entering the green infrastructure measure.

In some cases, the path of travel for pedestrians passes through or across the green infrastructure measure, such as a series of stormwater planters in a sidewalk and adjacent to on-street parking. In these cases, the width of the pedestrian passage, as well as the design of the edge conditions must consider pedestrian volumes and access and safety for people of all abilities. Refer to **Section 3.1 General Design Strategies and Guidelines** for more detailed information.

Site and Parking Lot Pedestrian Circulation Design Considerations

For site and parking lot applications, the question that must be asked is: Where is the primary pedestrian destination(s) in relation to the site or parking lot? For stormwater management, it is best to align landscape facilities perpendicular to the sheet flow of water in order to maximize the potential for capturing runoff. Sometimes this optimum alignment conflicts with the desired pedestrian flow to and from a destination. It is important to design a site and/or parking lot such that it provides bridges/pathways over the stormwater facilities and/or walkways for people to safely walk alongside the stormwater facilities (See diagram on the opposite page). Assuring that pedestrians can easily cross over stormwater facilities is essential to prevent people from cutting through, and disturbing, the landscaped areas. In parking lot situations where stormwater facilities are sited next to parking stalls, the designer should allow adequate space for people to step out of and into their vehicles and not be forced to step into the landscape. Refer to **Section 3.1 General Design Strategies and Guidelines** for more detail. Inadequate provisions for pedestrian circulation often result in trampled plants, soil compaction, and erosion.

◄ *A perimeter concrete curb was installed around a series of street stormwater planters to help protect both pedestrians and the stormwater facilities.*



Perpendicular Pedestrian Flow

Pedestrian circulation is perpendicular to a stormwater facility alignment

▲ *Failed pedestrian circulation within a parking lot. Due to poor design, people have trampled this stormwater planter to the point where the landscape cannot grow.*

▲ *Good circulation within a parking lot. This rain garden has several walkways that allow pedestrians to access their destination without walking through the landscape area.*

▲ *The striping of this parking lot next to a stormwater planter allows for a 3-foot egress zone between the parking stall stripe and the landscape area. This protects both people and the landscape.*

4.2 Key Design and Construction Considerations
Designing for Pedestrian Circulation

NEVUE NGAN ASSOCIATES

▲ *A perimeter concrete curb was installed around this urban rain garden to help protect both pedestrians and the stormwater facility.*

URBAN RAIN DESIGN

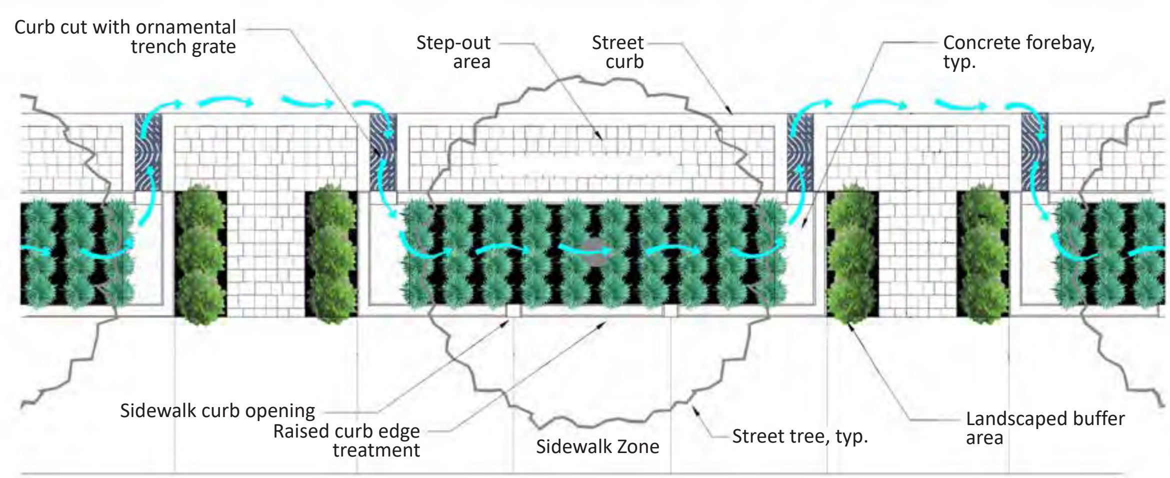
▲ *This urban rain garden at a street corner features a well-integrated raised timber edge treatment for detecting a drop in grade.*

Street Pedestrian Circulation Design Considerations

Green streets can enhance pedestrian safety by providing more buffer against vehicular traffic, reducing pedestrian crossing distances, and/or improving sight angles at intersections. However, there are sometimes conflicts between the need for pedestrian circulation and the placement of stormwater facilities, especially when a street needs to provide on-street parking. There are, however, ways that stormwater facilities can be integrated into differing street conditions while still maintaining on-street parking and adequate pedestrian circulation.

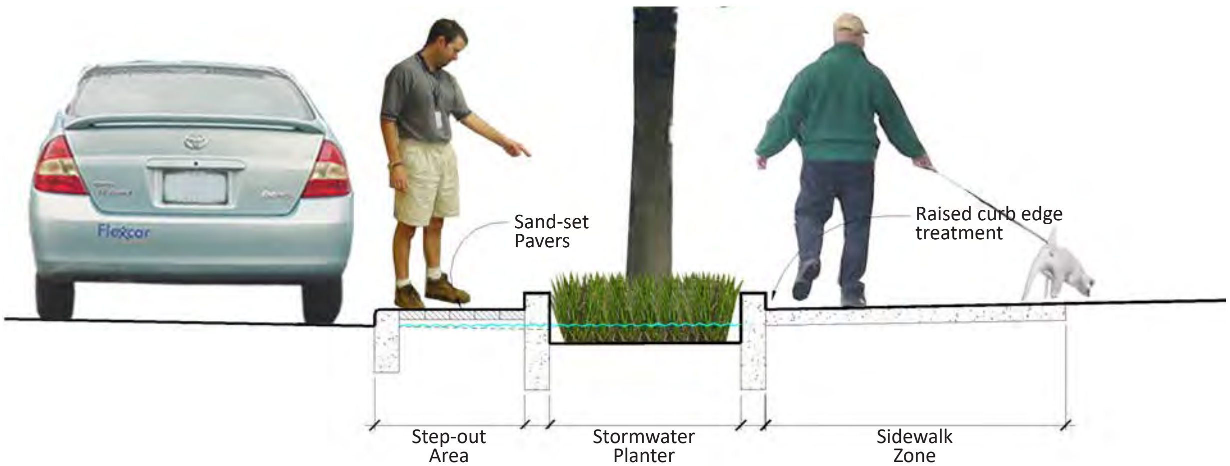
When on-street parking is designed next to a stormwater facility, it is critical to consider where people will walk when they get out of their vehicles. People need adequate room and a place to step when they get out and in of their vehicle that does not interfere with the stormwater facility. Refer to **Section 3.1 General Design Strategies and Guidelines** for more detailed guidance. Furthermore, pedestrians need to have enough access from the sidewalk to the parking zone. This can be provided by installing frequent walkways or bridges between or across stormwater facilities. The middle photo on the preceding page within the sidebar shows how on-street parking can be accommodated with stormwater planters and still allow pedestrians to access parked vehicles and the sidewalk.

See **Chapter 3 Design Strategies and Guidelines** for additional guidance on how and when to provide a vertical warning element, other edge design considerations, and the clear width for pedestrian path of travel. Also, refer to current state and federal requirements, and consult with the jurisdiction's ADA Coordinator.



Example On-Street Parking Pedestrian Flow Option

Pedestrian step-out area and pathways from the street to sidewalk is prioritized, see **Chapter 3** *for specific street guidance*



Example On-Street Parking Egress Zone Cross Section

The pedestrian step-out area is shown between the street and stormwater planter system, see **Chapter 3** *for specific street guidance*


NEVUE NGAN ASSOCIATES

▲ *This street utilizes stormwater planters adjacent to on-street parking. It provides a continuous 3-foot pedestrian egress zone and walkways that allow people to access the sidewalk and parking zone.*


URBAN RAIN DESIGN

▲ *A "curbless" green street features a drop in grade less than 4 inches and has multiple steel bridges that allow pedestrians to cross over the stormwater planter system.*


URBAN RAIN DESIGN

▲ *Low-profile railing systems can be an aesthetically pleasing way to direct pedestrian traffic.*

4.3 Key Design and Construction Considerations
Dealing with Steep Topography/Using Check Dams and Weirs

URBAN RAIN DESIGN

Dealing with Steep Topography

There are many steep slope conditions found within San Mateo County. The primary land use type in these conditions is rural/semi-rural and suburban residential development. Although these streets and sites may not generate large volumes of stormwater runoff, the velocity of stormwater runoff from developed hillsides is a potential concern. Hence, a good approach is to design stormwater facilities that help slow runoff as much as possible. There are several methods that can be used.

First, look for ways to improve the overall street and site design such as street geometry and alignment so that space can be provided for stormwater facilities. Many streets in these conditions are narrow and constrained for the addition of green infrastructure. Green infrastructure can be placed on flatter cross streets to capture runoff from steeper streets to reduce both runoff velocity and volume. Portions of a parking lane or sidewalk can be removed to allow the placement of a green infrastructure measure. Intersections are typically designed to be flatter, and can accommodate green infrastructure in curb extensions or mini roundabouts.

Second, build terraced stormwater planters and swales that help flatten the interior slopes of landscape areas compared to the steepness of a street, site, or parking lot. Closely-spaced check dams and weirs can then help slow down the flow of water, mimicking a more natural condition. Depending on the underlying soil conditions, some of this water might also infiltrate into the native soils. A geotechnical engineer should be consulted during the design process to evaluate and analyze steep areas for susceptibility to landslides.

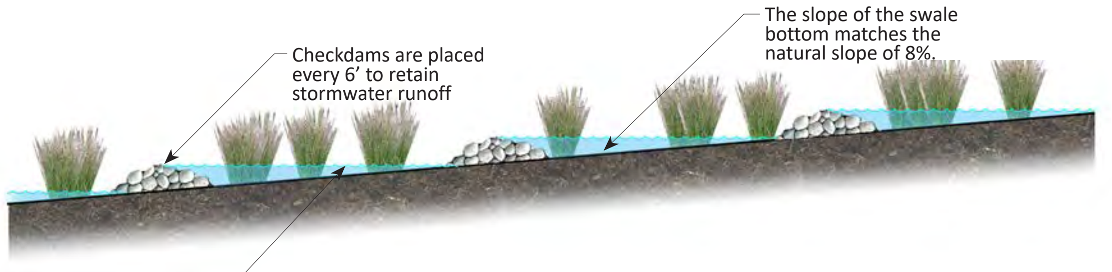
Using Check Dams and Weirs

Check dams and weirs are the "speed bumps" of stormwater management. They are designed and strategically placed within a stormwater facility to slow the flow of runoff. Check dams are structures in the landscape that retain stormwater. Weirs are a notch within a checkdam with an adjustable height to allow for varied amounts of stormwater retention. Check dams should retain stormwater to relatively shallow depths, with a maximum retention depth of 6-12 inches of runoff during storm events.

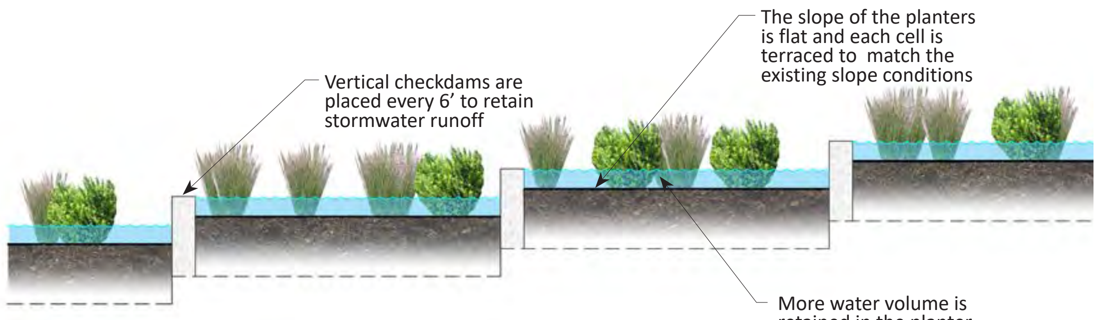
◄ *A series of metal weirs terrace the grade of this building stormwater planter to conform with a 8% slope ADA accessible ramp.*

Both check dams and weirs can be made from a variety of construction materials, such as rock, concrete, metal, wood, or any other durable material. The number and spacing of check dams are largely dependent on the stormwater goal of a project and the particular site conditions. For green street, site, and parking lot applications, slopes greater than 4% should have a check dam at least every 25 feet. In steeper conditions, check dams will need to be placed at a greater frequency and may need to be made from the most durable hardscape materials to withstand the forces of the water.

Check dams may also be placed within swales and planters that have little or no longitudinal slope in order to promote infiltration. This should be done only where soil conditions are conducive to infiltration (Class A or B soils) or where there is an underdrain system installed in the stormwater facility.



Vegetated Swale Example



Stormwater Planter Example

▲ *A metal weir separates a drop in grade from one stormwater planter to the next. Scuppers along the weir allows for overflow to occur at controlled points.*

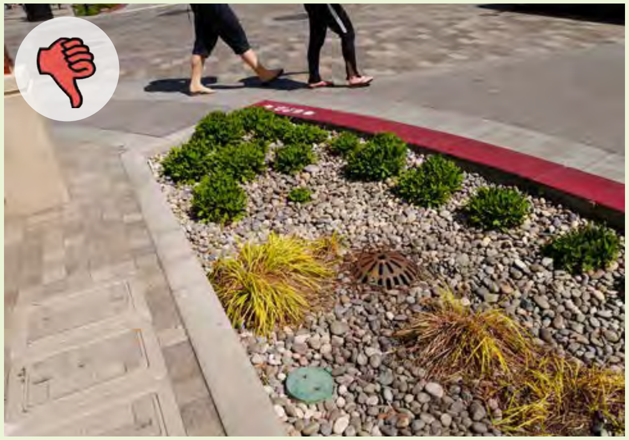
▲ *This adjustable weir can control how much water is to be retained within a rain garden.*

▲ *Simple checkdams made of stacked rocks or gravel can be used on gently sloped stormwater facilities.*

4.4 Key Design and Construction Considerations
Overflow Options


URBAN RAIN DESIGN

▲ *This storm inlet's rim is placed at a fixed height of over 8 inches. If this rain garden does not infiltrate at a reasonable rate, it could suffer the effects of too much prolonged standing water.*


URBAN RAIN DESIGN

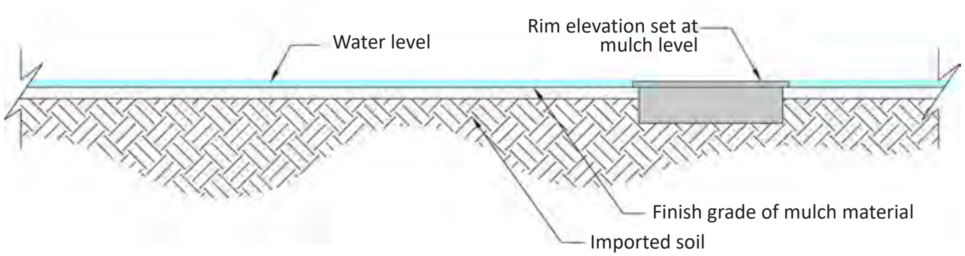
▲ *Conversely, this stormwater curb extensions inlet rim is fixed at the finish grade of rock mulch leaving little opportunity for water retention.*

Overflow Options

Overflow within green infrastructure systems can be managed in several ways depending on what type of stormwater infrastructure is already available. Try whenever possible to have a viable surface overflow as the primary overflow and the piped system as a secondary overflow. In retrofit conditions, simply allowing water to overflow from the stormwater facility through a curb cut and exit back into the street or parking lot where it can eventually be captured by an existing storm drain inlet is the most cost-effective and least intensive option. Another option for handling overflow is to construct a new storm drain inlet located either within the stormwater facility or immediately adjacent to an exit curb cut.

Undesirable Overflow Inlet Placement

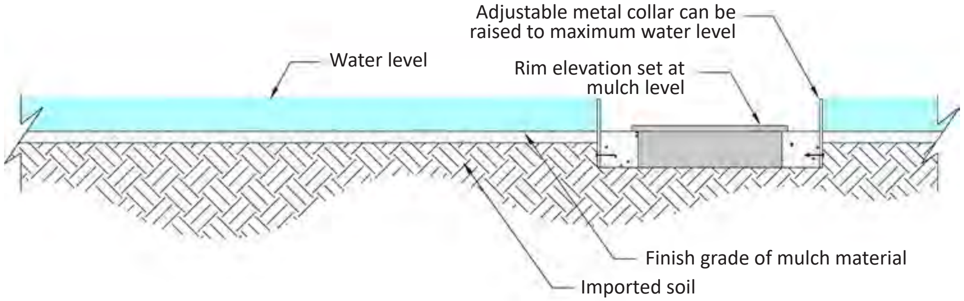
Many projects in San Mateo County have overflow inlets rim fixed at predetermined elevations that are either too high or too low for optimum stormwater retention. Having a fixed retention depth is taking a risk that infiltration/retention of water will work as planned and leaves no ability to adjust for changing conditions in the future. The illustrations below show the common conditions of retaining too much or too little water due to a fixed inlet rim elevation. The opposite page illustrates possible weir/check dam alternatives to maximize the potential flexibility of water retention depths.



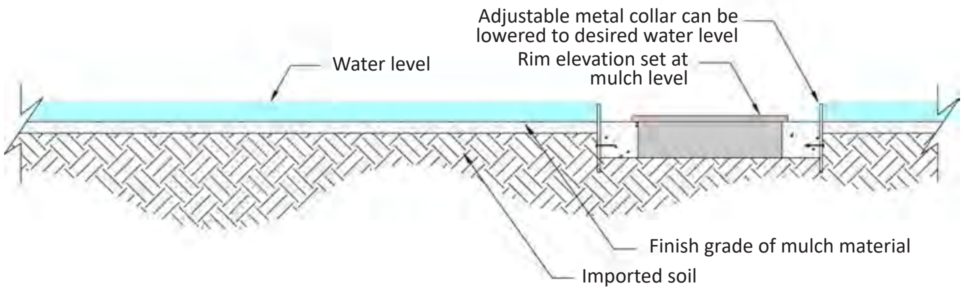
Undesirable Inlet Placement: Fixed Flush Position

Flexible Inlet/Weir/Checkdam Placement

To maximize performance and provide flexibility of water retention levels, one can incorporate adjustable check dams and weirs within green infrastructure facilities. These structures can be made from metal, plastic, or even types of weather-resistant wood types , and are adjustable to raise or lower water levels throughout the landscape or immediately prior to the inlet. Place the inlet structure flush with the mulch grade and use the adjustable weir to dictate the optimum water retention level. The scenario below illustrates how an adjustable weir at an inlet can be raised or lowered for better water level control. Adjusting the height of weirs should only be done by appropriately trained personnel.



Raised Metal Weir for Maximum Water Retention



Lowered Metal Weir for Minimal Water Retention


URBAN RAIN DESIGN

▲ *This stormwater planter has several metal weirs placed along the flow path of water to encourage infiltration.*


NEVUE NGAN ASSOCIATES

▲ *This HDPE weir surrounds an inlet that is flush with the soil grade. The weir dictates the water level.*


URBAN RAIN DESIGN

▲ *Surrounding a flush inlet are raised bricks to create a simple raised weir effect and retains additional runoff.*

4.5 Key Design and Construction Considerations

Designing with Poor Soils

KEVIN ROBERT PERRY

Designing with Poor Soils

In San Mateo County, many sites will not have both the relatively flat terrain and high percolation rates typically needed for regulated project infiltration facilities. Infiltration facilities should not be used in areas with Class C or D soils, that have a high-water table, or that have known soil contamination. Infiltration is also infeasible in areas with steep slopes or high clay content soils. As a result, sites with these unfavorable soil conditions will have to incorporate design measures that do not have a high-level of reliance on stormwater infiltration.

One way this can be achieved is through a general reduction of impervious area, which in turn reduces the amount of runoff needing treatment. For instance, increasing a site's landscape area by 25% decreases the site's stormwater runoff by somewhat less than 25% without the use of any stormwater treatment facilities. See **Section 3.2 Buildings and Sites Design Strategies and Guidelines** for additional discussion on site planning techniques that can be used to reduce levels of stormwater runoff. While this can be an effective strategy for sites and parking lots, an extensive change in impervious area within a street can typically only be achieved by using pervious pavement, because there is typically not enough "extra" space within a street right of way to shift from serving a transportation function to landscape area. The limited landscape area gained within a street right of way should be designed as active green infrastructure measures. This must also be feasible in terms of slope and other street context considerations, and capital and maintenance costs.

Stormwater facilities designed in Class C or D soils will require the use of imported soil and often an underdrain system. As water moves through the amended soil in the facility, it enters the underdrain to be discharged back into the storm drain system or dispersed back into the natural environment. These types of flow-through facilities attenuate peak flows and reduce total runoff volume through evapotranspiration, as well as treat and improve water quality.

The Countywide Program recommends that perforated or slotted underdrains be used where the native soil infiltration rates are low (Class C and D soils) in order to allow for some infiltration. The **C.3 Regulated Projects Guide** and **Appendix 3 Sustainable Streets Typical Design Details** of this Design Guide provide information on the design and construction of underdrains for a variety of stormwater facility types. The **C.3 Regulated Projects Guide** also provides information on imported soil specifications. If the proper soil is used and the stormwater facility is built in accordance with the reference guidelines, the soil bed should be able to infiltrate stormwater at a minimum rate of 5 inches/hour prior to the water entering the underdrain.

Allowing for Flexibility in Design and Size

Some flexibility in the sizing and design of green infrastructure may be needed for some building, site, parking lot, and street projects. For example, on Hydrologic Soil Groups C and D there may be situations where the stormwater treatment system could be designed without an underdrain provided sufficient stormwater treatment is achieved without retaining stormwater runoff for a prolonged period of time. In these situations, shallower and larger stormwater treatment systems may be needed.

Planting trees, shrubs, and other plant material with extensive root systems can help loosen tight clayey soils, provide more capillary storage space, and allow for greater evapotranspiration of water. There may also be occasions where a project is not a regulated project, but a jurisdiction or private development may wish to implement green infrastructure within their project. An example of this is the Carolan Street green street case study sidebar in **Section 1.1**. In these instances, the project proponent can determine what treatment type (sediment or volume retention) and capacity is appropriate for the green infrastructure facility and then translate the treatment capacity into the load reduction credit towards the jurisdiction's GI Plan load reduction target. By recognizing and using a range of opportunities to provide green infrastructure, the jurisdiction indicates its level of commitment to implementing green infrastructure and receives some credit towards meeting their MRP and GI Plan obligations.

To encourage the implementation of stormwater facilities in the street right of way, where there may be space, utility, and/or other constraints, the Bay Area Stormwater Management Agencies Association (BASMAA) has developed guidance for the sizing and design of green street projects that cannot meet the treatment facility sizing requirements for regulated projects[1]. This guidance allows for a street's green infrastructure measures to use a smaller sizing factor and be counted towards the treatment of impervious area and reduction in pollutants as defined by the targets of each jurisdiction's GI Plan. Refer to **Section 4.12 General Sizing of Green Infrastructure Facilities** for more information.

When stormwater facilities are used in poor soil conditions, it is important to include design flexibility for check dams and weirs. Newly-constructed stormwater facilities and stormwater facilities built in poor soil conditions may initially infiltrate less stormwater. Once plants have established and a stormwater facility has matured, infiltration rates may increase and allow for more retention of water during storm events. The overall retention of stormwater can be controlled by adjusting the height of check dams and weirs as needed. Designing for flexibility will ultimately allow for maximum performance efficiency over time.

1 As allowed per Provision C.3.j.ii.(3)(b) of the MRP.

▲ *Adjustable weirs within these stormwater planters allow for the flexibility of how much water is retained. These weirs are set to retain a maximum of 6 inches of water but can be lowered to retain less water if desired.*

▲ *This very shallow landscape strip has a large footprint to accept building rooftop runoff. Only 1 to 2 inches of runoff is retained in this facility.*

▲ *A HDPE overflow weir surrounds a drain inlet that is flush with the soil surface. The weir dictates how much water is retained at any given time and can be replaced with a different height weir or removed completely.*

4.5 Key Design and Construction Considerations

Designing with Poor Soils

Designing for Specific Soil Conditions in San Mateo County

There are a multitude of soil conditions within San Mateo County and each stormwater facility should be designed to function properly within a site's specific constraints. The adjacent section drawings of green infrastructure design options illustrate three basic conditions:

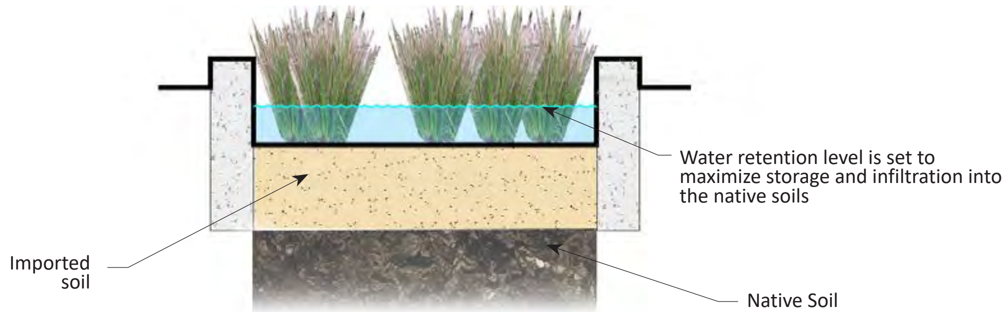
Condition 1 consists of native soils that are relatively good at allowing infiltration of stormwater runoff, thus the facility design maximizes the amount of retained water. This design solution can be utilized whenever soils allow moderate to good infiltration (Class A or B Soils).

Condition 2 illustrates a design option for places with poor native soils (Class C or D soils). This design solution maximizes a stormwater facility's horizontal footprint and reduces the ponding depth of stormwater to prevent any prolonged periods of standing water. This option may be appropriate for projects that are not subject to regulated project stormwater requirements but still want to provide water quality and flow reduction benefits projects.

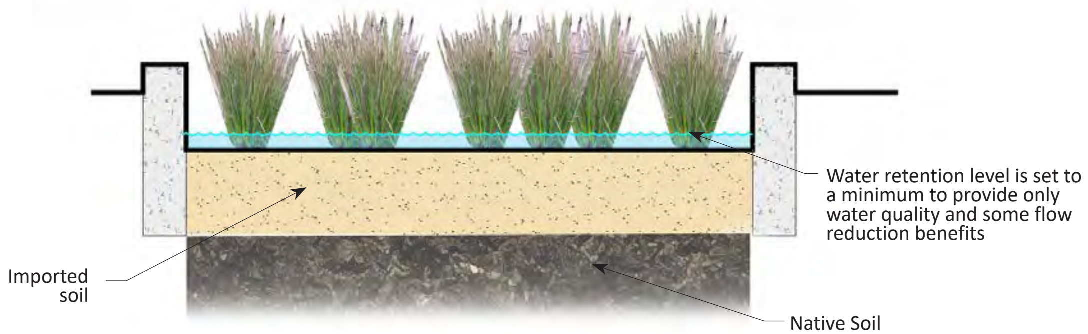
Condition 3 shows how including an underdrain system in poor soil conditions (Class C or D soils) allows greater water retention, similar to Condition 1. Condition 3 may be necessary to meet regulated project stormwater requirements.

To help manage constraints to infiltration that are common in San Mateo County and where infiltration of the C.3.d amount of runoff is infeasible, bioinfiltration or rain gardens may be used if drainage is sufficient or underdrains are provided. The design should maximize infiltration to the underlying soil. Some indirect infiltration to groundwater will occur and will enhance the effectiveness of these treatment measures. Site design measures such as pervious pavement may be used if soils are amended and positively drained.

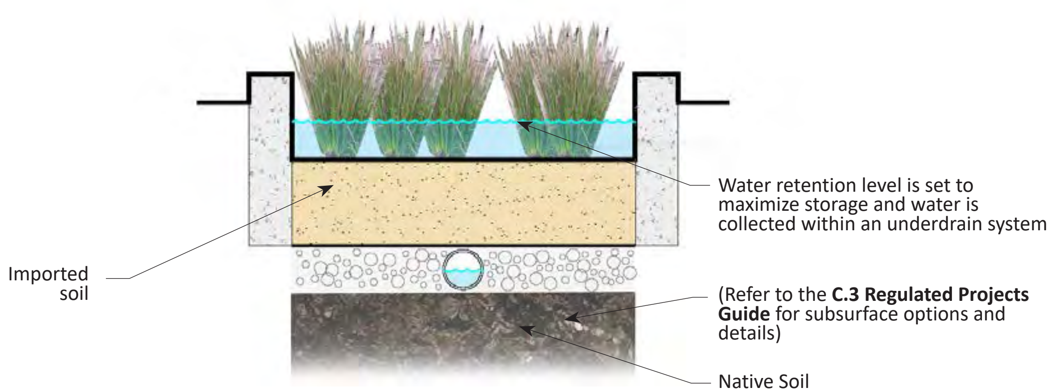
◄ *To achieve greater stormwater management performance, an underdrain system is installed within the Brisbane City Hall Rain Garden project.*



Condition 1- Good Native Soils without an Underdrain



Condition 2- Poor Native Soils without an Underdrain



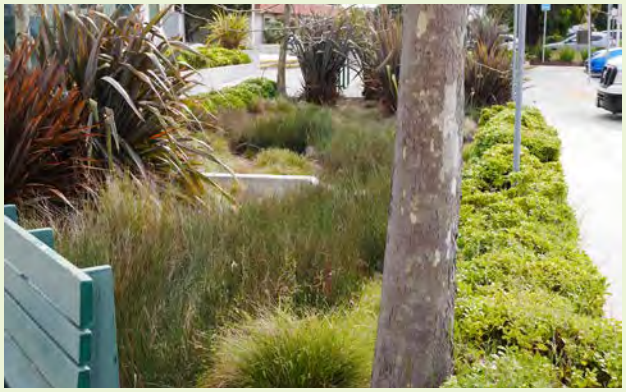
Condition 3- Poor Native Soils with an Underdrain

NEVUE NGAN ASSOCIATES

▲ *This plaza rain garden in Portland, Oregon utilizes the "Condition 1" cross section. The soil is sandy loam; hence the cross section retains 6 to 8 inches of runoff without an underdrain.*

NEVUE NGAN ASSOCIATES

▲ *This parking lot rain garden in San Mateo County utilizes the "Condition 2" cross section. The soil is very clayey with no underdrain; hence the cross section is quite shallow.*



URBAN RAIN DESIGN

▲ *This parking lot rain garden in San Mateo County utilizes the "Condition 3" cross section. The soil is very clayey but does have an underdrain and storage layer, hence the cross section retains 6 to 8 inches of runoff.*

4.6 Key Design and Construction Considerations

Designing with Utilities

Addressing Potential Utility Conflicts

Utility conflicts with stormwater facilities are probably the greatest perceived physical constraint in implementing building, site, and parking lot as well as green street projects. There is a perception that utilities and stormwater facilities cannot coexist, but they definitely can with the right site conditions and design solutions. With some green infrastructure projects, especially those within low-density residential areas, there may be very few, if any, utility conflicts.

Cost Effective ↔ Cost Prohibitive

Easy to Implement ↔ Difficult to Implement

Step 1: Avoidance

Whenever possible, locate green infrastructure clear of any utility conflicts. This may result in some treatement measures not being well-suited for the particular street and location, even if they are less expensive to build. Avoidance can also mean that the green infrastructure's dimensions are reduced in order to provide an adequate setback from utilities.

Step 2: Acceptance

Green Infrastructure may conflict with existing utility location, but involved entities accept that utility constraints do not preclude the green infrastructure from being built. There is an acceptance of the soil or permeable pavement coverage and general clearance between the green ingrastructure and utilities. Also, if utilities ned to be accessed, it is accepted that the green infrastructure would be temporarily impcted, but restored to its original condition.

Step 3: Mitigation

Green Infrastructure is allowed to coexist near a particular utility, but the original design is adjusted to mitigate concerns about proximity to the utility. The green infrastructure design may be significantly altered to provide enough soil or permeable system cover over the utility, or key features (i.e., check dams, inlets, outlets, trees, etc.) may need to be moved to avoid conflict.

Step 4: Utility Replacement

In order for the green infrastructure to work, the utility needs to be replaced and/or relocated so that conflicts no longer exist. This can be the most complex, cost-prohibitive, and difficult design option to implement. But, in somecases, the age of the utility is a factor in selecting this solution. it might be more advantageous to replace an aging utility during the green infrastructure construction than at a later date.

One significant constraint involving utilities and stormwater facilities is providing adequate access to utility lines for repair or replacement. This may require repair of a stormwater facility's landscape and associated hardscape elements. Identifying who, or which private entity, agency or utility provider, is responsible for repairing any temporary damage to a stormwater facility will need to be determined prior to construction. Elements such as pervious pavement and low-expenditure landscape stormwater facilities over utility lines might actually reduce the need for cutting and replacing concrete and asphalt and improve access to underground utilities and should be considered during the planning and design phase.

Other utility conflict issues with buildings, sites, parking lots, and streets include, but are not limited to:

- Providing adequate soil cover around utility lines and gravel envelopes
- Minimizing the migration of infiltrated stormwater
- Finding adequate space for vaults and valve boxes next to stormwater facilities

It is important to first understand the different approaches for addressing potential utility conflicts or constraints. The diagram on the opposite page illustrates a process to help identify and resolve utility conflicts. This process emphasizes the ideal choices of either avoiding utilities or accepting the conflict to reduce construction costs. If this is not possible, more costly design solutions, such as mitigation or replacement/relocation of utility lines, can be explored.

No Room for Utility Vaults/Infrastructure

Utility vaults can be a difficult constraint to overcome particularly when placing green infrastructure within streets. In general, all utility vaults should be located outside of the "wet" zone of the treatment measure. Many small utility vaults associated with lateral services (e.g. water service vaults) can be located outside of the footprint of measures without needing to replace the infrastructure. However, when every square foot of space is at a premium, sometimes even these smaller vaults need to be relocated and replaced to maximize the amount of landscape space available for stormwater treatment. Larger utility vaults should be avoided whenever possible or completely lined so that water cannot migrate into the vault.

Refer to **Section 3.1 General Design Strategies and Guidelines** for more detailed information.

CD+A

▲ *These stormwater curb extensions have been designed to have street lights and their electrical boxes within the planters. Even though this was a retrofit project the sidewalk, curb, and gutter are new and the utility boxes could have been moved into the sidewalk.*

CD+A

▲ *Various utilities are elevated above the ponding elevation. Utility providers and contractors should be reminded that utilities should be located outside of green infrastructure areas if possible.*

NEVUE NGAN ASSOCIATES

▲ *A geotextile liner is installed within a flow-through stormwater curb extension to prevent infiltration near a utility vault.*

4.7 Key Design and Construction Considerations

Capturing and Conveying Surface Runoff

Capturing and Conveying Surface Runoff

One of the primary considerations for designing stormwater facilities associated with building, sites, parking lots, and streets is determining how the runoff enters a stormwater facility. There are three primary ways that runoff is directed into stormwater facilities- sheet flow, curb cuts, and building downspouts. Sheet flow describes stormwater runoff that enters a stormwater facility evenly distributed on the pavement surface without concentrating flow. Curb cuts allow stormwater to enter a stormwater facility, at the surface at specific points along a raised curb, thus concentrating runoff both in velocity and volume. Curb cuts should be spaced frequently along the length of the curb to distribute the water flow as evenly as possible into and within the stormwater facility. Roof downspouts, like curb cuts in function, concentration building runoff into specific points where the water is conveyed from the rooftop to the ground plane.

Of all the methods, sheet flow is by far the better design because it mimics the natural flow of water across the landscape, employs a less complicated design, and is less prone to failure. Sheet flow, or "curbless" streets, sites and parking lots, typically employ a concrete band edging that is flush with the stormwater facility and the impervious area surface. Having this concrete band provides a clean edge along the more malleable asphalt surface. In addition, the concrete band is easier to fine grade than asphalt in order to direct water into the stormwater facility.

Curb cuts along a raised curb system are commonly used to allow water to flow into stormwater facilities. This approach channelizes water flow and can be prone to failure if the curb cut design is poor and/or there is a build-up of sediment or debris at the curb cut. If curb cuts are used, they should be carefully designed. Curb cuts should be spaced frequently along the length of the curb to distribute the water flow as evenly as possible within the stormwater facility.

A flaw in curb cut design is to use a "notched" or small opening penetrating the curb. These designs often fail because the opening for stormwater runoff is restricted and results in trapped sediment and debris. When a notched curb cut is plugged with debris, it often goes unnoticed. It is recommended that an 18-inch minimum width "open" curb cut be used at entrances to stormwater facilities, however, in some instances, a curb cut with a "top" can be used to prevent vehicle tires from entering the green infrastructure facility.

◄ *A concrete runnel conveys building rooftop water into the Mt. Tabor Middle School Rain Garden in Portland, Oregon. Instead of piping the water into the rain garden, this water is kept on the surface to mimic natural water flow.*

With steeper conditions in parking lots, it is recommended to design small, low-profile asphalt or concrete berms at each curb cut inlet to guide stormwater flow into the stormwater facility. Without such a measure, runoff can sometimes flow past the curb cut and bypass the stormwater facility during intense storm events. Grated curb cuts are often used in street and site applications to allow water to flow underneath sidewalks. Grated and "topped" curb cuts need special design attention and maintenance to assure water will flow into the stormwater facility. When used, grates need to be slip resistant and American Disability Act (ADA) compliant.

Both sheet flow and curb cut systems need to allow for a minimum 2-inch drop in grade between the sidewalk/parking lot/street gutter grade and the finish grade of the stormwater facilities mulch elevation. This drop in grade assures that water will freely enter the landscape space even if there is some sediment accumulation.


NEVUE NGAN ASSOCIATES

▲ *Sheet flow of stormwater runoff enters a stormwater planter from a public plaza space.*


NEVUE NGAN ASSOCIATES

▲ *A notched curb cut is way too small and constantly overloaded with sediment.*


NEVUE NGAN ASSOCIATES

▲ *A curb cut placed immediately adjacent to the overflow inlet does not allow runoff to enter the landscape and insted flows directly into the inlet.*


KEVIN ROBERT PERRY

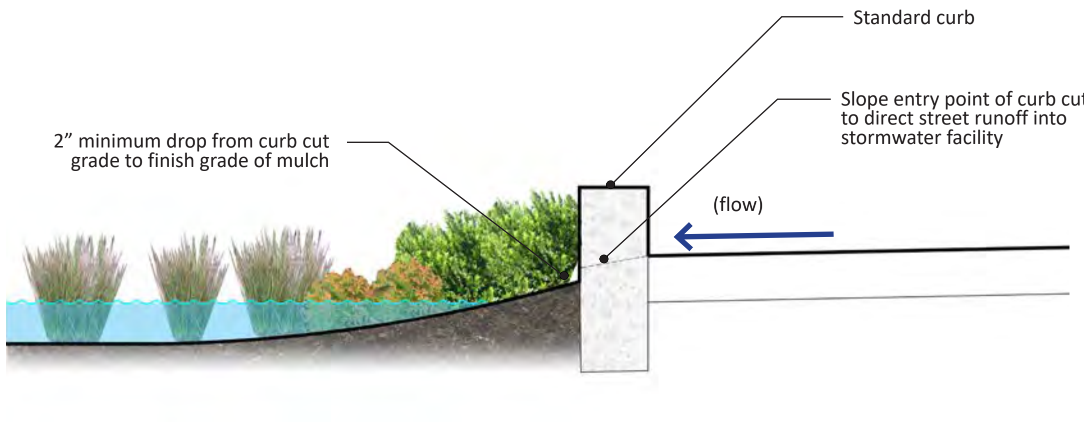
▲ *A curb cut blocked by cobbles and sediment prevents water flow into this stormwater facility. There is not enough grade change between the curb cut entry and the finish grade of landscaping.*

4.7 Key Design and Construction Considerations

Capturing and Conveying Surface Runoff

▲ *A standard curb cut allows stormwater runoff to enter a parking lot rain garden. This curb cut has 45 degree chamfered sides.*

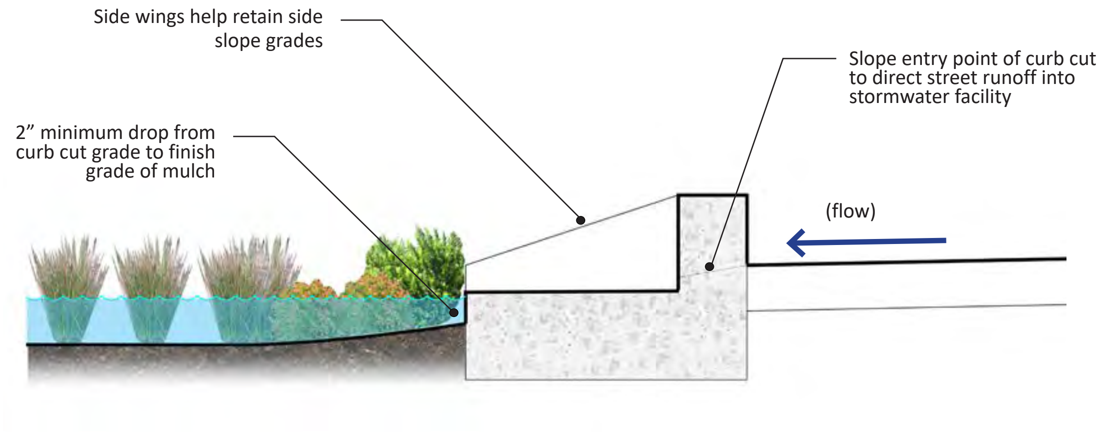
▲ *This street median uses multiple standard curb cuts to allow runoff to enter the landscape area.*



The Anatomy of a Standard Curb Cut

(For shallow stormwater facilities that do not have steep side slope conditions)

1. Opening should be at least 18 inches wide
2. The curb cut can have vertical sides or have chamfered/rounded sides (as shown)
3. Need to slope the bottom of the concrete curb cut toward the stormwater facility
4. A minimum 2-inch drop in grade should occur between the curb cut and the finish grade of the mulch layer
5. Small rock can be used as a stable mulch material at the curb cut opening to prevent erosion



The Anatomy of a Standard Curb Cut with Side Wings

(For stormwater facilities that have steeper side slope conditions)

1. Opening should be at least 18 inches wide
2. Need to slope the bottom of the concrete curb cut toward the stormwater facility
3. A minimum 2-inch drop in grade should occur between the curb cut and the finish grade of the mulch layer
4. Small rock can be used as a stable mulch material at the curb cut opening to prevent erosion

▲ *A standard curb with wings allows stormwater runoff to enter a stormwater facility. The wings help retain the side slope grade on each side of the curb cut opening.*

▲ *This curb cut with side wings retains the side slope soil grade within a street stormwater curb extension project.*

4.7 Key Design and Construction Considerations

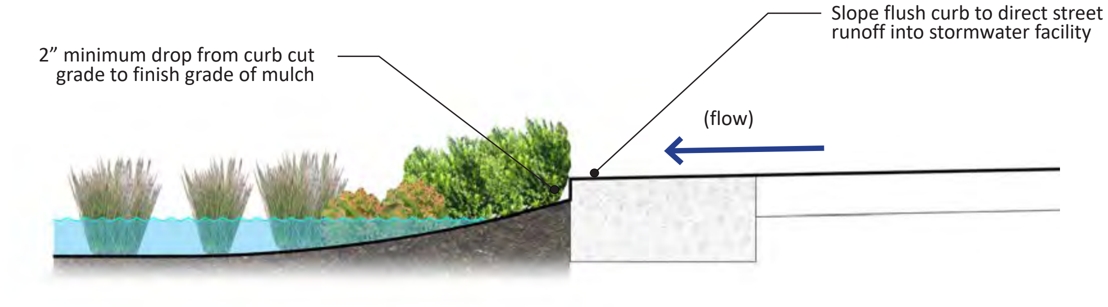
Capturing and Conveying Surface Runoff


KEVIN ROBERT PERRY

▲ *This flush condition allows stormwater runoff to enter, evenly distributed, within a rural street green gutter system.*

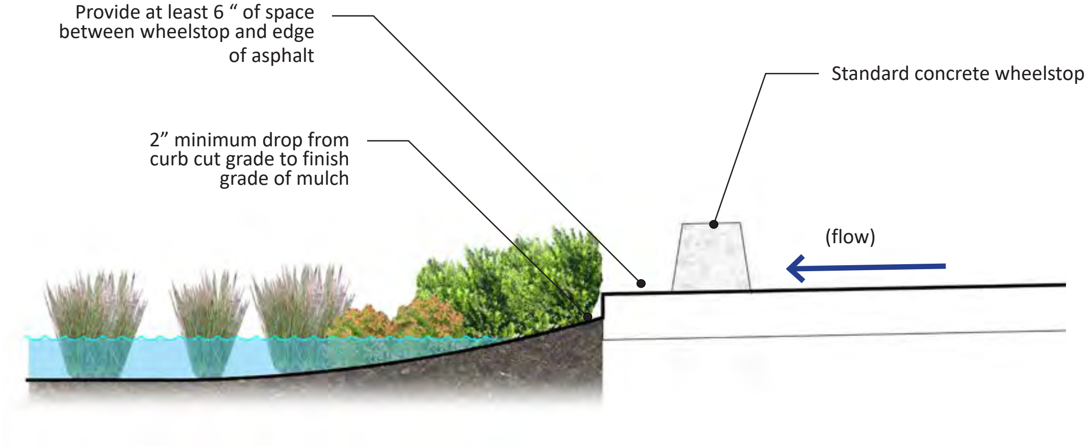

KEVIN ROBERT PERRY

▲ *This sheet flow example allows for sheet flow of runoff into a rain garden.*



The Anatomy of a Concrete Flush Curb/Sheet Flow

1. Concrete flush curbs/sheet flow allow stormwater runoff to enter a stormwater facility evenly alongside a street or parking lost edge
2. Need to slope the concrete flush curb toward the stormwater facility
3. A minimum 2-inch drop in grade should occur between the flush curb and the finish grade of the mulch layer
4. There is no need for pea gravel along the curb edge for dissipating concentrated flow



The Anatomy of a Standard Wheelstop Opening

(Common in parking lot applications, but they can also be applied to certain street conditions)

1. Wheels tops allow water to flow through frequently spaced openings.
2. Need to provide a minimum of 6 inches of space between the wheelstop edge and edge of asphalt paving. This is to provide structural support for the wheelstop
3. A minimum 2-inch drop in grade should occur between the asphalt/concrete and the finish grade of the stormwater facility
4. Small rock can be used as a stable mulch material at the wheelstop opening to prevent erosion

▲ *The 3 foot space in between these wheelstops allows stormwater runoff to enter a rain garden within a parking lot. This design could be improved by including more of a drop in grade between the asphalt and the landscape area.*

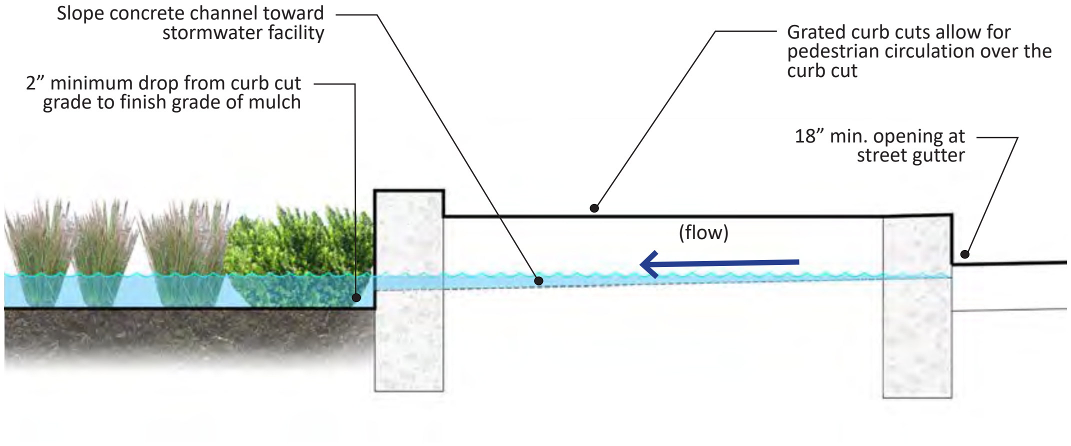
▲ *This parking lot allows runoff to enter a rain garden using the 3 foot space between wheelstops.*

4.7 Key Design and Construction Considerations

Capturing and Conveying Surface Runoff

▲ *A grated curb cut allows stormwater to pass under a pedestrian egress zone to the stormwater facility.*

▲ *Grated curb cuts conveying street runoff should be at least 12 inches wide, preferably 18 inches wide to adequate handle stormwater flow.*



The Anatomy of a Grated Curb Cut

(Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway)

1. Grates need to be ADA compliant and have sufficient slip resistance
2. Need to slope the concrete channel of the curb cut toward the stormwater facility
3. A minimum 2-inch drop in grade should occur between the flush curb and the finish grade of the stormwater facility
4. To help direct water into the grated curb cut, designers can either recess the gutter pan slightly at the curb cut opening and slope the concrete towards the channel or place a 1 to 2-inch high asphalt or concrete berm on the downstream side of the curb cut to help direct runoff into the channel.

Conveying Surface Runoff with Trench Drains and Speed Bumps

Conveying stormwater runoff on or near the surface can be accomplished with several techniques. Using trench drains and small-scale speed bumps are good ways to efficiently direct runoff to landscape areas without using underground pipes.

Trench drain systems are designed to convey stormwater runoff within a shallow channel while maintaining unimpeded pedestrian or vehicular access. Trench drain grates can vary considerably in size and shape, as well as material choice and patterns. Trench drain channels, to which a grate is affixed or mounted to, can be designed with a variety of profiles and depths.

Using speed bumps to direct water into landscape areas is a simple and inexpensive design strategy in parking lots. Speed bumps can be used to direct surface runoff near the beginning of a stormwater facility to increase treatment time. Also, small speed bumps can be installed as a "backstop" near curb cut entries within parking lots to direct water into the stormwater facility. Speed bumps do not have to be very high. A 2-inch-high speed bump is typically adequate for directing stormwater flow.

KEVIN ROBERT PERRY

▲ *This asphalt speed bump redirects stormwater into a rain garden curb cut during storm events. Without the speed bump in place, runoff would bypass the curb cut and create a missed opportunity for stormwater treatment.*

NEVUE NGAN ASSOCIATES

▲ *This trench drain example connects two stormwater facilities within an industrial parking lot site.*

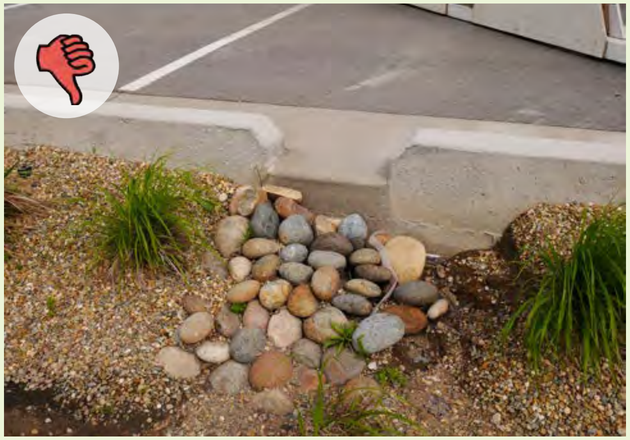
NEVUE NGAN ASSOCIATES

▲ *A concrete unit paver is placed at the exit point of this trench drain. The pad helps prevent erosion by dissipating water velocity as water drops from the trench drain to the finish grade of the stormwater facility.*

4.7 Key Design and Construction Considerations

Capturing and Conveying Surface Runoff

URBAN RAIN DESIGN



▲ *This curb cut entry does not allow for good erosion control, ease of water flow, nor is there any design for a sediment forebay. Ultimately, this will become a maintenance issue to constantly remove sediment and eroded soil.*

KEVIN ROBERT PERRY

▲ *A 3x3 foot recessed concrete pad is used to collect sediment. The plant material acts as a dam allowing debris to settle on the pad for regular removal.*

Designing for Sediment Capture

In sheet flow situations, sediment and other debris drop out evenly along the length of the stormwater facility. This can reduce the need for frequent removal of sediment from within the facility. However, when curb cuts are used, and runoff enters a stormwater facility as concentrated flow, so too does the debris load. The value of using sediment forebays depends highly on how much sediment and other debris the street, site, or parking lot typically produces. Some stormwater facilities may not need a sediment forebay at all. Other stormwater facilities, particularly those located within parking lots and streets that have substantial leaf drop, would most likely benefit from having a sediment forebay and a regular maintenance schedule to clear debris from it.

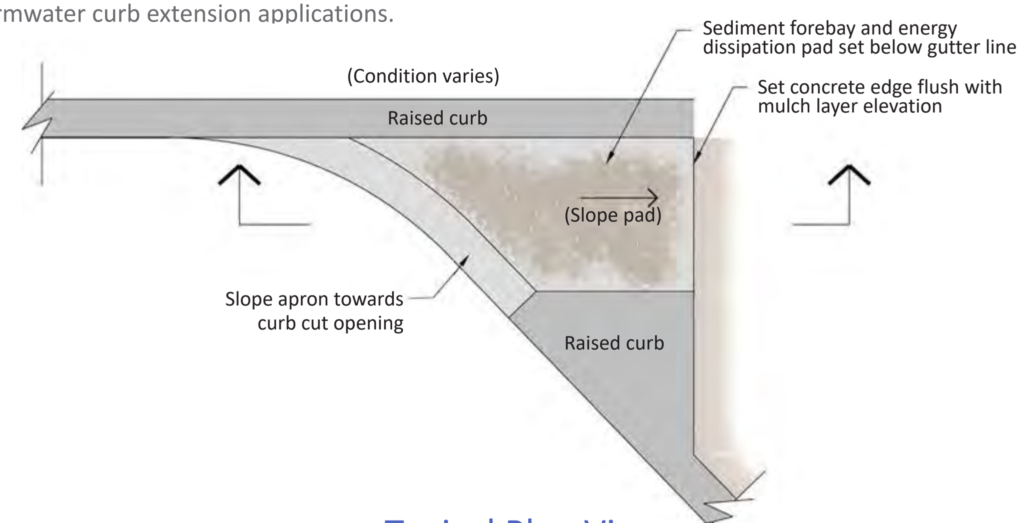
Sediment forebays help define a space at the entry of a stormwater facility for sediment and debris to collect and be periodically removed. Providing this space can help reduce maintenance by trapping sediment before it is transported into established landscape areas. The goal of a sediment forebay is to minimize the amount of sediment to be transported, not to eliminate the sediment.

Ultimately, a sediment forebay should be sized and designed so that it is seamlessly integrated into the landscape area. The design of a sediment forebay can be as simple as leaving a small, shallow-graded, non-planted area right after the entry curb cut. It is recommended that the sediment forebay be mulched with pea gravel to minimize erosion. High density planting located on the downstream side of a sediment forebay can help act as a containment dam for sediment and debris

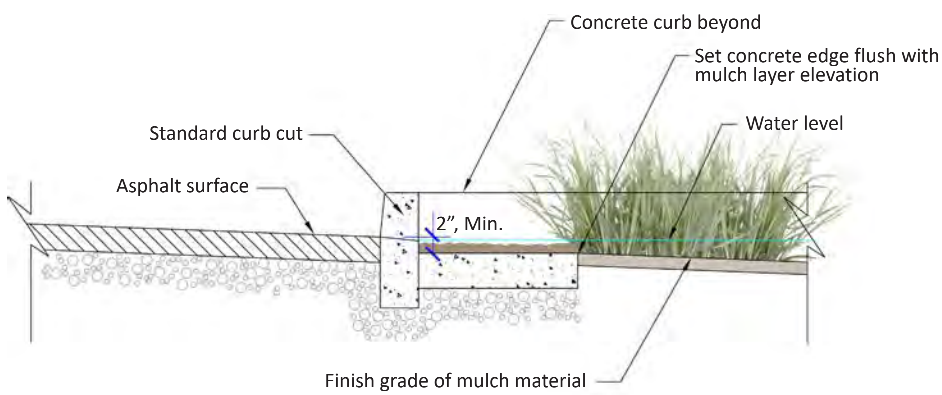
Both sheet flow and curb cut systems need to allow for a minimum 2-inch drop in grade between the sidewalk/parking lot grade and the finish grade of the stormwater facilities mulch layer. This drop in grade assures that water will freely enter the landscape space even if there is some sediment accumulation.

Sediment Forebays for Stormwater Curb Extensions

Because streets are typically the primary conveyance system of stormwater runoff within the urban watershed, they often produce and transport the highest sediment load. For this reason, special consideration should be made to allow for a sizeable sediment forebay for stormwater curb extensions receiving gutter flow. The sketches below illustrate some basic guidance on sediment forebays for stormwater curb extension applications.



Typical Plan View



Typical Cross Section

▲ *This stormwater curb extension has no concrete forebay. Sediment builds up and blocks runoff from entering.*

▲ *This stormwater curb extension has a concrete forebay that captures sediment that is removed regularly.*

▲ *While this is a good concrete pad, the elevation needs to be lowered at least 2 inches to allow for sediment capture.*

4.8 Key Design and Construction Considerations
Capturing and Conveying Rooftop Runoff

NEVUE NGAN ASSOCIATES

▲ *A simple residential downspout disconnection directs roof runoff into a front yard.*

KEVIN ROBERT PERRY

▲ *An artful rainwater conveyance system from an office rooftop.*

Residential Downspout Disconnection

Downspout disconnection is one of the simplest ways that a homeowner, even one with a small yard, can help with stormwater management. Many residential downspouts in San Mateo County are connected to a municipal storm drain system. Disconnecting the downspouts and directing runoff onto front, back, or side landscape areas slows and filters rainwater and lets it absorb into soils. Downspout disconnection can be easily integrated with rainwater harvesting or new green infrastructure facilities such as rain gardens, stormwater planters, and vegetated swales.

Creative Routing of Stormwater Runoff

Unlike conveying water on the ground surface, directing rooftop water to the ground plane considers gravity and allows for considerable flexibility and creativity on how and where water can be moved. Water can sheet down surfaces, spill over cascading terraces, move through a series of runoffs, drip down rain chains, or be integrated into rainwater artwork.

KEVIN ROBERT PERRY

▲ *This plaza space in Portland, Oregon directs roof runoff via a series of granite paver channels allowing water to flow through the joints of the pavers until it reaches the landscape.*


STACY LEVY-ARTIST

▲An art installation that showcases the movement of water from a schoolyard rooftop into a stormwater landscape.


URBAN RAIN DESIGN

▲This rain garden was strategically placed to capture the roof runoff from an existing roof downspout already integrated into the wall of the building.


URBAN RAIN DESIGN

▲ A roof downspout is disconnected and routed "aqueduct style" into a rain garden at UC Davis.


KEVIN ROBERT PERRY

▲ A beautiful channel system directs rainwater over a lighted art installation.


KEVIN ROBERT PERRY

▲ A "fish ladder" conveys roof runoff into a stormwater landscape avoiding the trash receptacle area.


KEVIN ROBERT PERRY

4.8 Key Design and Construction Considerations

Capturing and Conveying Rooftop Runoff

Stormwater Canopies

In some cases, available landscape area may be in places where the ground plane space for management of water is limited or difficult to achieve due to surface grades. Constructing stormwater canopies that capture rainfall above ground and route it to nearby landscape areas such as planters, rain gardens, and vegetated swales, is a potential option. Stormwater canopies can be built alongside of buildings or on top of existing buildings that have downspouts that are internally plumbed in order to route runoff to the perimeter of the building. They can also be designed as large-scale shade/shelters for plaza areas, schools, and outside dining areas that capture direct rainfall and route the water to nearby landscape areas.

Stormwater canopies are not yet compliant as a **C.3 Regulated Projects Guide** strategy, but they have been successfully built in locales outside of San Mateo County and may be a promising emerging stormwater management strategy.

WITHERSRAVENEL.COM

▲ *This large stormwater roof canopy at the Chatham Park Medical Facility in North Carolina captures and directs runoff into the surrounding landscape.*

LAURIE OLIN / OLIN

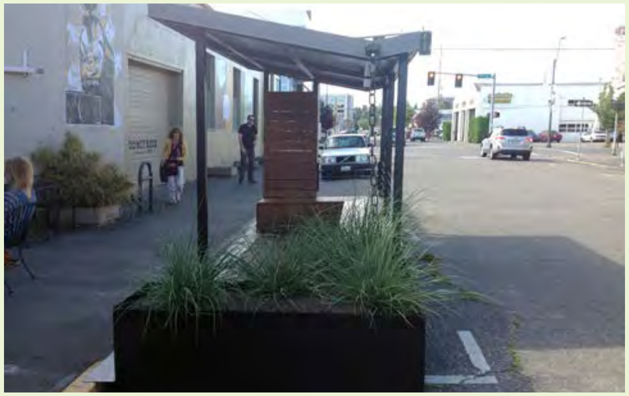
▲ *This large stormwater canopy in Director's Park in Portland, Oregon directs runoff down vertical cables and into a raised stormwater planter.*

PINTEREST.COM

▲ *Stormwater canopies protect pedestrians from rain and redirect runoff to adjacent landscape areas.*

KEVIN ROBERT PERRY

▲ *Stormwater canopies can be any shape or size and can be placed in almost any urban condition.*



URBAN RAIN DESIGN

▲ *A downtown temporary parklet's roof captures runoff directs it to a raised planter.*

4.9 Key Design and Construction Considerations

Soil Preparation, Landscape Grading, and Mulch Placement

KEVIN ROBERT PERRY

Soil Preparation and Mixture

In general, it is good to amend native soils with organic material because a rich soil allows for healthy plant growth and helps promote the microbiological processes beneficial for the removal of certain types of pollutants. Many sites, especially retrofit conditions, have little or no organic material within the native soil structure because they have been paved over for many years. If possible, consult with a soil scientist to determine the best mix for a site's imported soil. In general, a three-part mix of weed-free compost, sand, and loamy topsoil works well. Specific recommended mixture percentages are detailed in the **C.3 Regulated Projects Guide** for Biotreatment Soil Media (BSM).

Due to its high sand content, regulated project soils are fast draining and do not retain moisture, as such, it is not a preferred planting soil media for vigorous plant growth and health, especially for trees. Options to improve regulated project certified soil for trees and other vegetation includes the addition of amendments to increase the water holding capacity of the soil. This can be done by replacing a portion of the sand component with amendments or admixtures to increase its water holding capacity, and that can improve nutrient value such as biochar, perlite, ground coconut coir, pumice, and vermiculite. The resulting soil mix proposed to be used as an alternative to the standard regulated project BSM must be tested and pass the qualitative soil requirements outlined in the **C.3 Regulated Projects Guide**.

Green infrastructure that is not a regulated project can use amended planting soil as long as it is designed to allow excessive runoff to either flow back out to the gutter or another treatment measure. Alternatively, an overflow structure can be provided with a connection to the existing storm drain system. Amended planting soil can provide a better growing environment for trees and other plants as it can retain water longer allowing more time for plants to take up the water. These plant health benefits can be achieved, while still providing some bioretention or bioinfiltration function, in terms of treatment and hydromodification. Refer to **Appendix 4** for additional discussion about BSM soils.

General Landscape Grading

Accurate grading of stormwater facilities is critical for assuring the success of a green street, site, or parking lot project. The designer and contractor must work together during construction to assure that the project is correctly built to plan. In most situations, adjustments to the grades will need to be made in the field. This is especially true when attempting to match existing conditions to new conditions in retrofit projects.

When designing and installing stormwater facilities, the grade of the imported topsoil or biotreatment soil media should be left 3 inches below the desired finish grade to allow for a layer of mulch. If the finish grade of the stormwater facility is built without considering a mulch layer, the stormwater facilities will be graded too high and water cannot get into the stormwater facility/curb cut.

Mulch Types

Mulch material can be made of organic material (e.g., composted arbor mulch) or it can consist of rocks. For organic mulches, care should be taken to use a weed-free source. Bark mulch does tend to float during a stormwater facility's initial storm events, however, this tends to decrease over time as the mulch material settles and the plant material matures. Rock mulch is a good choice for stormwater facilities that experience high velocities of runoff and have a higher potential for erosion. For rock mulch used in green street and parking lot projects, care should be taken to select rock that is sized appropriately based on the expected sediment load of the runoff. The type of rocks chosen depends on where the runoff is coming from and its pollutant/sediment load. It can be a maintenance headache to clean out sediment in the voids between larger rocks. For green street, site, and parking lot projects, the best type of rock mulch is pea gravel because it allows for easier removal of sediment accumulation.

When removing sediment from a pea gravel mulch, it is easy to tell where the sediment load ends and the pea gravel layer begins. If necessary, the entire sediment and pea gravel layer can be removed, and a new pea gravel layer can be applied. This allows for the original finish grade of the stormwater facility to always be maintained.

While a major component of grading stormwater facilities is to accurately build the finish grade of soil, it is equally important to assure that the grades of the hardscape elements (i.e., curb cuts, trench drains, curb heights, etc.) are also constructed correctly. Even an 1/8-inch discrepancy in elevation can mean the difference between stormwater freely entering a curb cut or not.

The Countywide Program has a specification for composted wood mulch and a list of some mulch suppliers. See www.flowstobay.org/preventing-stormwater-pollution/with-new-redevelopment/c-3-regulated-projects/ for more information.

NEVUE NGAN ASSOCIATES

▲ *During the construction process, the native soil is rototilled or broken up by other means to limit compaction.*

NEVUE NGAN ASSOCIATES

▲ *New imported soil is placed within a planter. The imported soil's finish grade is set 3 inches lower to allow for a mulch layer.*

CD+A

▲ *Compost should be cultivated into native soil as recommended by the soil laboratory analysis report.*

4.9 Key Design and Construction Considerations

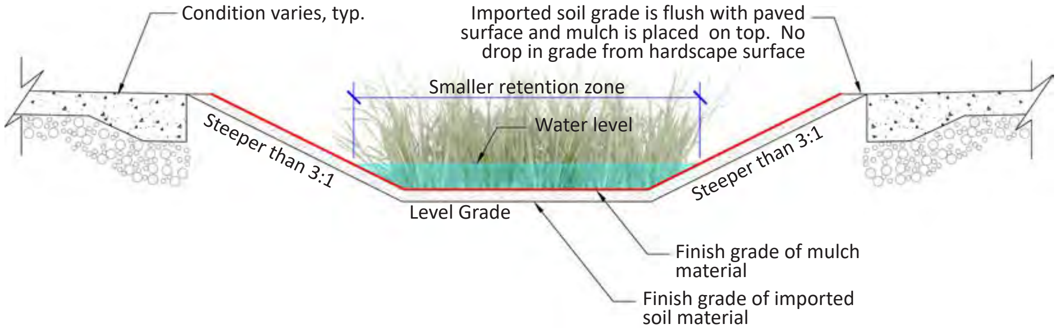
Soil Preparation, Landscape Grading, and Mulch Placement

▲ *This newly installed green infrastructure facility will have consistent problems with erosion control and plant health issues because of steep side slope conditions (steeper than 3:1 slope).*

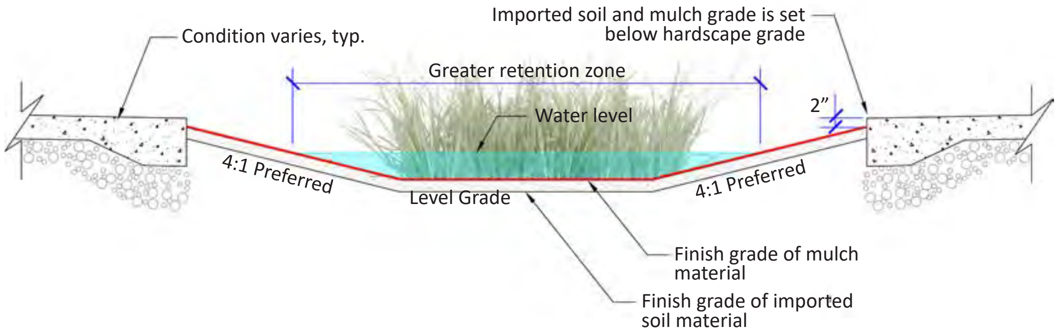
▲ *This rain garden is graded very shallow to allow ponding of water, but it is not excessively deep or have steep side slopes. Ultimately this rain garden will perform better over time and will be easier to maintain.*

Effective Landscape Grading

Many stormwater facilities built in San Mateo County are designed to be too deep and with very steep side slopes. These types of conditions have permanent operation and maintenance consequences including erosion issues, plant desiccation, and difficulty to physically access plant material. For future projects, it is best to design facilities with gradual side slopes and shallow depth facilities to help limit erosion, better mimic natural landscape conditions, and promote more flat space for water contact. The type of green infrastructure facility may need to be reconsidered to have curb walls rather than side slopes in narrow locations to limit the issues associated with erosion, constrained areas for tree planting, and other conditions. See below for grading comparisons.



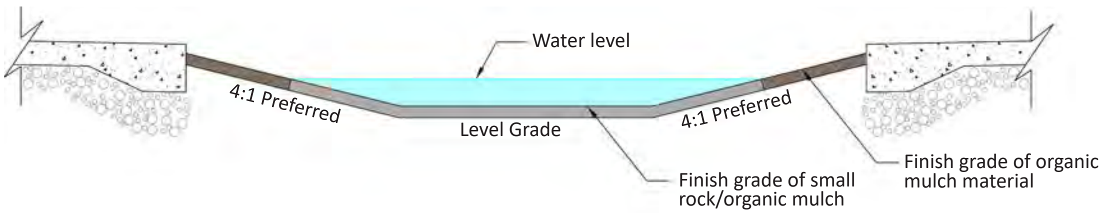
Undesirable Grading Scenario: Steep Slopes/Deep Facility



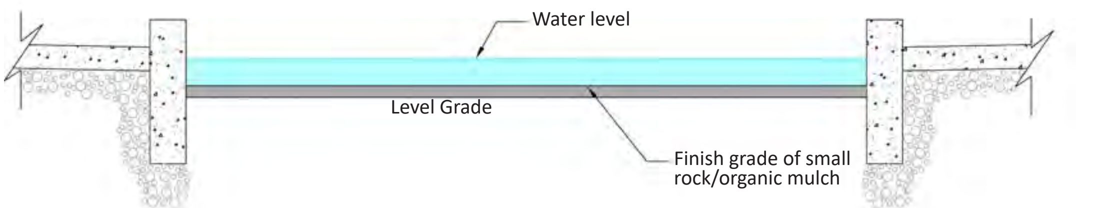
Optimum Grading Scenario: Gentle Slopes/Shallow Facility

Proper Mulch Placement

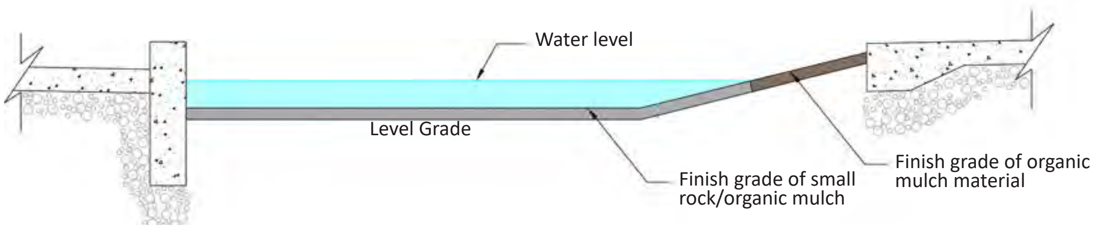
Mulching plant material is a critical maintenance activity that helps keep plants and soil healthy. Care needs to be taken to both the choice of mulch material and placement of the mulch. Organic mulch is best placed in areas that do not have contact with ponding or moving water to limit mulch movement. Pea gravel or small rock is a better choice where water is ponding or being conveyed through the landscape. See below for different conditions based on facilities having side slopes, no side slopes, or a hybrid facility.



Mulch Placement With Side Slope Condition



Mulch Placement With Planter Level-Grade Condition



Mulch Placement With Hybrid Condition


URBAN RAIN DESIGN

▲ *The basin portion and wetted zone of the side slopes of this rain garden is mulched with pea gravel and the upper side slopes are covered with organic mulch.*

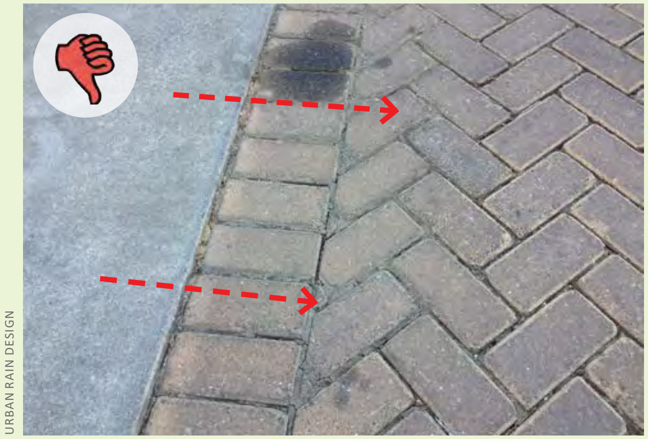

URBAN RAIN DESIGN

▲ *This flat planter-style landscape is completely mulched with small rock to control erosion with water flow.*


URBAN RAIN DESIGN

▲ *This stormwater curb extension has a hybrid of both pea gravel below the flow line of water and organic mulch along the side slopes that are above the flow line of water.*

4.10 Key Design and Construction Considerations
Effective Placement of Pervious Pavement

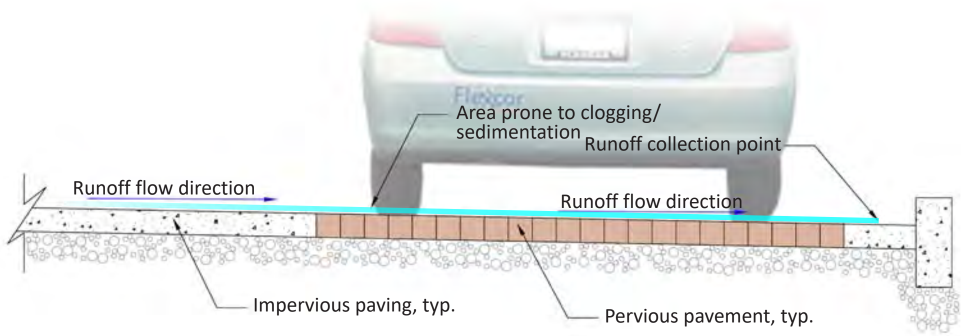


▲ *Stormwater runoff and sediment from impervious area is flowing onto and constantly clogging the joint spaces of concrete interlocking pervious pavers.*

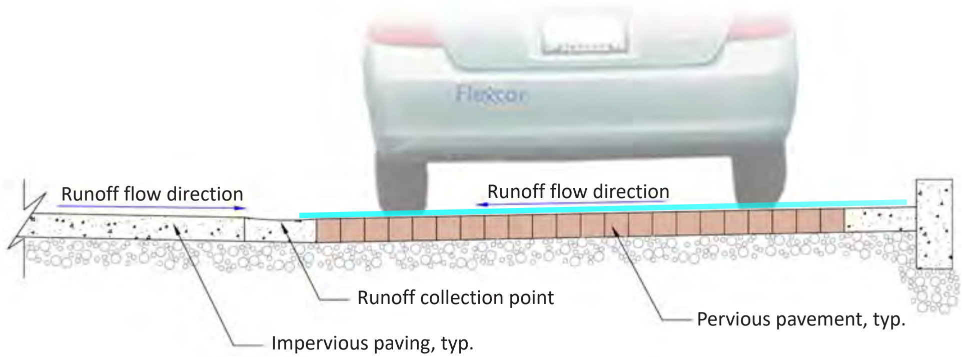
▲ *This application of permeable pavers only has direct rainfall to manage. There is no impervious area runoff directed to it.*

Effective Placement of Pervious Pavement

Pervious pavement works the best and is easiest to maintain if it only receives direct rainfall on it rather than run-on from adjacent impervious areas. When an impervious area runs onto pervious pavement it carries sediment loads that clog the pores of the pavement or the joints between the pavers depending on the type of pervious pavement. If pervious pavement is used, try to direct runoff away from the pervious surfaces to help reduce sediment transport. See sketches below.



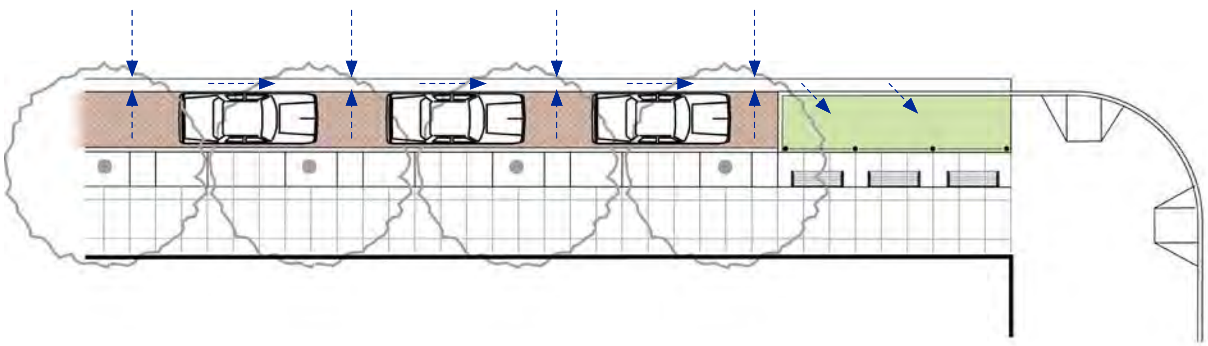
Undesirable Pervious Pavement Placement: Impervious Area Run-on



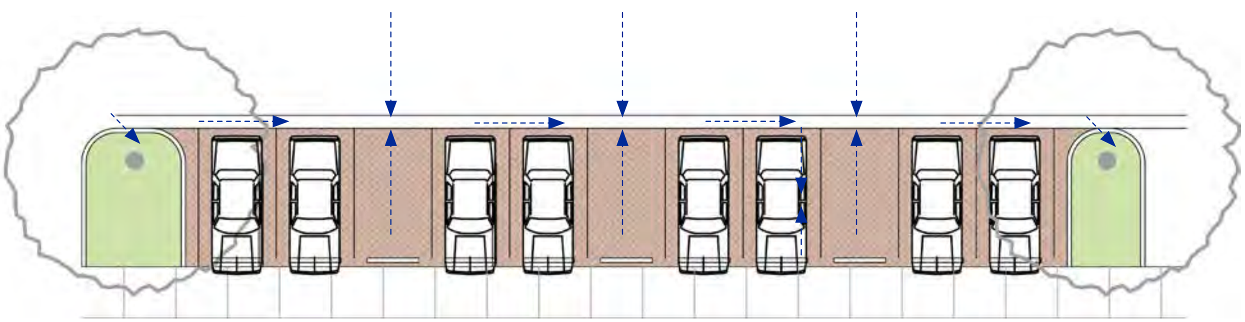
Optimum Grading Scenario: No Impervious Area Run-on

Optimal Pervious Pavement Placement/Grading Scenarios

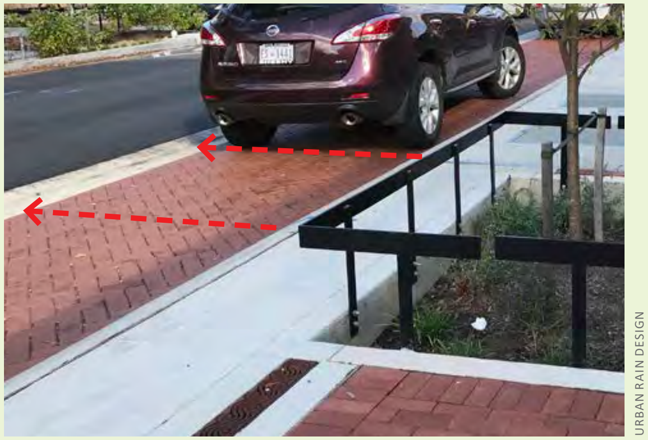
The design sketches below illustrate a street condition and a parking lot condition where pervious pavement is placed in parking stalls, but the majority of imperious area runoff is directed away from the pervious pavement.



Street Condition: Pervious Pavement in Parking Stalls



Parking Lot Condition: Pervious Pavement in Parking Stalls



▲ *This commercial street features pervious pavement within the parking lane of the street, however the parking lane is graded so the pervious pavement only manages rainfall and no run-on from impervious areas.*

▲ *This parking lot features pervious pavement within the parking stalls, however the parking stalls are graded so the pervious pavement only manages rainfall and no run-on from impervious areas.*

4.11 Key Design and Construction Considerations

Choosing and Placing Appropriate Plant Material

Putting the "Green" in Green Infrastructure

Green infrastructure projects should all be designed as amenities and with maintenance in mind. Hence, the decision on what plant material should be installed within a project site is an important one. There are essentially three primary considerations in choosing plants for a stormwater project: 1) general aesthetics; 2) choosing plants that can survive in both "wet" and "dry" conditions and are tolerant of sandy soils when biotreatment soil media is used; and 3) determining the correct plants for long-term maintenance anticipated for the project. Plant selection is also affected by use of Bay-friendly guidance if certification is required or desired and adherence to a jurisdiction's Water Efficient Landscape Ordinance (WELO). In addition, plant selection should consider climate adaptation and resiliency and future weather patterns such as temperature and changing rainfall volumes and durations. Refer to **Appendix 4** for additional information on plant use and selection. For additional information on maintaining landscaped stormwater facilities see **Chapter 6 Operations and Maintenance** of this Guide.

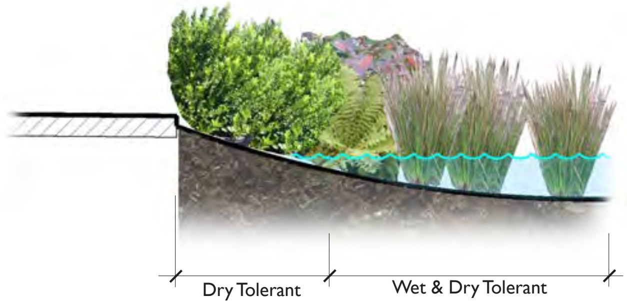
The overall look of a building, site, street, or parking lot stormwater landscape project can vary considerably. Plantings can have a relatively formal and manicured appearance, or they can have a more "natural" look. Regardless, the choice of plant material should fit with the surrounding landscape context (i.e., residential, urban, etc.). The overall diversity of plant material within a green street, site, building, or parking lot project can also affect aesthetics. A highly diverse planting palette with differing textures, colors, and growing heights can be very desirable. This is especially true for larger stormwater facilities and those that incorporate side slopes in the design. For those stormwater facilities that are smaller and more linear, such as stormwater planters, a single-species planting may be more appropriate. Regardless of the chosen palette, it is important to design and install the plant material at an appropriate density. Too often, stormwater facilities are installed with too few plants, so few, in fact, that one can't really call the project a "green street." A well-designed stormwater facility should have no bare ground showing after a two-year plant establishment period.

Except for trees, choose lower-growing plant material that do not exceed three feet in height. Low-growing plants tend to be more aesthetically and functionally preferable for green street and parking lot applications. In addition, low-growing plant varieties help to reduce ongoing maintenance by eliminating the need for plant trimming.

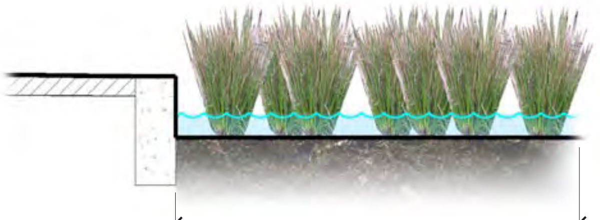
◀ *Well-chosen trees and landscaping provide a host of primary and secondary benefits, ranging from improving stormwater quality to increasing economic vitality of neighborhoods and commercial districts.*

The last aesthetic consideration is how much of the plant material should be designed as evergreen versus deciduous. It is recommended that at least 70% of the plant palette, excluding trees, be evergreen. This helps to ensure that green street, site, building, and parking lot projects have year-round plant structure. Having a predominantly evergreen green street also helps slow water runoff due to the persistence of leaves.

Green infrastructure projects may have different planting zones based on the type of stormwater facility used. Stormwater facilities that are designed with a side slope condition have two planting zones: dry and wet. Shrubs, groundcovers, and perennials that thrive in drier conditions should be placed on the upper portions of the side slopes while plants that can tolerate both wet and dry conditions are best suited for the low, flat bottom zone of the stormwater facility. Stormwater facilities that have only a flat-bottom condition with no side slope (e.g., stormwater planters) have only one planting zone that should only be planted with species that tolerate both wet and dry conditions. The illustrations below show the typical planting conditions based on stormwater facility type. It should be noted again that plants chosen for wet zone conditions should also have a level of drought tolerance in order to minimize, or potentially eliminate, the need for supplemental irrigation during dry periods.



Typical Side Slope and Flat-Bottom Planting Condition



Typical Flat-Bottom Planting Condition


QUADRIGA INC.

▲ *Differing texture and color of plant species combined with a high density of plant material can create very beautiful stormwater facilities.*


KEVIN ROBERT PERRY

▲ *Formal stormwater facilities that have a very manicured look can sometimes be indistinguishable from conventional landscapes.*


URBAN RAIN DESIGN

▲ *More natural-looking stormwater facilities can often provide a striking contrast to the formal appearance of urban sites and parking lots.*

4.11 Key Design and Construction Considerations

Choosing and Placing Appropriate Plant Material

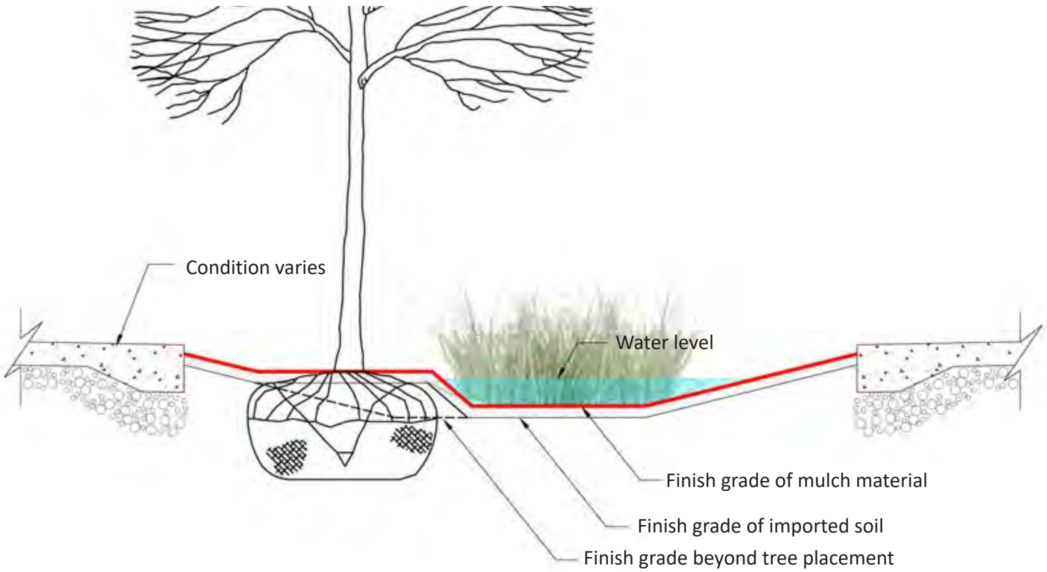
New Tree Placement

Trees are encouraged to be used within green infrastructure facilities whenever feasible and best suited for the site conditions. It is important to check with your local municipality's arborist for recommended tree species. Just as important as selecting an appropriate tree species, is to design for the correct placement of the tree within the stormwater facility. This is especially applicable with green infrastructure facilities that incorporate side slopes that transition in grade from the sidewalk/street elevation to the bottom of the stormwater facility. A common design mistake is to place the tree's rootball within the side slope grade to attempt to keep it out of contact with water. However, this tree placement scenario is not ideal for the following reasons:

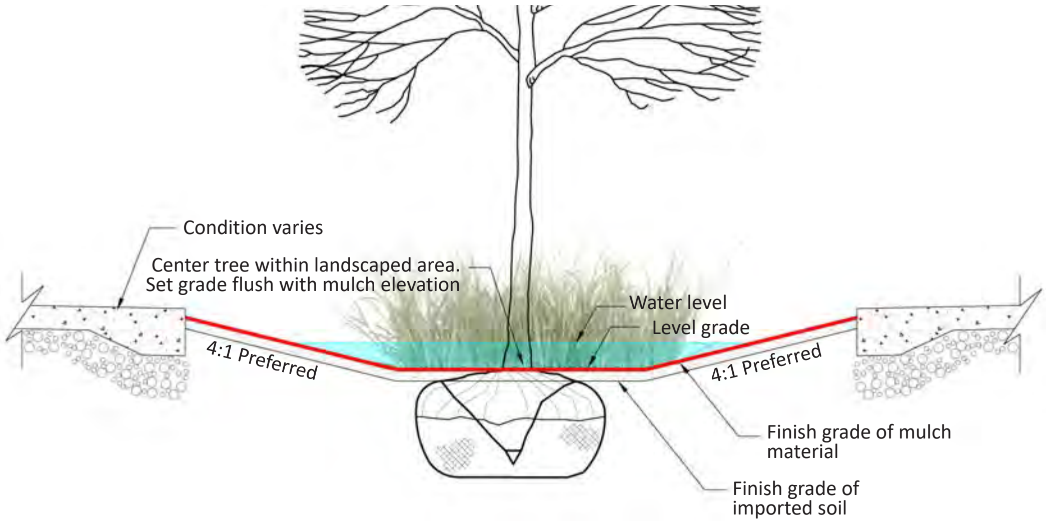
- It creates a "bulge" in the side slope grade that is prone to erosion and sometimes reduces the flow of water through the facility
- The raised rootball unnecessarily fills in a portion of the facility and reduces the overall stormwater retention capacity
- The tree placed along the side slope can be prone to leaning/falling over in the direction of the slope gradient as it matures
- It sites the tree closer to hardscape areas limiting the ability for tree roots to spread equally around the tree and may exacerbate sidewalk heaving as the tree matures
- From an aesthetic perspective, the offset tree placement can look out of balance within the landscape space

Conversely, the ideal tree placement is centered within the landscape space and at a flush elevation of the surround mulch (i.e. no raised condition above the wet zone) even if the tree is placed within the wetted zone of the green infrastructure facility. Most new trees, when properly selected, and allowed to adapt at a young age to their growing environment, can adapt to periods of water inundation. By placing trees within the center of the landscape and flush with the bottom elevation of the facility, the tree is balanced within the landscape, maximizes the amount of water retention, and can spread roots equally from the tree's rootball.

Other options exist to provide better growing conditions for trees within green infrastructure measures. These include placing tree root balls on existing native soil, if the native soils meet the regulated project infiltration rate requirements. For larger size facilities, trees can be located within an area of improved amended planting soil within a larger regulated project soil area or adjacent to a regulated project soil area.



Undesirable Tree Placement Scenario: Tree "Bulge" on Side Slope



Optimum Tree Placement Scenario: Tree Centered in the Landscape

▲ *The yellow dashed line shows how the grading within this stormwater curb extension is warped due to the tree placed above and outside the wetted zone. This scenario reduces the retention capacity of the landscape.*

▲ *Conversely, this stormwater curb extension features street trees located in the center of the landscape area and flush with the facility bottom. There is no mounding of the rootball area.*

▲ *Trees centered within the landscape have the most stable growing environment and can spread their roots equally throughout the facility.*

4.11 Key Design and Construction Considerations

Choosing and Placing Appropriate Plant Material

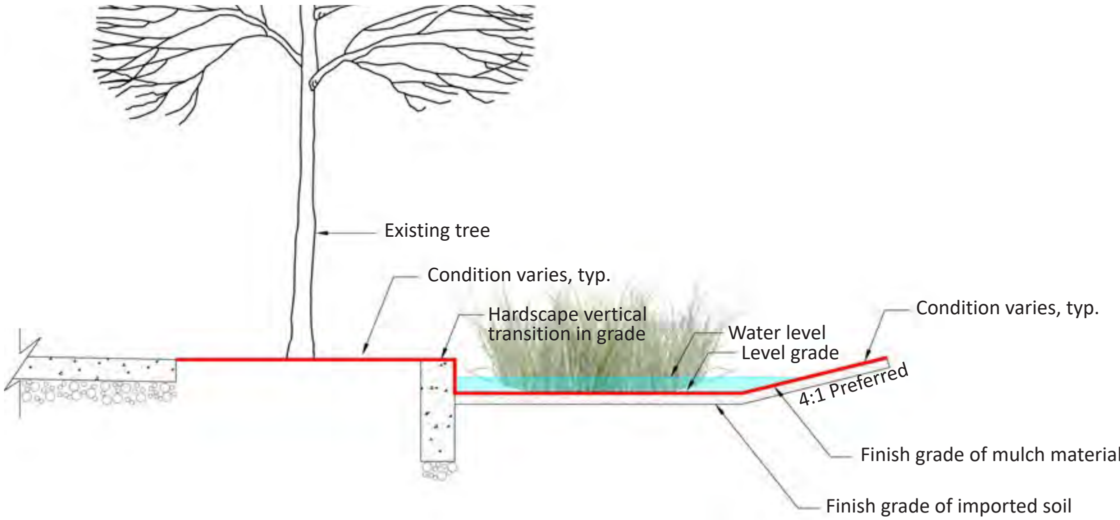
Working With Existing Trees

It is common to encounter mature existing trees living along streets, within parking lots, and around building perimeters that also happen to be excellent locations for green infrastructure facilities. This does not mean that existing trees and stormwater facilities cannot coexist. With some additional thought and care throughout the design and construction process, mature trees can play a integrated role with many green infrastructure projects. Some key design and construction questions when siting stormwater facilities adjacent to existing trees are, but are not limited to:

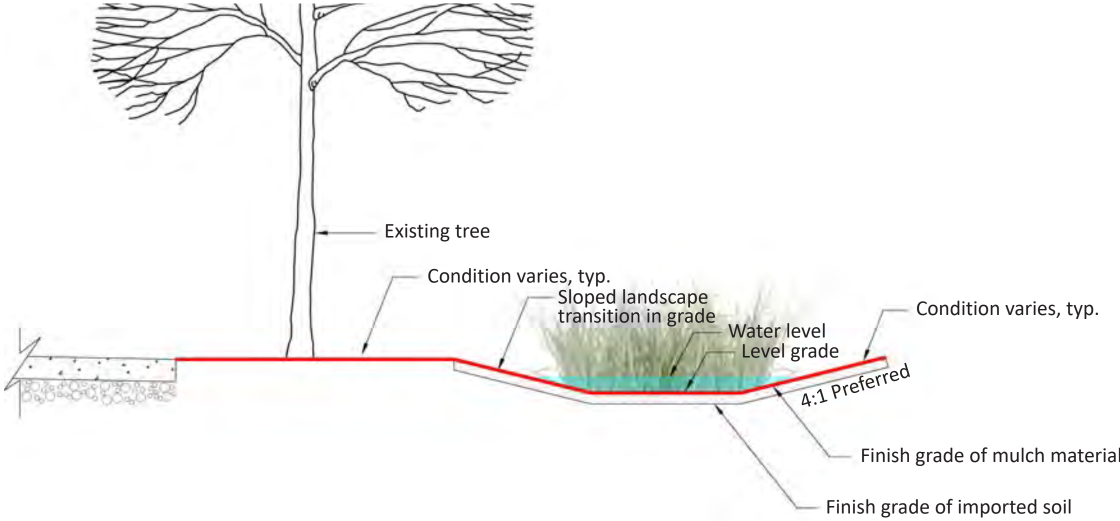
- Can the existing tree species thrive with the additional stormwater runoff at or near the tree's root zone?
- Is there enough horizontal space to allow for both the stormwater facility and still maintain the existing tree's current root zone space?
- Will there need to be significant regrading around the existing tree's dripline, and if so, do the existing site conditions allow for this to happen and still allow the tree to thrive?
- Can new plants and irrigation equipment be sited under the existing tree without harming existing roots?
- How can you assure during the construction process that the contractor will adhere to preserving the existing tree?

One of the most critical design decisions when integrating green infrastructure with existing trees is properly grading the soil to preserve as many roots as possible and determine how much runoff would ideally be retained (if any) within the dripline of the tree. Two common design methods to transition in grade from the existing tree grade to the recessed stormwater facility is to either allow for a vertical transition of grade by using hardscape material or a gentle sloping landscape transition. Both of these scenarios are illustrated on the opposite page. In either scenario, how far to start the transition in grade from the base of the tree trunk will need to be determined by assessing where the existing tree roots can handle disturbance and increased water input. This should always be determined by both an experienced arborist and landscape architect.

◄ *This stormwater curb extension retrofit along an existing residential street in Spokane, Washington allowed for the preservation of many mature street trees. Take note that there is still a vertical curb that allows for the transition of grade between the existing tree and the retrofitted stormwater curb extension.*



Vertical Curb Transition Between Existing Tree and Facility



Sloped Landscape Transition Between Existing Tree and Facility


KEVIN ROBERT PERRY

▲ *Stormwater curb extensions constructed at the NE Siskiyou Green Street used the existing street curb to be the vertical transition in grade between mature trees and the finish grade of the facility.*


KEVIN ROBERT PERRY

▲ *This stormwater curb extension had enough horizontal space to gently transition in grade between the mature trees and the finish grade of the facility.*


URBAN RAIN DESIGN

▲ *This stormwater curb extension allowed for both a gentle transition in grade and an ADA accessible metal grate to be placed over the landscape to accommodate better pedestrian circulation around the tree.*

4.11 Key Design and Construction Considerations

Choosing and Placing Appropriate Plant Material

Top Plant Recommendations for Green Infrastructure Facilities

The following list of plants is divided in three categories: trees, plants suited for growth on the side slopes of stormwater facilities, and plants that withstand both inundation and dry conditions at the basin of the facility. This list includes key plants that are observed to be some of the best candidates for planting within stormwater facilities. This is only a small listing of possible plant choices. Additonal planting information is available in **Appendix 4** of this guidance document and a more extensive plant list exists within Appendix A of the **C.3 Regulated Projects Guide**, a document produced as part of the Countywide Program. The document can be found at www.flowstobay.org.

Category	#	*Scientific Name* / Common Name	Light Preference	Water Requirement	Size ↑ Height ⇔ Width	CA Native	Notes
TREES	1	***Acer rubrum*** Red Maple	Sun to Partial Shade	Medium	↑ 50′ ⇔ 40′	No	Good performer within the basin of stormwater facilities.
	2	***Gingko biloba*** Maidenhair Tree	Full Sun	Medium	↑ 60′ ⇔ 35′	No	Long-lived, can perform well with poor soils and wet conditions.
	3	***Lagerstroemia indica*** Crepe Myrtle	Full Sun	Low	↑ 6-25′ ⇔ 6-20′	No	Good small tree that can perform in both dry and wet conditions.
	4	***Nyssa sylvatica*** Black Tupelo	Sun to Partial Shade	Medium	↑ 40′ ⇔ 25′	No	Can perform well with in wet and dry conditions.
	5	***Platanus acerifolia 'Columbia'*** London Plane Tree	Full Sun	Medium	↑ >50′ ⇔ 35′	No	Long-lived, can perform well with poor soils and wet conditions.
	6	*Quercus spp.* Oak	Full Sun	Varies	Varies	Varies	When planted young, can perform well with wet and dry conditions.
SIDE SLOPE PLANTS	7	***Bulbine frutescens*** Stalked Bulbine	Sun to Partial Shade	Low	↑ 1′-2′ ⇔ 1′-2′	No	Very drought-tolerant, no trimming needed.
	8	***Mimulus aurantiacus*** Sticky Monkey Flower	Sun to Partial Shade	Low	↑ 3′ ⇔ 3′	Yes	Very drought-tolerant, no trimming needed.
	9	***Muhlenbergia rigens*** Deer Grass	Sun to Partial Shade	Low	↑ 4′-5′ ⇔ 4′-6′	Yes	Very drought-tolerant, light trimming once annually.
	10	***Salvia chamaedryoides*** Germander Sage	Full Sun	Low	↑ 1′-2′ ⇔ 3′-4′	No	Very drought-tolerant, no trimming needed.
	11	***Teucrium chamaedrys*** Wall Germander	Full Sun	Low	↑ 1′-2′ ⇔ 2′-3′	No	Very drought-tolerant, no trimming needed.

BASIN PLANTS

#	*Scientific Name* Common Name	Light Preference	Water Requirement	Size (Height / Width)	CA Native	Notes
12	***Carex divulsa*** Berkeley Sedge	Sun to Partial Shade	Low	↑ 1'-2' ↔ 1'-2'	Yes	Good sedge for shade. Hand brush out leaves annually.
13	***Carex flacca*** Blue Sedge	Sun to Shade	Medium	↑ 6"-1' ↔ 1'-1.5'	No	Good sedge for sun/part shade. Light trimming once annually.
14	***Chondropetalum tectorum*** Small Cape Rush	Sun to Partial Shade	Low	↑ 2'-3' ↔ 2'-3'	No	Good rush for sun to part shade. No trimming needed.
15	***Juncus inflexus 'Blue Dart'*** Blue Dart Rush	Full Sun	Medium	↑ 1'-2' ↔ 1'-2'	No	Good rush for full sun. No trimming needed.
16	***Juncus patens 'Elk Blue'*** Elk Blue California Gray Rush	Sun to Shade	Low	↑ 1'-2' ↔ 1'-2'	Yes	Good rush for full sun. Light trimming once annually.
17	***Lomandra longifolia*** Dwarf Mat Rush	Sun to Partial Shade	Low	↑ 3'-0" ↔ 3'-0"	No	Good grass for sun/part shade. Hand brush out leaves annually.

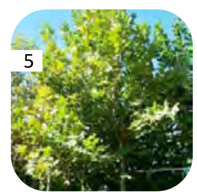
TREES

LAMBIQUE

SEWILCO

VILLAGE NURSERIES

KRISTINE PAULUS



VILLAGE NURSERIES

CHRISTIAN LINDER

SIDE SLOPE PLANTS

VILLAGE NURSERIES

JOE DECRUYENEARE

STAN SHEBS

VILLAGE NURSERIES

VILLAGE NURSERIES

BASIN PLANTS

ANDREY ZHARKIKH

ELSA SPEZIO

VILLAGE NURSERIES

FOREST & KIM STARR

VILLAGE NURSERIES

ANNA GREGORY (FLICKR)

4.12 Key Design and Construction Considerations

Sizing of Green Infrastructure Facilities

Standard Sizing Methodology

MRP Provision C.3.d specifies minimum hydraulic sizing requirements for stormwater treatment measures at regulated projects. Regulated projects must treat the water quality design flow or volume of stormwater runoff through infiltration, biotreatment, or capture and use. Certain regulated projects must also meet the sizing requirements for hydromodification management (HM) in Provision C.3.g, depending on the location and amount of impervious surface created and/or replaced on the site.

Chapter 5 of the **C.3 Regulated Projects Guide** contains detailed procedures for sizing specific stormwater treatment measures using volume-based sizing criteria, flow-based sizing criteria, or a combination flow and volume approach. The volume-based design standard is capture and treatment of 80% of the annual runoff (the small, frequent storm events.) There is also a simplified sizing method for biotreatment in which the surface area of the treatment measure is equal to 4% of the contributing impervious area, i.e., a sizing factor of 0.04[3].

In general, green infrastructure facilities are required to meet the same sizing criteria as regulated projects. Green infrastructure should be sized to treat the C.3.d flow and/or volume of runoff from contributing impervious surface areas in the public realm (e.g., street, sidewalk, parking lot, etc.) as well as portions of adjacent parcels that drain to those areas if necessary. If site constraints in the public right of way prevent sizing green infrastructure to meet C.3.d sizing requirements, the alternative sizing methodology described below may be used.

3 This sizing factor is based on a permeability of 5 inches per hour (in/hr) through the biotreatment soil media and a rainfall intensity of 0.2 in/hr, as specified in MRP Provision C.3.d.

Alternative Sizing Methodology for Street Projects

Recognizing that green infrastructure in the public right of way may not be able to meet the standard sizing methodology due to constraints such as lack of space, utility conflicts, or other factors, the MRP allows non-regulated green street projects with documented constraints to use an alternative sizing methodology. BASMAA has developed regional guidance for alternative sizing, based on a hydrologic modeling analysis, with sizing curves for the minimum bioretention surface area needed to provide treatment of 80% of annual runoff (per C.3.d) and design approaches to use when the C.3.d sizing requirements cannot be met[4].

The hydrologic analysis report provides an equation to calculate the minimum bioretention sizing factor to meet C.3.d based on the mean annual precipitation (MAP) of the project site:

Sizing Factor = 0.00060 x MAP + 0.0086

Where: Sizing Factor is the ratio of the surface area of the bioretention facility to the impervious area contributing runoff

Based on this equation, green street bioretention facilities in some areas of the County can be sized with as low as a 2% sizing factor and still meet the C.3.d sizing requirements.

If a green street opportunity is constrained such that the minimum sizing factor cannot be achieved, undersized green infrastructure measures may still be worth constructing to provide some water quality, runoff reduction, urban greening, or other community benefits. The sizing curves in the BASMAA guidance can be used to determine what percentages of the C.3.d volume are treated in smaller facilities. Refer to **Appendix 7** for the complete document, *Guidance for Sizing Green Infrastructure Facilities in Street Projects*, and its companion technical memorandum, *Green Infrastructure Facility Sizing for Non-regulated Street Projects*.

4 BASMAA, 2018. *"Guidance for Sizing Green Infrastructure Facilities in Street Projects."*


URBAN RAIN DESIGN

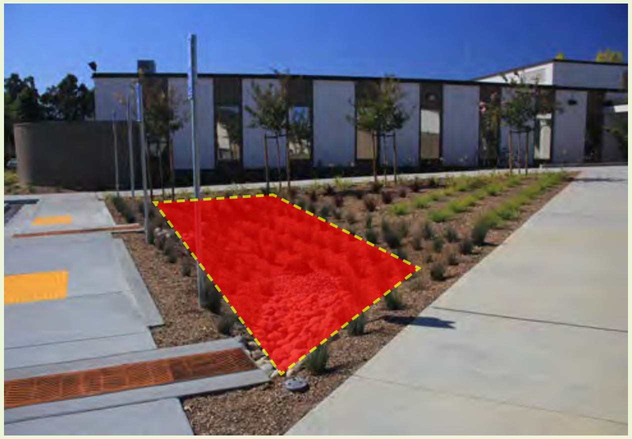
▲ *Regulated green infrastructure projects, such as this green street project, will need to meet the minimum sizing requirements specified in the MRP Provision C.3.d.*


KEVIN ROBERT PERRY

▲ *Non-regulated projects can be alternatively sized with a landscape system as low as a 2% sizing factor.*

4.12 Key Design and Construction Considerations

Sizing of Green Infrastructure Facilities


URBAN RAIN DESIGN

▲ *This triangular space does not maximize the potential for stormwater management. Only the red shaded portion is graded to accept runoff.*


URBAN RAIN DESIGN

▲ *Same project site, same issue of wasted landscape space that could be utilized for additional stormwater management. Only the red shaded portion is graded to accept runoff.*

Designing Beyond What Is Required

Many new and redevelopment sites have ample landscape or hardscape area within the overall site plan to incorporate green infrastructure to capture and manage stormwater runoff. However, designers often simply follow the standard sizing methodology and allocate the bare minimum amount of stormwater landscape required even if there is ample space to spread the footprint of the stormwater treatment area throughout the site. What results is not only "doing the bare minimum", but it also often creates a disjointed landscape feature with a "pit" within an expanse of conventional landscape.

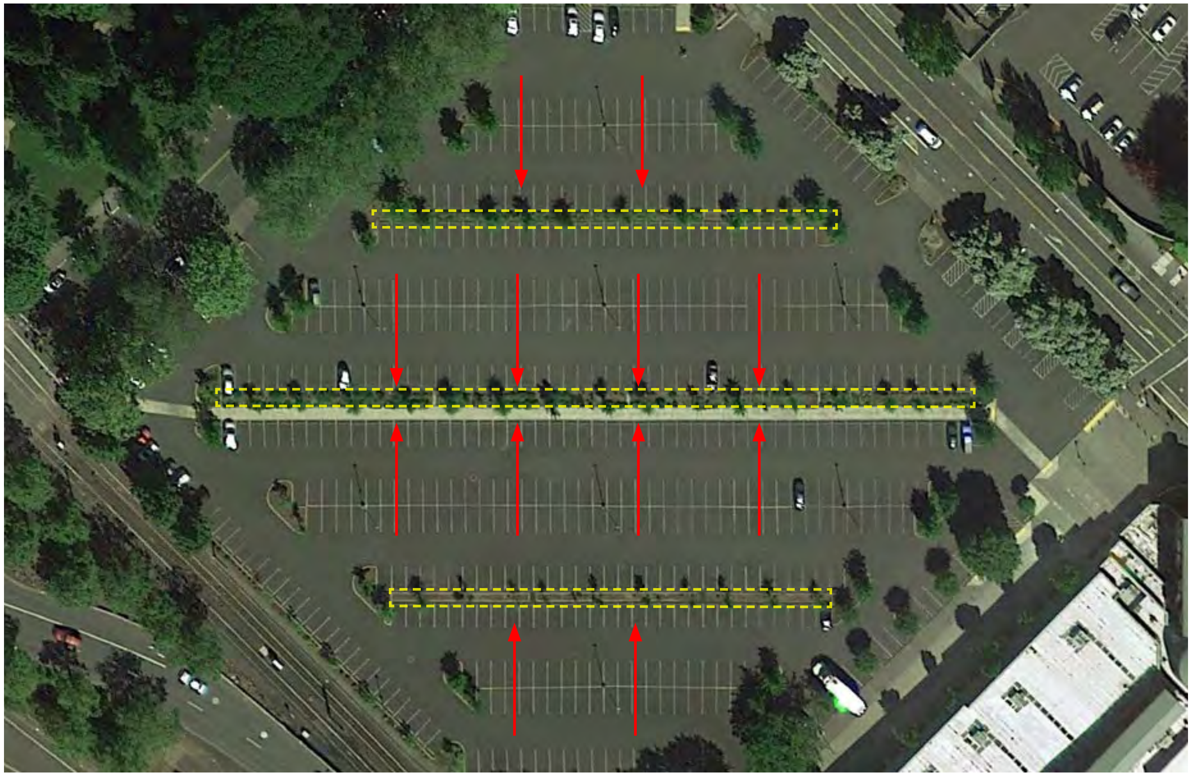
A better and more cohesive landscape approach is to certainly meet the site's minimum required sizing but to also strive to maximize the footprint of the recessed stormwater landscape within the available site area. This will help to manage as much stormwater runoff as possible and integrate the stormwater better within the entire site design rather than looking like an add-on to the surrounding landscape.

Limited Capacity Facilities

Similar to not maximizing the footprint of the overall site landscape area is not providing enough retention depth so water can be collected, slowed, and treated. Many facilities, while adequately sized according to a sizing methodology, are graded so shallow that they do not retain enough water to meaningfully manage runoff within the landscape or the overflow inlet does not allow for the retention of water. While predominately a grading issue, allowing little or no water retention effects the overall sizing assumption and limits the performance of the facility. An exception is if a facility is designed with no underdrain system within an area of poor draining native soils. In this situation, it is the correct approach to limit the retention depth of water as to not have of standing water in facilities for prolonged periods of time.

"One Size Takes All" Facilities

Providing enough landscape space is just one component in adequately sizing stormwater facilities. The other consideration is where to place this landscape to capture runoff once it is sized. The most common placement of a stormwater facility is at the lowest elevation of the drainage management area to maximize the capture potential of landscape. This is the best approach to siting and sizing facilities that capture less than 10,000 SF of impervious area runoff. However, this "one size takes all" facility can quickly be overcome with a drainage in a short period of time with larger parking lot conditions. With sites that have large parking lots or buildings footprints, it is better to distribute and space the stormwater facility landscape throughout the drainage shed as to manage the runoff in smaller doses during storm events. This approach helps lessen the burden on each landscape system and helps mimic the natural hydrology of slowly spreading water through the landscape.


GOOGLE EARTH

▲ *This large parking lot retrofit in Portland, Oregon distributes stormwater landscape evenly so that runoff is capture in smaller volumes rather than conveying all the runoff into one larger stormwater facility.*

Helpful Tips for Increasing Opportunities for Green Infrastructure in San Mateo County

Many development and street projects do not trigger C.3 Regulated Project requirements due to their size or nature of project. For projects such as these, project proponents should be encouraged, and even incentivized, to provide green infrastructure measures to aid in reaching each jurisdiction's targeted pollutant load reductions and to provide other community benefits.

For constrained non-regulated green street projects that are desired to achieve treatment credit, utilize BASMAA's guidance that allows for green infrastructure measures to use a smaller sizing factor. **See Section 4.12** for more detail.


WWW.PINTEREST.COM/PIN/487655465888451951

▲ *This large parking lot distributes the stormwater landscape evenly throughout the parking lot.*

4.12 Key Design and Construction Considerations
Sizing of Green Infrastructure Facilities


URBAN RAIN DESIGN

▲ *This stormwater planter captures stormwater runoff at the perimeter of a parking lot.*


URBAN RAIN DESIGN

▲ *This parking lot features distributed landscape spaces within the interior of the parking lot to capture stormwater runoff.*

Sizing Example for a Parking Lot

The opposite page shows a typical parking lot condition in San Mateo County with approximately 53,000 square feet of impervious area draining towards the periphery of the site. The two examples illustrate the amount of landscaped space needed to manage the stormwater runoff with a hypothetical simplified 4% sizing criteria. Using this sizing percentage, the design for both examples would require 2,120 square feet of landscaping designed to capture the impervious area runoff. Each example, however, distributes the 2,120 square feet of drainage in different ways.

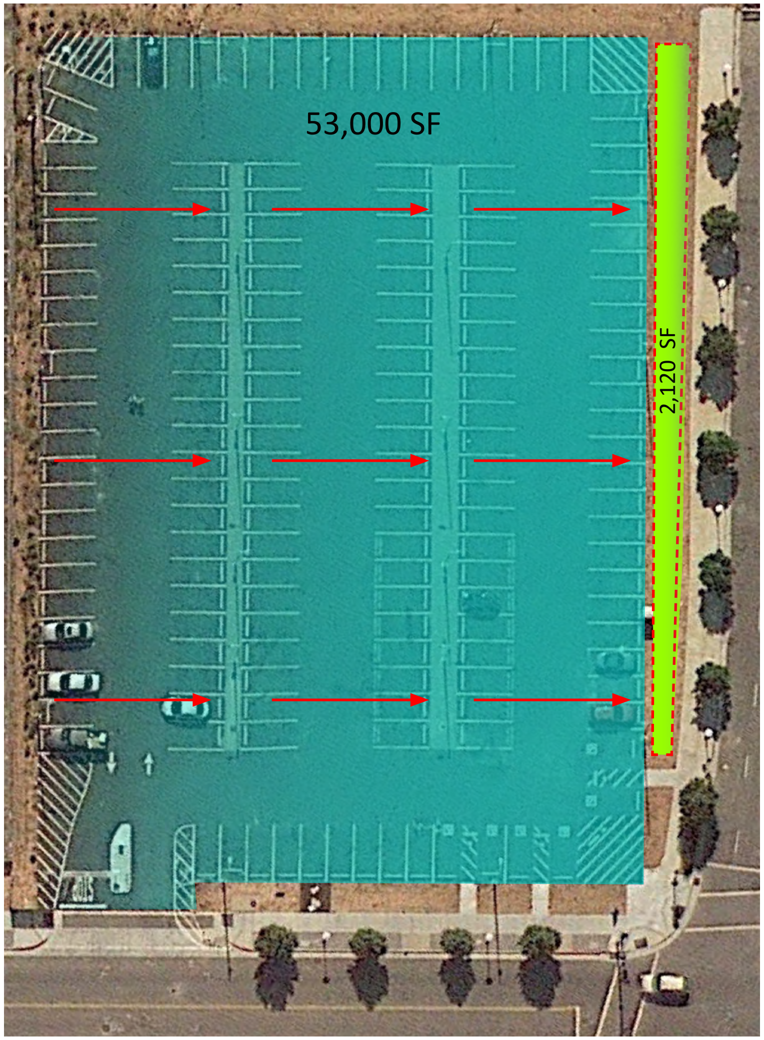
Alternative 1: Peripheral Stormwater Landscape

Consolidates the entire 2,120 square feet of require landscaping along the periphery of the parking lot and modifies the existing landscape's grading and planting to capture the parking lot runoff. Where there is existing space on the edge of parking lots, this alternative works well.

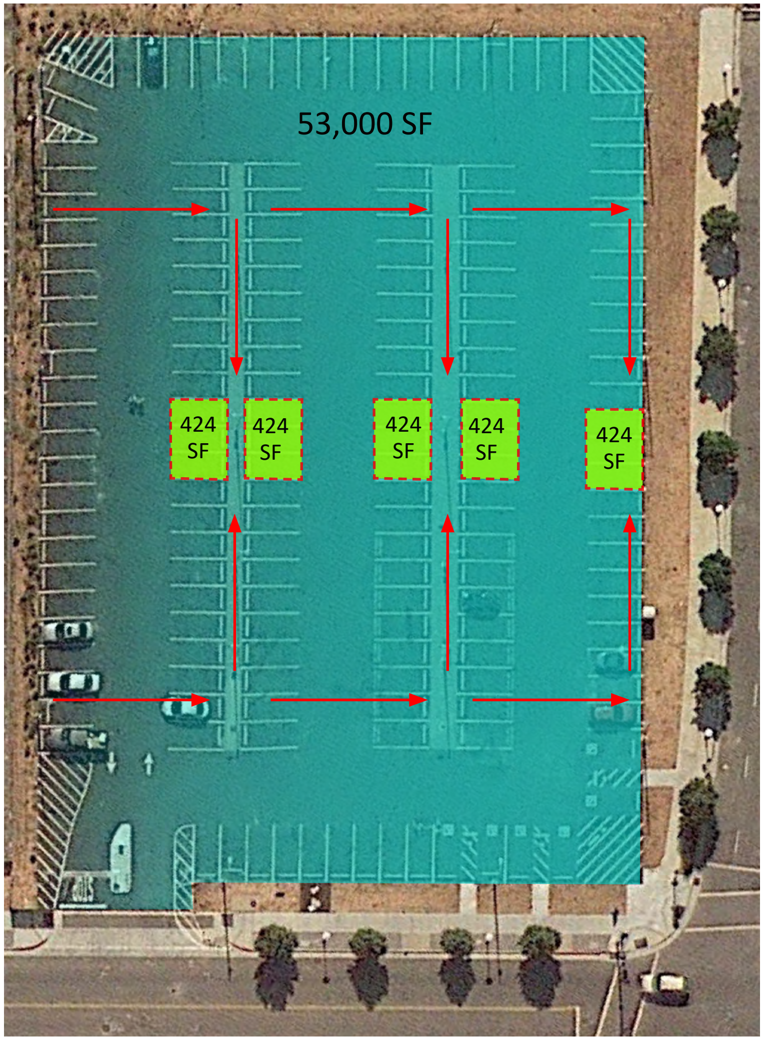
Alternative 2: Distributed Stormwater Landscape

In some cases, there isn't the luxury of existing space around parking lots or the existing grading prohibits the change of this landscape. In this situation, the stormwater landscape required will need to be added within the layout of the parking lot itself. Alternative 2 illustrates how parking stalls are consolidated into five distributed stormwater planters, each measure approximately 424 square feet, to capture the impervious area runoff.

Both Alternatives 1 and 2 have adequate amount of stormwater landscape required to meet the 4% sizing criteria. When space is very tight to meet this sizing, it is also recommended to also use pervious pavement systems in the parking stalls. This combined approach will lessen the amount of stormwater landscape needed to meet the sizing requirement.



Alternative 1: Peripheral Stormwater Landscape Allocation



Alternative 2: Distributed Stormwater Landscape Allocation

CD+A

4.13 Key Design and Construction Considerations

Construction Administration Process

Construction Administration Process

Designers and/or the project engineer (city or client representatives) need to be prepared to spend time on the construction site and to review the contractor's submittals in order to provide proper review of materials used and observation of construction techniques employed to implement the design. However, often times there is only limited budget available for the construction administration process. Due to the innovative nature of green stormwater infrastructure for buildings, sites, parking lots, and streets, it is important for everyone involved with the planning and design of these projects, and especially for retrofit projects, that a well-planned and funded construction administration scope and schedule be developed and implemented. Without adequate construction administration, a project, no matter how well designed, can lose functional and aesthetic value. In addition, many contractors are not only new to installing green stormwater infrastructure, but they can also be new to the construction of some other elements of complete streets design which are often used in the design of green sustainable streets. Therefore, it is important to maintain strong communication between the designer, project engineer, contractor, and subcontractors from the bidding process all the way to the construction close-out of the project. The following outlines a general schedule of construction phases in which the designer and project engineer should be at the project site in close coordination with the contractor. Refer to the other portions of the GreenSuite for additional guidance.

Project design and construction documentation, procedures, and administration also needs to consider whether the project will seek, or is required to satisfy, other certifications such as LEED® or Bay-Friendly Landscape. Requirements for these and other certification may differ from standard design and construction by specifying the use of organic products, products produced locally, and other considerations. The designer and project engineer need to understand and incorporate these elements, as necessary.

Pre-Construction Planning Phase

The bid documents should establish specific qualifications for each discipline that will do work related to the construction of green infrastructure in order to establish quality assurance in the contractor selection process. This may include requiring certain certifications or other appropriate proof of experience in constructing green infrastructure. At the pre-construction meeting, the designer and project engineer should jointly explain the function, design, and expected construction quality of the green infrastructure and related elements to ensure that the design goals are met. This should include discussion of any special procedures related to potentially targeted project certifications, such as a LEED® or Bay-friendly Landscape certification.

Construction Phase

Demolition Phase

For retrofit projects, carefully remove existing concrete or asphalt and limit the amount of debris that mixes into the native soils. For instance, concrete and asphalt debris can be detrimental to plant health as they raise the alkalinity of the soil. Chunks of debris mixed into the soil limit the soil volume available to plants and negatively affect soil texture. After removing existing concrete or asphalt areas and stockpiling native soils that are intended to be used for green infrastructure, the native soil should be analyzed by an accredited soil testing laboratory to ensure that it is suitable to support healthy plant growth and vitality regardless of the landscape area being used for green infrastructure or not, and meets the required percolation rate if the facility will be infiltrating into the native soil. The laboratory should also recommend any needed soil amendments to improve the quality of the native soil and/or recommend the use and quality of imported soil. The compaction of native soils in areas to be used for green infrastructure should be avoided during the demolition and later construction phases. Finally, the contractor or designated utility company representative must check the site to verify the location of existing and new utility lines, vaults, and related equipment that are identified in the construction documents, and verify if there are any additional utilities that are not identified in the documents, as utility infrastructure may impact the placement and function of the stormwater facility.

Grading Phase

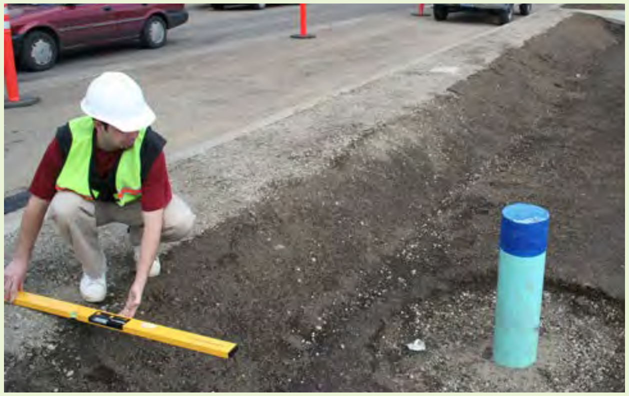
In new and some retrofit site, parking lot, or street projects, grading and re/construction will occur. The rough grading and placement of paving materials must be done carefully around green infrastructure facilities and prevent compaction of soils where native soils are to be used for green infrastructure, excepting where soil compaction is needed for structural elements such as deepened curbs. Subsoils and poor soils should be not be stockpiled or inadvertently placed onto native soils that will be used for the green infrastructure facilities. Care should also be taken to verify that elevations shown on surveys and construction plans can be achieved on site and that the grading of paved surfaces will provide proper stormwater flow into green infrastructure measures.


CD+A

▲ *In retrofit projects, existing curb and gutter can be sawn cut to project parameters and aid in reducing erosion of soil at existing landscape. Wrapped wood lumber or straw wattles can be used to protect existing tree trunks from damage.*


CD+A

▲ *Demolition phases need to protect existing utilities and structures to remain, and in some cases, allow for the extension or modification of those improvements. In this example, an existing storm drain line was designed to extend out into in this rain garden.*


NEVUE NGAN ASSOCIATES

▲ *Both hardscape and soil grades should be checked frequently by both the contractor and designer during the construction process.*

4.13 Key Design and Construction Considerations

Construction Administration Process

NEVUE NGAN ASSOCIATES

▲ *Imported soil is being "delivered" to stormwater planters by means of a conveyor belt shooting the soil mix from 50 feet away. The entire process is orchestrated via remote control by the contractor and landscape architect.*

CITY OF FORT COLLINS, CO, BASIL HAMDAN

▲ *Stakes and ties provide this newly planted tree with support while it acclimates to its new condition. An agreement between a developer and the city allowed multiple shared use green infrastructure measures to collect runoff from private and public areas.*

Hardscape Construction Phase

Forms and subsurface drain lines, facilities, and other components should be inspected prior to pouring concrete and/or installing asphalt or other paving, including edging of permeable pavers or similar units, to ensure accurate grades and elevations for conveying runoff into and out of stormwater facilities. In some cases, it is best to place pervious pavement after the planting phase to avoid getting soil dropped onto and clogging the system. If pervious pavement is placed prior to planting, it should be protected during subsequent phases to prevent soil, sediment, and other debris from entering the pervious pavement.

Green Infrastructure Grading and Soil Preparation Phase

Soil preparation and grading activities for green infrastructure should be done in dry conditions without standing water on the soil surface or in planting pits. Compaction of soil in green infrastructure areas with heavy equipment during construction must be avoided. Native soil should be excavated to the design depth. For conditions where native soil will be used for green infrastructure, any compacted soil should be rototilled prior to placement of stockpiled soil or imported soil and planting. Imported topsoil mix and/or compost should be tilled-in with the native soil conditions in 6-inch lifts or as otherwise recommended in the soils report or specifications, and as required by local ordinances (e.g., water efficient landscape).

For conditions where a biotreatment soil media is used, the soil media should be placed in 6-inch lifts. Foot-compaction or a landscape roller should be used to finish the grade and settle the soil in the stormwater facility. Soil grades of green infrastructure measures must be designed to account for an additional 3-inch mulch layer. Final grades of the stormwater facility should be checked and adjusted in the field as necessary to assure that bottom elevations and side slopes are built accurately. Stormwater entrances should be temporarily blocked off as needed in order to protect the newly graded soil from receiving stormwater flow. This will allow time for the soils and mulch to settle, plants to establish roots, and limit erosion.

Plant Installation Phase

Plant installation activities should be done in dry conditions without standing water on the soil surface or overly wet soil. If plants are installed in dry summer months, an irrigation source should be established to water plants at least for the length of the establishment period identified in the project specifications. The contractor should be required to provide a submittal showing that plant species and quantities have been ordered prior to the plants being delivered to the project site. Consideration should be given to having the designer and project engineer inspect and approve plants at the nursery prior to delivery. For projects that are to be certified as Bay-friendly Landscape, it should be ensured that any plant substitutions maintain project credit achievements. The specified mulch material should be applied after approval of any required submittals.

Stake trees for stability until tree roots extend beyond the root ball and are established in the bioretention soil. In windy sites, three stakes are recommended. Once established, remove tree stakes and ties.

No fertilizers should be applied in green infrastructure areas. If additional nutrients are needed as determined by the soil laboratory analysis, compost tea can be applied. See the **C.3 Regulated Projects Guide** for additional information.

Post-Construction Observation Phase

Requirements of the Construction Contract

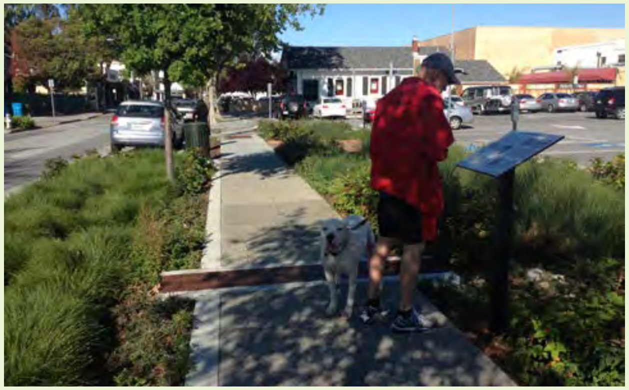
The project owner's representative/engineer and prime contractor should visit the project site often during the plant establishment and maintenance phase of the construction contract to determine if the green infrastructure is performing successfully. Particular attention should be given to any signs of erosion, poor plant health, lack of maintenance, prolonged periods of ponding of water, and inlet/overflow/check dam malfunctions and related issues. There are particular recommended practices for pervious pavement installations; refer to **Section 3.1 General Design Strategies and Guidelines**, **Section 3.5 Sustainable Streets Strategies and Guidelines**, and pervious pavement specifications in **Appendix 4**. This will also be the time operations and maintenance of the project begins and, for green streets and other public projects, is generally the responsibility of the jurisdiction. See **Chapter 6 Operations and Maintenance**.

Other Post-Construction Evaluation

A post-construction survey of the general public is recommended, particularly for public projects, to determine if the project is successful from a community perspective. In the case of a green streets project, the survey should include questions about both the performance and perception of the green infrastructure component and the complete streets aspects of the project.

CD+A

▲ *Projects should be observed as to whether the project is functioning as designed and corrected if issues are found.*



KEVIN ROBERT PERRY

▲ *Post-construction surveys of users and maintenance personnel can aid in improving future projects.*

NEVUE NGAN ASSOCIATES

▲ *Sand bags are placed in front of curb cut inlets in order to help protect soil and plant material immediately after planting.*

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

SHERWOOD DESIGN ENGINEERS

▲ *Orange County Great Park and the City of Irvine are implementing an ecodistrict-based Water Management Plan to capture stormwater from 5,550 acres of contributing watersheds and reuse it for non-potable uses. Pretreated stormwater and dry-weather runoff is directed and stored in retention basins to mitigate flood risk, allow for natural recharging of local aquifers, and enable the reuse of runoff for irrigation purposes.*

CD+A

▲ *A drop structure and rubber dam have been placed within an existing culverted drainage channel within Mayfair Park, Lakewood, CA, to divert dry-weather and first flush stormwater runoff for treatment, storage, and reuse for park irrigation needs or to be returned to the channel. Treated water is not infiltrated, as site soils do not have adequate permeability. Real time controls optimize the facility's performance.*

Regional Multi-Benefit Stormwater Capture and Reuse Projects

Overview

Regional stormwater capture projects consist of facilities that capture and treat stormwater from off-site. The primary objective of regional projects is often flood attenuation, but many also contain a water quality treatment or infiltration component. Regional stormwater capture projects collect runoff from large drainage areas and typically require larger parcels for siting the facility. Ideal locations for regional stormwater capture projects exist in public open spaces such as parks, sports fields, parking lots, and schools. Common examples of regional stormwater capture are detention basins, retention basins, and subsurface infiltration galleries or chambers. Subsurface structures may be preferable in developed areas so as to retain the use and function of the ground surface in the project. Subsurface infiltration systems can take the form of perforated metal or plastic pipes, concrete arches or vaults, or plastic chambers and crates with open bottoms (SMCWPPP 2016).[5]

It can be beneficial for multiple jurisdictions and agencies to collaborate and share in the implementation and maintenance of green infrastructure projects, including those where watersheds and stormwater runoff do not match jurisdictional boundaries. Regional projects provide an opportunity for partnerships to explore and implement projects that can provide an entire region, watershed, or neighborhood with greater environmental benefits for a reduced cost. Partnering on such projects can offer many benefits in planning, funding, constructing, operating, maintaining, and evaluating green infrastructure improvements. Regional stormwater capture projects can provide a wide economy-of-scale savings and achieve multiple goals with a single, larger project rather than with multiple smaller projects. By sharing resources and funding, regional projects can be delivered more efficiently. While it can be challenging to develop mechanisms for sharing the planning, capital, operations and maintenance, and administrative aspects of a regional project, the outcome can be worth the additional time and resource investment required to make these projects possible.

There are a number of opportunities for regional and local agencies to partner with state and federal agencies, such as Caltrans, to utilize sources of funds reserved for water quality improvement, hazard mitigation, and multi-benefit stormwater capture and management projects. In this way, state and federal agencies can meet their mitigation goals while benefiting local watershed objectives. The following three projects (one local to San Mateo County) are case studies of regional multi-benefit stormwater capture projects that can inform future projects.

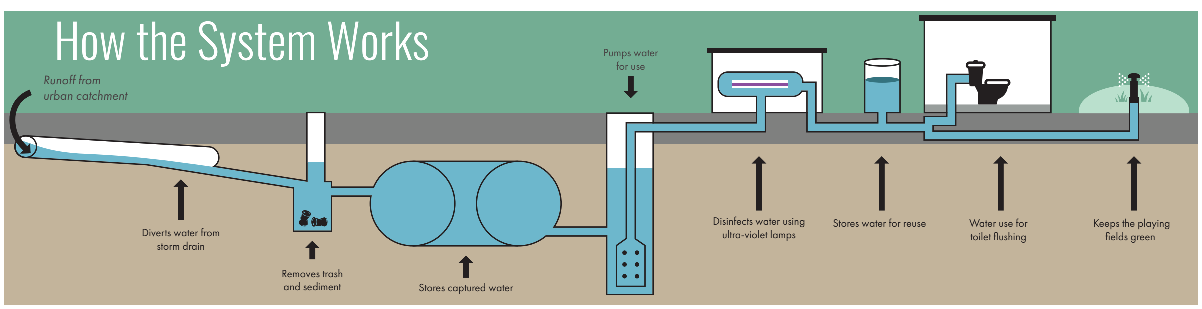
[5] Stormwater Resource Plan for San Mateo County. Paradigm Environmental and Larry Walker Associates for San Mateo Countywide Pollution Prevention Program. February 2017. Pages 49-50.

Los Amigos Park, Santa Monica, California

The Los Amigos Park Storm Water Harvesting and Direct Use Demonstration project was a collaborative effort between the City of Santa Monica, the Santa Monica Malibu Unified School District, and the Metropolitan Water District of Southern California. The grant-funded project is intended to demonstrate the effectiveness of harvesting urban runoff for beneficial uses such as indoor flushing and park irrigation, which currently use potable water. This project involves capturing runoff from a storm drain near the park, pretreating flows with a hydrodynamic separator, including removal of trash and debris, storing flows in a subsurface storage system, and treating the water with ultraviolet light before it is used for irrigating and flushing toilets within the park.

Los Amigos Park is a 3-acre park shared by two elementary schools and is used by the City and various youth sports leagues at other times. This project reduces pollutant loads, offsets potable water use, and uses urban runoff as a resource. It also aligns with the goals set forth in the Santa Monica Bay Enhanced Watershed Management Program Plan and the City's sustainability goals. Monthly monitoring and quarterly evaluations ensure the park and systems are maintained and in good shape. The demonstration project will provide results on design, installation, and operation, which will be relevant and transferable to other projects and help break down barriers to local water resource development.

Construction began in mid-2016 and was completed in 2017, with a cost of just under $2 million. The project stores approximately 53,000 gallons of urban runoff and is expected to treat up to 550,000 gallons of stormwater and dry-weather runoff annually, offsetting an equivalent amount of potable water use.[6, 7]



CITY OF SANTA MONICA

[6] City of Santa Monica, Los Amigos Park Storm Water Harvesting and Direct Use Demonstration webpage, https://www.smgov.net/bebp/project.aspx?id=53687095405.
[7] City of Santa Monica, Los Amigos Park Brochure.

CITY OF SANTA MONICA

▲ *Stormwater runoff and dry-weather discharge from a 50-acre urbanized watershed is diverted from flowing into Santa Monica Bay and instead treated, stored, and reused for irrigation and toilet flushing.*


CITY OF SANTA MONICA

▲ *After excavation of the project site, concrete chambers are lowered into place to store diverted stormwater below the park's open space.*


CITY OF SANTA MONICA

▲ *Following the installation of underground infrastructure, the field is covered and restored. The captured and treated runoff is used to irrigate and to flush toilets at the park.*

CHAPTER 4

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

LOTUS WATER

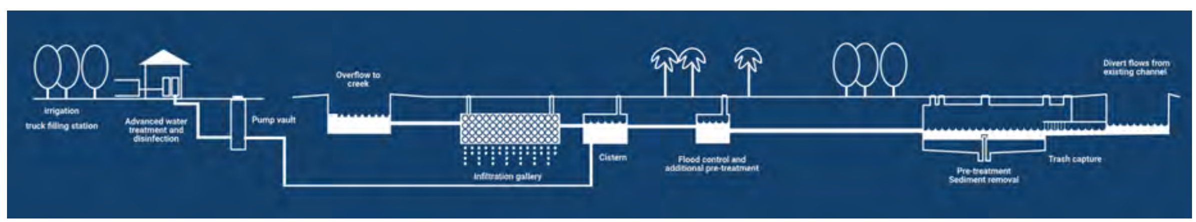
▲ *Stormwater from the existing Colma Creek flood control channel will be diverted into Orange Memorial Park's subsurface stormwater treatment system. Overflow in excess of the system's storage capacity will be treated and discharged back into the channel.*

CITY OF SOUTH SAN FRANCISCO/ DESIGNER: LOTUS WATER

▲ *Conceptual diagram of the completed Orange Memorial Park Regional Project showing the main components of the multi-benefit regional stormwater capture project.*

Orange Memorial Park, South San Francisco, California

Orange Memorial Park Stormwater Capture Project was completed in 2022 and provides tangible watershed improvement and community co-benefits and is the first regional stormwater project of its kind in the Bay Area. The project captures runoff through the installation of an instream diversion and pre-treatment structure (trash screen and sediment removal chamber) at the upper end of the Colma Creek flood control channel within the park and supports control measure implementation goals under the Municipal Regional Stormwater Permit related to trash, pollutants of concern load reductions and green stormwater infrastructure. The pretreated water enters a diversion pipe leading to an underground stormwater storage reservoir. A portion of the storage facility functions as a cistern, holding water for treatment and eventual non-potable irrigation use in the park and adjacent trails, as well as for use in City water trucks. The remainder of the subsurface gallery functions as an infiltration chamber, which can recharge up to 80 million gallons annually into the Westside Groundwater Basin. The storage facilities were installed below the existing baseball and softball fields, which were replaced with new turf. A flow splitter located just upstream of the storage facilities discharges treated overflow back into the channel when storage capacity is exceeded. This regional project, spearheaded by the City of South San Francisco, provides multiple benefits in addition to improving water quality, including reducing localized flooding and reusing treated water for irrigation and groundwater recharge. The project captures and treats 16% of the annual drainage from approximately 6,500 acres of land in the Cities of South San Francisco and Daly City, and Town of Colma, and portions of the Cities of San Bruno and Pacifica, unincorporated San Mateo County, and Caltrans right of way. Of the 16% annual average volume captured by the facility, 9% of the diverted flow is pretreated and discharged back to the channel, 6% is infiltrated, and 1% is captured, disinfected and used for irrigation The City of South San Francisco obtained approximately $15.5 million from Caltrans to fund the project.[8] The City currently has a maintenance agreement with the San Mateo County Flood and Sea Level Rise Resilience District to fund operations and maintenance.



CITY OF SOUTH SAN FRANCISCO

8 Orange Memorial Park Water Capture Project, City of South San Francisco.

Bolivar Park, Lakewood, California

The Bolivar Park Storm Water Management Project was designed to reduce the City of Lakewood's potable water consumption; address copper, lead, and zinc loads in stormwater runoff; and meet regulations set by the Los Cerritos Watershed Management Plan. The project uniquely utilizes a "smart" system that allows the City to exceed original performance estimates projected in the Watershed Management Plan. The project was created in partnership between Los Angeles County and the City of Lakewood and was completed in May 2018, funded entirely by Caltrans for $11 million.[9]

This project captures runoff from approximately 3,020 acres of the Los Cerritos Channel Watershed. It uses an air-inflated rubber dam diversion system that redirects urban stormwater runoff from the Del Amo Channel through a pre-treatment system that removes trash, debris, and sediment. The stormwater is then pumped into a 2.9 million-gallon storage chamber and infiltration facility located beneath ballfields in the park. The stormwater is then treated and used for non-potable irrigation, satisfying 100% of the park's annual irrigation needs. View a video of the construction of the project's subsurface storage and infiltration facilities here.[10]

The project is highly efficient largely due to the incorporation of smart water technology and real-time controls. Sensors installed in the underground storage chamber and infiltration facility monitor and measure water levels against the National Weather Service data through a cloud-based system to determine the system's best course of action in anticipation of upcoming storm events. If rain is expected, the technology evaluates whether the stormwater system has the capacity to fully capture all stormwater during the upcoming storm and avoid flooding. If the system doesn't anticipate adequate storage capacity, it will consider options to free up storage, including reducing the diversion rate, increasing irrigation use, evaluating infiltration rates for groundwater recharge, or discharging treated stormwater back into the channel.[11]

9 "Building a SmartBMP: Lakewood's Water Capture Project at Bolivar Park." California Stormwater Quality Association, https://www.casqa.org/asca/building-smartbmp-lakewoods-water-capture-project-bolivar-park
10 "Bolivar Park Smart Stormwater Capture System." Atlas, https://the-atlas.com/projects/bolivar-park-smart-stormwater-capture-project
11 "Bolivar Park Stormwater Project – Lakewood, CA," YouTube video, 1:56, posted by "StormTrap", December 12, 2017, https://www.youtube.com/watch?v=yPKmM8j-D50


STORM WATER SOLUTIONS

▲ *Treated water is piped approximately 650 feet from the channel and treatment equipment to the underground facilities so that the underground facilities can be placed under the park's open ballfields.*


CD+A

▲ *The treatment and smart system equipment is located on a remnant parcel fronted by streets on three sides and the channel and a pedestrian bridge on the other. Some equipment is sited above ground, while other equipment is underground below the astroturf and concrete pad. Bolivar Park is in the background, center to left.*


CD+A

▲ *The ballfields and other park areas were restored after placement of the underground storage and infiltration chambers.*

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

WWW.COMMONS.WIKIMEDIA.ORG GRENDELKHAN

Use of Recycled Water and Salt Water Intrusion

The use of recycled water and the issue of salt water intrusion with respect to green infrastructure are discussed together, as both introduce salts to planting areas, which can have significant impacts on soils and plants, and potentially affect the function of green infrastructure facilities. Some locations in San Mateo County near the bay or ocean currently experience salt water intrusion. These conditions may worsen due to sea level rise, king tides, storm surges, and related events. While measures can be taken in the installation of green infrastructure to ameliorate the impacts of increased salt concentrations, such as using planting soils and amendments that are low in salts and salt tolerant plant species, the application of recycled water high in salts and salt water intrusion may still be problematic to the long term vitality of plants. Due to the potential effects of salt water intrusion, which may back up in storm lines or enter the storm drain system with rising groundwater levels, outfall drain lines in areas that are susceptible to salt water intrusion should have flap gates installed and green infrastructure areas should be lined to reduce rising groundwaters from limiting stormwater runoff storage and filtration to avoid harming plant vitality and reducing the effectiveness of the green infrastructure. In applications of recycled water, salt levels should be evaluated to ensure the plants in a green infrastructure facility will thrive - alternatively, the recycled water may be diluted with potable water to achieve salt levels within a range acceptable to most plants.

Salt spray may also occur in the vicinity of green infrastructure measures where high-saline recycled water is used for sprinkler/spray irrigation or gets splashed onto green infrastructure plantings and can burn the leaves of the plants. In these situations, use plants that are tolerant of both salt spray and irrigation water that is high in salinity.

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

Rural and Semi-rural Areas

Overview

Rural and semi-rural areas have site characteristics that differ from more developed or urban areas and pose unique considerations for jurisdictions and designers to identify opportunities and implement green infrastructure facilities. Areas of San Mateo County, such as Atherton, Portola Valley, Hillsborough, Woodside, Pacifica, and parts of other communities and the unincorporated County often have streets and roads that are not fully improved with typical urban infrastructure elements such as sidewalks, curbs, gutters, catch basins, and storm drain infrastructure. Development patterns are more dispersed, primarily residential in character, and lower density, outside of main street and commercial areas. Neighborhoods and buildings can be located a distance from storm drain systems, if they are present.

Where streets are curbless, runoff flows across the roadway onto unpaved shoulders, vegetated areas, or into swales instead of flowing to and along curbs and into catch basins and piped systems. Erosion can occur at a higher frequency due to greater instances of unvegetated areas, concentrated runoff into constrained facilities, and compacted roadway shoulders and parcel areas from vehicles and construction equipment. In some cases, roadways, driveways, and other spaces around buildings are unpaved and regularly compacted from use, leading to increased off-site runoff. These conditions in particular pose safety challenges to pedestrians and cyclists navigating the streets, especially in inclement weather. Also, parking lots can be isolated and few in number, often only within more developed commercial and industrial areas. This can lead drivers to informally park along rural and semi-rural road shoulders, further compacting the soil and compounding erosion and runoff challenges.

Rural and semi-rural areas typically have narrow areas beyond the roadway within the right of way. These areas can have a higher incidence of steep slopes and hilly terrain and an increased presence of mature trees that make green infrastructure impracticable. In some cases, jurisdictions only own the paved roadway, and have narrow easements placed on adjacent private property for utility and other encroachments. These issues are further compounded with the predominance of poor soil conditions for infiltration found in San Mateo County that can limit the use of green infrastructure strategies. Because of these factors, areas that are feasible for green infrastructure facilities may be challenging or limited; however, there are many strategies that can be considered to identify and prioritize green infrastructure opportunities and implementation.

WATER NZ

▲ *BEFORE: An unimproved semi-rural road with ditches was selected to be retrofitted with green infrastructure facilities.*

WATER NZ

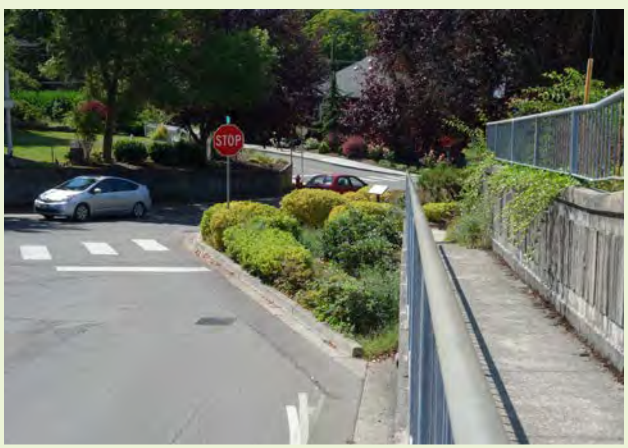
▲ *AFTER: A curbless rain garden was installed to manage stormwater runoff from the road and beautify the roadway.*

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

BLUEGREENBLDG.ORG

▲ *Parks offer the opportunity for cities to integrate green infrastructure facilities and education into the public realm.*



CD+A

▲ *Excess right of way at many rural intersections can easily be converted into green infrastructure facilities - in this case a rain garden. The rain garden also provides the additional benefit of shortening the pedestrian crossing and narrowing the street to calm traffic.*

Planning and Design Opportunities

Jurisdictions in rural and semi-rural areas should look for synergistic opportunities for stormwater management and utilize identified and future capital improvement projects and other planning and public works opportunities that may already be underway or anticipated. Capital improvement projects that include the improvement or addition of bike and pedestrian facilities and other major street projects offer opportunities to include and integrate green infrastructure. Many times, it is more efficient and cost effective to treat stormwater where there are larger expanses of impervious areas, such as at public sites including city halls, libraries, and schools, and commercial areas with parking lots. In addition, certain types of projects are more likely to obtain grant funding opportunities or receive local funding to integrate complete streets improvements, such as capital improvement projects, main streets, primary circulation routes, and safe routes to school projects. It may also be more efficient for rural and semi-rural communities to identify and participate in shared regional stormwater runoff harvesting and reuse projects for green infrastructure opportunities. By preserving and building off of what is already present and working, jurisdictions can save time and money in reaching their stormwater management goals.

Planning for green infrastructure in rural and semi-rural areas should always begin with an in-depth site analysis. Typical strategies may include converting a ditch or vegetated swale into a self-retaining area or rain garden, improving compacted and other soils to increase infiltration, adding appropriate vegetation and biotreatment soil media for pollutant removal, or rerouting flows to where the stormwater can best be treated. Depending on a site's existing conditions (e.g., vegetation, soil), physical configuration (e.g., shape, slope), and location (e.g., shoreline, road, site, creekbed), additional strategies may be used. Check dams may be necessary in steeper areas to slow the flow rate of stormwater, culverts may be needed to direct stormwater flow across roads, and catch basins and other structures can be useful at points of discharge along a treatment area.

Some jurisdictions in San Mateo County are currently in early planning and design phases of green infrastructure projects that will convert existing ditches or vegetated swales into stormwater planters or rain gardens. Kitsap County, Washington is an area with a similar rural and semi-rural context, and has used this and several other strategies to manage and treat stormwater in more rural areas[12]. The Plan provides technical and design guidance in how to retrofit ditches into bioretention facilities for different contexts, locations, and conditions to meet local water quality requirements. General strategies suggested include dispersing flows as a sheet flow across wide embankment areas, using check dams and reinforced slopes in swales along sloped terrain, filtering and reducing the velocity of runoff, and strategically routing flows into existing streams or adjacent biotreatment areas across amended and planted surfaces. This document also contains a decision flow chart to assist in designing the appropriate green infrastructure enhancement based on criteria including the existing ditch cross section, slopes of both the ditch and side slope, need for a structure, and plant selection.

In cases where infiltration is limited due to poor site soils or existing stormwater infrastructure is non-existent or is too far to be feasible to connect into, there may be opportunities to use dry wells, infiltration detention vaults, and infiltration galleries that store and slowly infiltrate stormwater or piping to redirect stormwater flows to where it can be managed. The Elmer Avenue Neighborhood Retrofit project in Sun Valley, CA, retrofitted an unimproved low-density residential street into a green street project to provide a range of neighborhood benefits including reducing local flooding, increasing groundwater supply, and providing sidewalks and street lighting. Because there was no existing storm drain infrastructure, open bottom catch basins and subsurface infiltration galleries were placed under the roadway.[13] Other green infrastructure measures used include bioswales, permeable paver sidewalks and driveways, and rain barrels.


COUNCIL FOR WATERSHED HEALTH

▲ *BEFORE: Compacted shoulders and neighborhood flooding used to characterize this Elmer Avenue Neighborhood.*


COUNCIL FOR WATERSHED HEALTH

▲ *AFTER: The Elmer Avenue Neighborhood is retrofitted with stormwater planters that collect and pass stormwater through a catch basin and infiltration gallery. The addition of street trees, sidewalks, and street lighting enhance neighborhood safety and connectivity.*


COUNCIL FOR WATERSHED HEALTH

▲ *Subsurface catch basin and infiltration gallery infrastructure installed under Elmer Avenue.*

[12] For more information, see Kitsap County's Roadside Ditch and Shoulder Water Quality Enhancement Plan. While the document is older and the strategies discussed are based in Washington and reflect different regulatory requirements, much of the discussed scenarios are similar to rural and semi-rural conditions found in San Mateo County and can be a useful guide to area designers and engineers.

[13] See http://urbancoast.org/wp-content/uploads/2014/10/V3_13_EdwardBelden.pdf, https://dpw.lacounty.gov/wmd/svw/elme avenue, and https://www.landscapeperformance.org/case-study-briefs/elmer-avenue-neighborhood-retrofit for more information.

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County

JENNIFER LEE

▲ *A rain garden captures and treats stormwater from on-site. The rain garden could have been expanded across the entire frontage of the site to treat a higher percentage of the site's runoff and/or partner with the city to treat street runoff.*

CD+A

▲ *Narrow rights of way and steeper terrain in rural and semi-rural areas limit the ability to use green infrastructure measures. Flatter intersections, such as this example, and cross streets may offer locations for green infrastructure.*

In rural and semi-rural areas where streets and roads can be curbless, rather than relying on curbs and gutters to direct stormwater runoff, runoff sheet flows off to the side of the roadway. Therefore, green infrastructure facilities should be sited and designed to maximize the collection and treatment of the runoff. This can include placing green infrastructure on one or both sides of the street, and/or depending upon the grading of the street, placing the infrastructure at the end of the block with the lowest elevation or at the low spots along the street to capture runoff, and upstream of a catch basin or drop inlet if one is present or added. Green infrastructure facilities need to be designed to allow safe and convenient passage of pedestrians, regardless of whether a sidewalk is present or not. There may be cases where roadsides function as informal parking or “shoulders” and inhibit the natural function of vegetated areas and swales as green infrastructure due to soil compaction and disturbance. Installing pervious pavement and/or landscaped green infrastructure at these locations can create a functional and protected green infrastructure facility that provides needed parking paired with stormwater management and treatment. In a similar way, rural and semi-rural stormwater curb extensions and roadside stormwater planters and rain gardens, with or without curb edgings, can be designed and implemented to provide the twofold benefit of calming traffic and creating a more comfortable walking experience and increasing treatment area. Excess roadway in large or offset intersections can also be improved as green infrastructure to augment existing vegetated swales and treatment measures.

Many additional strategies are available to provide multiple benefits to rural and semi-rural communities. For example, existing trees are a significant resource to communities and should be preserved to enhance neighborhood character, and provide shade, habitat, and other ecosystem, public health, and community benefits. Existing trees that are preserved as part of a project can be used as site design measure. Remember that new trees planted along a street or within a project area can be designed as tree well filters or stormwater trees. Strategies such as amending soils with compost, and loosening compacted soils from grading, construction, parking and similar activities can also aid in allowing runoff to infiltrate into the ground quicker, reducing runoff volumes and velocities. Some rural and semi-rural jurisdictions in San Mateo County are identifiying new policies and procedures to maximize the use of green infrastrucutre in such settings. For instance, the Town of Hillsborough is prioritizing the use of infiltration or other hydromodification measures and site design measures that could act as green infrastructure before using non- green infrastructure strategies, like a closed detention pipe.

Policy, Regulatory, and Partnership Opportunities

Policies and regulations can also be developed to incentivize or require projects to implement green infrastructure. Some local Bay Area jurisdictions are crafting and adopting policies and regulations to increase the implementation of green infrastructure on a wider range of development and redevelopment/remodel projects than are currently required to per the MRP. These facilities are to be designed to meet the treatment levels defined for C.3 new and redevelopment projects. Specifically, Redwood City amended their municipal code to require large developments to install and maintain green infrastructure facilities as part of their frontage improvements, and require all new commercial and residential buildings over 1,000 square feet and substantial commercial and residential remodels to include green infrastructure facilities.[14] The Town of Atherton already requires certain residential redevelopment projects to provide onsite detention facilities to meet local hydromodification requirements. The Town amended their Drainage Criteria regulations to also require the provision of on-site green infrastructure facilities for substantial full-site single family residential redevelopment projects with the facility sized to also treat runoff from immediately adjacent public streets within either the public street frontage or within the frontage encroachment area on the residential property.[15]

Elements such as vegetated swales and other landscaped areas can be combined with other green infrastructure facilities to help reduce runoff volumes, velocities, and pollutants including trash and sediments. Trees can limit rainfall from reaching the ground and becoming runoff. Jurisdictions can develop or amend their tree preservation and urban forestry plans to preserve and add street and park trees to provide a range of benefits including stormwater management, carbon sequestration, reduction of heat island effect, and community enhancement.


KEVIN ROBERT PERRY

▲ *Curbless streets and stormwater planters with curbed bulbouts maintain rural and semi-rural character while providing structural support and boundary definition where needed.*


SEATTLE HOUSING AUTHORITY

▲ *Curbless stormwater planters with porous asphalt manage stormwater. Opportunities to provide a separated bicycle and pedestrian pathway were also pursued in the project.*


CD+A

▲ *Similarly to urban areas, green infrastructure can be installed in rural and semi-rural parking lots to manage on-site stormwater and reduce heat island effect and provide landscape.*

[14] For more information see: https://www.redwoodcity.org/departments/community-development-department/engineering-transportation/engineering/green-infrastructure.

[15] See https://www.ci.atherton.ca.us/247/Stormwater-and-Runoff for more information.

4.14 Key Design and Construction Considerations

Specialized Design Considerations for San Mateo County


CD+A

▲ *This Paso Robles, CA green infrastructure system links public and private properties to increase design, functional, and cost efficiencies.*


CITY OF HALF MOON BAY

▲ *Green infrastructure such as this rain garden at Half Moon Bay High School can be integrated into school grounds and along streets to share treatment of stormwater runoff.*

The use of public/private partnerships is another strategy that can be used in rural and semi-rural communities to provide greater efficiencies in planning, design, construction, maintenance, and costs. For instance, a project along the main street in Paso Robles, CA installed a stormwater curb extension that connects to a rain garden placed at the corner of a grocery store's parking lot via a trench drain under the street sidewalk. Many cities have partnered with a school or park district to implement green infrastructure facilities; see **Section 4.14, Regional Stormwater Runoff Harvesting and Reuse Projects** for case studies related to subsurface facilities. Some schools have incorporated green infrastructure such as rain gardens along the edge of streets; these are an opportunity for partnering and expanding the facilities to treat runoff from public streets as well.

Finally, it is critical that maintenance is performed regularly to ensure that the green infrastructure, site design measures, and other infrastructure facilities are functioning correctly, and that runoff is being captured and infiltrated, reused, or directed to a stormwater conveyance system. Jurisdictions can consider cost sharing with other jurisdictions to purchase specialized equipment that may not be used often, such as vacuum trucks or sweepers for pervious pavements, that otherwise they may not be able to purchase on their own.


BAY AREA PERVIOUS CONCRETE

▲ *Pervious pavements, such as the pervious concrete installed in this expansive parking lot, can be used to infiltrate stormwater, reduce runoff from the site, and improve water quality.*

Inland and Coastal Water Considerations

Jurisdictions within San Mateo County should also consider challenges that may arise where rural and semi-rural areas meet shoreline, creekside, and wetland conditions. These water bodies provide many ecological and community benefits and are particularly sensitive to erosion, water quality, and sedimentation, as they are often endpoints of downstream flows. Analysing upstream conditions and flow patterns and prioritizing areas and projects that treat this upstream runoff nearest to its source is crucial in managing and protecting water body edge conditions and water quality. Jurisdictions can reduce the creation of new impervious areas and the volume and concentration of runoff, pollutants, and erosion to downstream water bodies by intentionally using and strategically siting pervious areas and other low-impact green infrastructure opportunities.

Where there is existing or planned direct discharge into a stream or a body of water in the form of a culvert or stormwater pipe and there is a chance of sea level rise or tidal influences, flap gates can be installed to avoid backflow. Further, adequate erosion control measures such as those that dissipate and reduce runoff velocity at the outfall and along the green infrastructure facility or waterway such as vegetated embankments and cobbled outfalls, and flow spreaders can be provided. New green infrastructure should be placed outside of anticipated sea level rise, king tides, and similar areas if no protection measures are anticipated, unless the green infrastructure measure is appropriate along the water's edge such as wetlands and marshes. In addition, the use and siting of constructed or natural wetlands; living shorelines[16]; revegetated creek beds; vegetated or cobbled swales; trees, and restored soil strategies along water bodies can aid in increasing attenuation from storm events, infiltration, and water quality to protect the integrity of shorelines, creeks, and other water bodies.

[16] For more information, see https://oceanservice.noaa.gov/facts/living-shoreline.html.


CD+A

▲ *A constructed wetland pond in San Mateo collects and treats stormwater from surrounding neighborhoods.*


PORTOLA VALLEY TOWN CENTER

▲ *A portion of Sausal Creek was daylighted with the Portola Valley Town Center project. The restored creek design slows and helps treat stormwater runoff, protecting the creekbed from erosion and sediment pollution.*


SANMATEOORCH.ORG

▲ *Healthy and restored wetlands, marshes, and creeks can aid in improving water quality, increasing sea level rise resiliency, and reducing some flooding associated with storm events, in addition to enhancing and supporting Bay Area flora and fauna.*

Chapter 5

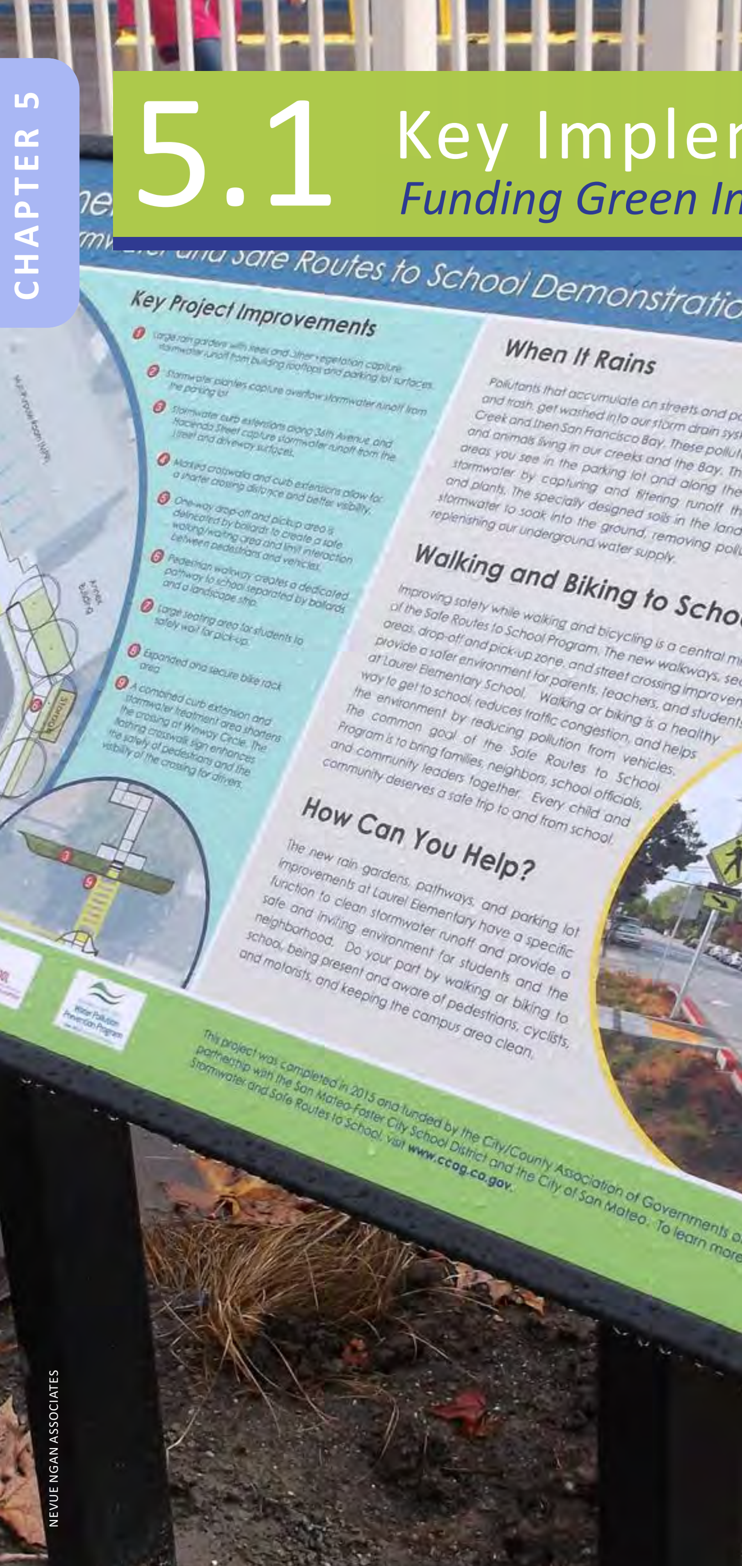
Key Implementation Strategies

◄ *A rain garden courtyard space at the Nueva School in San Mateo County.* Photo Credit: Quadriga Inc.

CHAPTER 5

5.1 Key Implementation Strategies

Funding Green Infrastructure and Reducing Project Costs



Strategies for Funding

Finding cost-efficient means to fund green infrastructure along with reducing the overall costs associated with designing, building and maintaining green infrastructure will require a proactive and coordinated approach to municipal stormwater planning and project implementation.

The future of funding green infrastructure is challenged by many factors, including funding approval thresholds established by Proposition 218, competing infrastructure needs within local jurisdictions, lack of education about the need for and many benefits of green infrastructure, and the opportunistic and resource intensive nature of green infrastructure grants. **Appendix A.6** of this Guide provides an analysis of the existing and potential options for funding green infrastructure in San Mateo County.

Some agencies have pre-Proposition 218 stormwater fees, but lack the political or public support to increase fees commensurate with infrastructure needs. Passage of SB 231 (Hertzberg) in 2018 and the inclusion of stormwater in the definition of “sewers” may support future revenue by allowing municipalities to bypass balloting requirements and raise or establish new fees similar to the way water, sewer and waste utilities are managed. Other local funding approaches could include the establishment of local benefit assessments, business improvement districts or enhanced infrastructure financing districts. Finding a long-term and robust revenue stream is essential to achieve the water quality and community benefit goals of green infrastructure. Regardless of the tools chosen for a specific community, a portfolio of different strategies and funding mechanism will likely be needed to adequately and efficiently implement widespread green infrastructure in the years ahead.

Innovative policies and coordination with private development projects are another option for reducing the public cost of building and maintaining green infrastructure. As communities throughout San Mateo County and the San Francisco Bay area advance green infrastructure planning and implementation, it is worth evaluating the green infrastructure potential of private new and redevelopment projects. Some municipalities in San Mateo County are already exploring ways to optimize new and redevelopment projects by requiring green infrastructure on more projects than mandated by State requirements, including larger residential or commercial remodel projects. For larger projects that require grading and frontage

◀ *An interpretative sign illustrating the Laurel Elementary Safe Routes to School Sustainable Stormwater Project in San Mateo.*

improvements, replacing standard landscaped areas with bioretention designed to receive flow from the right of way will not likely add significant project costs, but can create valuable green infrastructure benefits for the community. Working with private developers can also help address long-term operations and maintenance needs for frontage improvements and reduce the public burden of building and maintaining new infrastructure.

A critical aspect of successful funding is thoughtful planning. Integrated, multi-benefit planning for stormwater management opens doors to better coordination, new funding opportunities and potentially reduced costs. Integrated planning, for example, the *City of San Mateo's Sustainable Streets Plan*, identifies opportunities to combine diverse but interrelated goals to leverage broader stakeholder support from multiple disciplines, including complete streets and green infrastructure (www.sustainablestreetssanmateo.com). Integrated planning can also lead to developing new standards for municipal and new and redevelopment projects. New standards, like widening sidewalks and including street trees can then be paired with strategies to build road-way green infrastructure projects with private sector dollars. The San Francisco Estuary Partnership with support from Bay Area municipalities created the *Roadmap of Funding Solutions for Sustainable Streets* to identify and overcome funding hurdles to planning and building integrated sustainable street projects. In addition to building cross-sector funding solutions, the project also funded a design charette for new sustainable streets design details and paid for the designs at two intersections in the City of San Mateo and Sunnyvale (https://www.sfestuary.org/urban-greening-bay-area/).

Working cross-jurisdictionally and collaborating on regional scale projects for multi-benefit stormwater capture could provide many benefits beyond what is done traditionally with smaller scale green infrastructure planning and implementation. C/CAG, local municipalities, and state agencies like Caltrans are continuing their effort to work together towards achieving enhanced water quality objectives, increasing the cost-benefit of funding stormwater projects, and getting multiple benefits, including groundwater recharge, flood resilience and irrigation/potable water offsets. These types of inter-agency collaborations can help propel larger applications of green infrastructure throughout San Mateo County and bring in diverse sources of funding.

REID BOGERT

▲ *These end-of -block curb extensions at the reconstructed library in Half Moon Bay capitalized on the opportunity to combine green infrastructure with pedestrian improvements as part of a larger Capital Improvement Project.*

URBAN RAIN DESIGN

▲ *Laurel Elementary School uses very little piped infrastructure in the design which helped reduce overall design and construction costs.*

NEVUE NGAN ASSOCIATES

▲ *This green street rain garden project was funded in conjunction with a pedestrian safety and traffic calming project.*

5.1 Key Implementation Strategies
Funding Green Infrastructure and Reducing Project Costs


URBAN RAIN DESIGN

Reducing Project Costs

Beyond taking steps to secure more diverse and stable funding, there are opportunities to reduce costs when designing projects. Since the major opportunity in San Mateo County is to retrofit the existing built environment, the overall goal should be to reduce costs as much as possible and deliver additional non-stormwater-related benefits beyond water quality improvement when applying design solutions. In general, retrofitting building, site, street, and parking lot projects is costlier than implementing new development projects simply because the former has site constraints that must be addressed. For example, there are often extra costs associated with removing existing concrete or asphalt to make way for new green space. In some cases, using a “green” approach might cost more, but the ancillary benefits (such as traffic calming, improved neighborhood aesthetics, and a safer pedestrian environment) should also be considered. The following describes three ways to reduce construction costs during the planning and design process:

Minimize Impacts to Existing Infrastructure

One way to reduce construction costs is to minimize the impact to the existing storm drain infrastructure as much as possible and maintain existing storm drain inlet locations. Altering drain inlet locations and installing new storm drains at intersections can be very cost prohibitive in some projects. In many cases, stormwater facilities constructed up-gradient of existing storm drain inlets may require little, if any, alteration to infrastructure. Many green infrastructure projects in Portland, Oregon were built inexpensively because they minimized impacts to the existing piped infrastructure. For example, the NE Siskiyou Green Street project installed two stormwater curb extensions just upstream of the existing stormwater drain inlets and never touched the existing storm infrastructure. By avoiding any such impact, the project’s overall costs were reduced significantly. Early implementation projects in San Mateo have similarly proven the cost-savings of minimizing impacts to existing infrastructure. For example, in 2018 the City of Half Moon Bay easily sited an integrated Safe Routes to School and Green Streets Infrastructure Pilot Project adjacent to the redesigned public library where the only infrastructure that needed to be modified was the curb and gutter. To avoid utility conflicts, however, the city was asked to move the location of one curb-extension to accommodate an existing water line.

Look for High-Opportunity Projects

When searching for cost effective building, site, street, and parking lot projects, look for candidate sites that have minimal site constraints and maximum space for stormwater facilities. In some cases, there is available landscape space that can be easily regraded and planted to provide stormwater management. In other cases, there are streets and parking lots that have excess asphalt area that can be converted into a stormwater facility at minimal cost. High-opportunity projects also include building, site, street, and parking lot projects that have willing stakeholders, agencies, owners, or neighbors that can help provide advocacy or funding for a project. As an example, Redwood City has worked with new and redevelopment project sponsors to build green infrastructure into frontage improvements in some locations. The Stanford campus project at Bay Road and Warrington, for example, has included a stormwater curb-extension in the right of way.

Co-locating investments can also reduce costs. Integrating green infrastructure with planned infrastructure projects, like bike and pedestrian improvements, for example may essentially double the value of coordinated planning. A standard pedestrian bulbout, for example, can be designed to become a vegetated curb extension, expanding the utility of the infrastructure and achieving substantially more benefit. There is especially good linkage with complete streets benefits in planning integrated projects with respect to lowering green-house gas emissions and creating safer modes of transport. The challenge, however, is overcoming planning and funding silos between transportation and stormwater. Developments to better quantify the multiple benefits of green infrastructure, including green-house gas reductions, urban cooling and water reuse, may further support integrated projects by enabling full cost-benefit accounting and bringing more stakeholders to the table (www.epa.gov/green-infrastructure).

C/CAG is also advancing the work to identify high priority green infrastructure project sites in San Mateo County through its Countywide Sustainable Streets Master Plan. This countywide planning effort takes a closer look at the existing conditions of the stormwater infrastructure and microcatchments to better plan street-scale green infrastructure projects. The plan uses countywide LiDAR elevation data to delineate drainages to individual catch basins and establishes a GIS-based prioritization process for locating projects that are feasible from an engineering standpoint and incorporate community-specific goals to better align green infrastructure with planned corridor improvements. Prioritized project locations and capacities will also be driven by down-scaled precipitation-based climate change analyses, to help plan for a changing future with respect to increased, more frequent or sporadic storms. Finally, the cities and towns of San Mateo County will have a model sustainable streets policy to consider adopting locally. Additional tool will include a web-based project mapping a tracking tool to support local planning and provide an accessible way to track progress overtime toward achieving water quality and other community goals.

Keep Design Solutions Simple

Though there are many benefits to integrating projects with transportation enhancements, during the design phase of a project including green infrastructure, it is important to keep the design as simple as possible. Highly engineered design solutions can often increase project costs. It's important to remember, green infrastructure relies on a natural, landscape-based approach to stormwater management, and often less is more when it comes to designing this type of infrastructure. Evaluating local design standards and specifications can help reduce costs, especially with regards to the use of concrete and curb features, which can add significant costs.

One often over-designed component in green infrastructure implementation is the means by which water gets in and out of landscape stormwater facilities. Over-designed inlet structures not only increase project costs, but they often detract from the aesthetics of a project. Keeping the design simple and allowing water to surface flow in and out of stormwater facilities will help keep costs more manageable. Likewise, using only surface overflow to an existing downstream storm drain inlet, when possible, can simplify a project's design and greatly reduce costs.

When possible, green street projects should be located at intersections where a simple curb extension design can be easily integrated with an existing inlet, capture more drainage area than at a location upstream of the intersection and provide numerous pedestrian improvements, like reduced crossing distances, increased visibility and ADA-compliant curb ramps. There's the added benefit of avoiding parking space loss, because the end of the block is often a red curb zone.

URBAN RAIN DESIGN

▲ *This rain garden project that captures roof runoff at the UC Davis campus was built for under $3,500 and minimized the use of expensive materials.*

5.2 Key Implementation Strategies
Changing Municipal Policy and Code

NEVUE NGAN ASSOCIATES

With 21 different municipalities within San Mateo County using this design guidebook as a reference document, it would be difficult to account for all the code conflicts and stand-alone policy challenges that could arise in implementing green infrastructure projects. However, some relevant policy and code information from various County municipalities is presented, separate from this guidebook, on the SMCWPPP website (https://www.flowstobay.org/localcodes).

Though, there are many ways to encourage code changes that support the use of green infrastructure and many policy areas that can be worked on to improve the efficiency of building green infrastructure (including, planning and zoning policies, stormwater ordinances, standard details and specifications, maintenance policies, etc.), there are three main ways to advance green infrastructure in any community : 1) build demonstration projects; 2) provide the opportunity for open communication and collaboration between municipal staff to discuss issues; and 3) provide flexibility in green infrastructure design standards.

Changing Code with Demonstration Projects

One of the best methods to help municipalities change their development codes to favor green infrastructure projects is to build demonstration projects. By labelling a project as a “demonstration” or “pilot” project, it often allows city staff to relax their standards and allow the use of alternative methods without the burden of implementing widespread change. Demonstration projects allow city staff to evaluate the code on the site level rather than a city-wide scale. This can provide a much clearer perspective of what issues are truly in conflict. Most importantly, when city staff experience first-hand that the code conflict is not as critical in light of the other benefits provided by the demonstration project, they tend to standardize the approach for widespread application. San Mateo communities have benefited from demonstration projects in several cities that help show the public, elected officials and municipal staff that these projects can be successful and cost-effective. Each successive project also helps advance the design and engineering of sustainable streets, as lessons learned are accounted for in future projects.

◀ *Participants in a San Mateo County Green Infrastructure Design Workshop in 2008.*

Changing Code with Staff Collaboration

A critical tool for helping change existing municipal codes is to provide an avenue for inter-city and inter-county collaboration of ideas and concerns. Perhaps an ideal condition would be for all municipalities within the County to adopt a uniform and consistent set of codes and policies that support sustainable streets and parcel-based LID projects. This would undoubtedly take a great deal of time, effort and political will to accomplish, but this effort would provide the most comprehensive approach to dealing with potential code conflicts. More realistically, however, resolution of code and policy conflicts that arise during implementation of green infrastructure projects will occur through discussion and negotiation among municipal staff as projects evolve. Staff will need to consider multiple perspectives to arrive at a reasonable compromise that serves the greatest good. Through developing Green Infrastructure Plans, many communities in the County have found a need to form “green infrastructure task forces” that cut across departments, who may have had little overlap prior to the integration of green infrastructure with other Capital Improvement Projects, new and redevelopment projects, etc. Staff from Engineering, Streets and Roads, Maintenance, Parks and Recreation, Planning and Building, Transportation and other departments and divisions may have an express interest in forming new collaborations to effectively plan, build and maintain sustainable streets that are inclusive of complete streets and stormwater management.

Providing Flexibility in Green Infrastructure Design Standards

It is important to note that it is possible for municipalities to rush to provide inflexible design standards prior to developing a comprehensive array of design solutions for a wide variety of conditions. As a result, developers and municipalities could be limited to only one or two design solutions that are not well suited to the varying street, building, and site conditions in San Mateo County. It is best to provide flexible design guidelines that can be easily updated as green infrastructure solutions are refined and properly tested in demonstration projects. It is anticipated that the typical details and standard specifications provided in this Guide will evolve over time, and that agencies referencing these documents in their local policies and plans will adapt them to community-specific needs.

URBAN RAIN DESIGN

▲ *Staff and inter-agency collaboration can be in the form of workshops such as this workshop developed in San Mateo County in 2008.*

URBAN RAIN DESIGN

▲ *Flexibility in design standards allowed this street project in Washington D.C. to design, construct, and test innovative “Landscape Infiltration Gaps (LIGs)” to capture sidewalk runoff.*

5.3 Key Implementation Strategies

Creating Incentives

There are several options for creating incentives for municipalities and property owners to retrofit streets, buildings, and sites. As described below, these incentives can be classified into three different categories: reward-based incentives, mandate-based incentives, and community-based incentives. Especially where jurisdictions lack direct control over site improvements, incentives can become a very effective tool.

Reward-based Incentives

Reward-based incentives compensate a developer or property owner for incorporating green infrastructure elements into their project. This type of incentive may include utility fee discounts, tax benefits, project grant funding, or even expedited review and permitting of development proposals. Reward-based incentives are particularly applicable to private development associated with parking lot projects. However, when private development occurs in conjunction with public streets, reward-based incentives can also apply. An example of a reward-based incentive is the *City of Portland's Clean River Rewards Discount Program* that allows up to a 35% reduction in residential or commercial stormwater utility fees for employing certain landscape-based stormwater management strategies on-site. In a residential setting, providing rebates on green infrastructure improvements like rain barrels, cisterns, and pervious pavement can go a long way toward disconnecting impervious surfaces and using rainwater sustainably.

Mandate-based Incentives

This type of incentive requires a developer or property owner to employ green infrastructure strategies or their on-site stormwater management fee may be levied or increased. A municipality may also include policies for doing additional stormwater treatment on new and redevelopment projects via updated Conditions of Approval, which require a developer to implement green infrastructure on a broader variety of project types and sizes. Maintenance agreements may be updated to include long-term maintenance responsibilities on behalf of private entities to operate and maintain green infrastructure in the right of way adjacent to their property. Mandate-based incentives can result in a more wide-spread application of green infrastructure projects, but considerations must be made regarding partnering entities to promote a positive effort. A municipality may also require all street retrofits of a certain size, for example, include green infrastructure where feasible. Whether applied to public or private projects, mandate-based incentives may also create an additional administrative burden for municipal staff by expanding the scope of the stormwater program.

◀ *The Logus Road Green Street in Milwaukie, Oregon was built largely to solve both local flooding and pedestrian safety issues next to an elementary school. Finding projects that have multiple objectives are more likely to be funded and supported.*

Community-based Incentives

Many neighborhoods and business districts see the value of "greening" their environment in terms of improving quality of life, increasing property values, and increasing business profits. Local neighborhoods are often willing to combine resources and help pay for a green infrastructure project, or agree to undertake long-term maintenance, or simply provide advocacy for a municipality's green infrastructure efforts.

One way to bring to bear full community resources is to form a community benefit district. Such an entity is comprised of a network of businesses and other property owners within a defined area who voluntarily agree to pay additional property tax in order to finance capital improvements and services that enhance, but do not replace, those provided by the city. Alternatively, parking benefit districts serve the same function, but derive their funding from on-street parking meters or non-resident parking passes.

General problem-solving is another common form of community-based incentives. For example, green infrastructure projects have the potential to reduce neighborhood flooding, provide traffic calming, and provide pedestrian safety benefits. Communities are more inclined to endorse and provide incentives toward green infrastructure projects when they are part of a more comprehensive solution to neighborhood problems.

ASHLEY BLAZINA

▲ *Residential downspout disconnection programs often can give property owners incentives to install rain gardens to capture rooftop runoff.*

NEVUE NGAN ASSOCIATES

▲ *A proactive neighborhood in Davis, California organized their own green streets workshop to envision how green infrastructure could be strategically placed within overly-wide existing streets.*

5.4 Key Implementation Strategies

Public Education and Demonstration Projects

Effective Public Education

One of the best tools for successful stormwater management is educating the general public. There is a lot of confusion and misconception about various stormwater management strategies. People sometimes think of stormwater facilities as “swamps” or “mosquito nests” and are unaware of how these systems function and good examples of well-designed stormwater facilities. Likewise, people may not realize well-designed stormwater facilities can look just as good as, and perhaps even better than conventional landscapes.

Therefore, it is important to show the public specific examples of successful demonstration projects (local or otherwise) to provide reassurance that stormwater facilities can help protect the environment and also provide a unique and attractive neighborhood amenity. There are several ways to promote stormwater education and outreach, such as:

- Conduct public tours of successful stormwater projects built in the local area, including field trip tours for school children who would like to learn more about environmental sustainability.
- Offer public meetings/workshops on the topic of sustainable stormwater management.
- Provide specific education materials that explain that well-designed stormwater facilities should not allow any prolonged periods of standing water that promote mosquito breeding.
- Send out brochures or provide fact sheets that describe different ways to manage stormwater runoff.
- Install interpretative signs for key stormwater demonstration projects. The signs should describe the elements of a project and where to find more information.

Types of Demonstration Projects

Demonstration sustainable street, building, site, and site projects can be selected and designed using one or a combination of three approaches. Depending on the approach taken, demonstration projects can range from small to large, retrofit to new construction, and simple to complex.

◄ *The Brisbane City Hall Rain Garden Demonstration Project built in 2008 has been an extremely effective public education and communication tool.*

Strategic Approach

This approach locates stormwater facilities intermittently, but strategically, to provide the most efficient level of stormwater management on a site by site basis. Because this approach uses smaller facilities, it tends to be the least expensive to construct and maintain. This approach is widely used for retrofitting existing streets. **C/CAG's Countywide Stormwater Resource Plan** and **Sustainable Streets Master Plan** evaluate green infrastructure projects based on engineering feasibility and constructability in addition to water quality, community enhancement, transportation and other local planning priorities to strategically site green infrastructure.

Opportunity Approach

This approach locates stormwater facilities in areas where there are very few constraints and that offer high demonstration value. By using this approach, under-utilized landscape or impervious areas are converted into stormwater facilities of any size. Opportunistic approaches may also occur with new and redevelopment projects as they arise, or with other funding mechanisms, especially green infrastructure related federal, state and regional grant programs, or mitigation funds on large transportation infrastructure projects, for example.

Full-Integration Approach

To achieve sustainable streets in its entirety requires a full integration of building, site and street design. This approach integrates the entire site frontage for stormwater management, and offers the most stormwater management benefits, but it is usually the most expensive to build and maintain. Additional development impact fees, business licence fees or community/business assessments may be appropriate to help offset cost increases. From a policy perspective, Green Infrastructure Plans and relevant policy updates that are required to support implementation will go a long way towards creating more integrated sustainable streets throughout the County. Ongoing efforts, including sustainable streets master planning at C/CAG and coordination with other state agencies, including Caltrans, can provide previously untapped partnerships to advance green infrastructure in the transportation and regional planning sectors. Several communities in San Mateo have already engaged with Caltrans to pursue construction of large subsurface stormwater retention projects, in an effort to capitalize on the potential to infiltrate large volumes of water, clean runoff, capture and reuse stormwater, and update associated parks and athletic fields. Together, a holistic, watershed-based approach that includes all relevant stakeholders, from industry to municipal staff, to businesses and homeowners/developers will guide San Mateo towards a more resilient and well-managed urban landscape.

SMCWPPP

▲ *Public outreach and education is a critical element for success in developing widespread green infrastructure projects. This is a poster for promoting green infrastructure in San Mateo County.*

URBAN RAIN DESIGN

▲ *Demonstration projects in high visibility conditions, such as this project at Laurel Elementary School in San Mateo, offer great opportunities for education and outreach to the neighborhood.*

Chapter 6

Operations and Maintenance

◄ *This rain garden at The Cove at Oyster Point collects stormwater from both building and parking lot surfaces.* Photo Credit: Urban Rain|Design

6.1 Operations and Maintenance
Introduction

Maintaining Urban Green Infrastructure

Maintaining green infrastructure is not unlike providing health care for ourselves. For example, it is recommended for people to get health and dental check-ups/cleanings on a regular basis. Green infrastructure maintenance is very similar. With proper and regular care, stormwater facilities can last for decades and continually provide water quality and flow reduction benefits. Like our own bodies though, without reminders for regular green infrastructure maintenance, it is sometimes easy to neglect ongoing care or simply not care for it in the correct way. This, of course, can ultimately lead to problems.

The purpose of Operation and Maintenance within this guidebook is to provide landscape contractors, designers, municipal staff, and the community-at-large with simple and user-friendly recommendations and reminders on how provide for the successful long-term function of built urban green infrastructure systems in San Mateo County.

What This Guidebook Covers vs. C.3 Regulated Projects Guide

The Operation and Maintenance within this guidebook is a supplement document to the overarching **C.3 Regulated Projects Guide**. The **C.3 Regulated Projects Guide** contains extensive information on Operations and Maintenance in both Chapter 8 and Appendix H of the guide. However, this information has primarily been developed to assure that projects meet specific technical compliance in the Municipal Regional Stormwater Permit (MRP) and establish proper maintenance agreements and party responsibilities. For the more day-to-day guidance on green infrastructure maintenance and for non-regulated green infrastructure projects, the guidance within the following pages is the preferable resource to follow. This guidebook aims to provide very specific and detailed recommendations on how to maintain urban green infrastructure without the being too technical in nature. It is meant to be a visual "field guide" to discuss common operation and maintenance issues. Anyone wishing to receive more detailed and technical information on operation and maintenance compliance for San Mateo County should reference Chapter 8 and Appendix H of the **C.3 Regulated Projects Guide**.

The guidance within this guidebook is primarily focused on small to moderately sized ultra-urban landscaped-based green infrastructure facilities that employ biofiltration and pervious pavement applications found

◀ *This photo shows New York parks staff participating in a two-week green infrastructure maintenance training program. Similar programs can be used to train the general public in stewardship of urban landsacpe such as green infrastructure.*

within streets, parking lots, and development sites. These facilities might include stormwater facilities such as vegetated swales, rain gardens, stormwater curb extensions, stormwater planters, green gutters, tree well filters, and pervious pavement systems. While green roofs and cisterns (water harvesting) are becoming more popular green infrastructure systems, because they are not yet widespread, this guidebook will not cover the operation and maintenance of these types of facilities.

Subsections Summaries

To help you get started, an overview of this guidebooks chapters and appendices are as follows:

Section 6.1 Introduction describes the common types of green infrastructure maintenance issues found in San Mateo County, what do prepare for when conducting site maintenance, and types of green infrastructure maintenance programs.

Section 6.2 Hardscape and Functional Maintenance Activities describes maintenance issues found with the hardscape and functional elements of green infrastructure facilities such as sediment and trash removal, pervious pavement cleaning, erosion control and troubleshooting too much or too little standing water within landscape areas.

Section 6.3 Landscape-Related Maintenance Activities illustrates landscape maintenance related activities such as mulch application, irrigation system checks and repairs, trimming plant material, plant replacement, weeding, fertilization, and maintaining site safety, visibility, and site aesthetics.

Section 6.4 Maintenance Quality Observation Levels provides guidance to determine maintenance activities based on observed levels of needs.

Section 6.5 Annual Maintenance Actions provides a suggested detailed annual maintenance plan a for both hardscape/functional activities and landscape-related activities.

Section 6.6 Annual Landscape & Hardscape Maintenance Schedule illustrates a suggested an annual maintenance checklist by month for both hardscape/functional activities and landscape-related activities.

Appendix 5 of this guidebook also includes sample maintenance plans for green infrastructure landscape areas and pervious pavement applications.

CHAPTER 6

6.1 Operations and Maintenance
Introduction

URBAN RAIN DESIGN

▲ *Street sediment takes over this landscape on a regular basis without adequate prevention and maintenance.*

URBAN RAIN DESIGN

▲ *River rock used to minimize erosion inhibits flow and creates sediment accumulation that is difficult to remove.*

Sediment Removal Needs

Sediment accumulation within curb cut locations, and even within the entire landscape facility, has been a systemic problem for both green street and parking lot stormwater facilities. Most green street projects in San Mateo County are utilizing stormwater curb extensions that typically have a single main curb cut entry along the street curb. These types of stormwater facilities are excellent for capturing stormwater runoff, but they are equally strong in capturing sediment and small trash loads as water is flowing into the landscape. Parking lots that have large amounts of runoff also have issues with sediment loading at curb cuts, however, they typically have more frequently placed curb openings along stormwater facilities that result in more evenly distributed flow and sediment loading. In both parking lots and street applications, the following maintenance issues have been observed in San Mateo County green infrastructure facilities:

- Inadequate or missing hardscape forebays at curb cut locations to help collect sediment that causes excessive build-up or migration of sediment into landscape treatment areas.
- Little or no drop in grade between curb cuts and landscape areas which causes sediment to accumulate and prevent runoff from entering stormwater facilities.
- Too infrequent of maintenance schedule for removing both sediment and trash which causes further accumulation of material.
- Cobble/river rock placed at curb cut entrances causes sediment to build up between rock void space, promotes weed growth, and can inhibit the flow of stormwater if the cobble is placed above the grade of the runoff flow line.

Hardscape/Structural Maintenance Needs

Because green infrastructure is still a young practice of less than a decade and, without a widespread application throughout San Mateo County, there are not significant signs of hardscape and/or structural breakdown that is occurring. It is observed that pervious pavement systems require regular cleaning with several recent projects already showing signs of sedimentation within pervious pavement joints. If anything, the maintenance needed from a hardscape/structural sense is correcting poor design elements, such as:

- Inadequate or missing hardscape forebays at curb cut locations to help control erosion, ease sediment removal, and allow runoff to more efficiently enter landscape areas.

- Missing check dams/weirs to help retain water at desired ponding depths or check dams and weirs that do not retain water due to poorly chosen material that are prone to erosion.
- Poorly constructed curb cuts that do not easily allow water to enter the landscape because of hardscape grading issues. Maintenance options include the grinding down of pavement or even replacing the curb cut.
- Poorly installed overflow outlets which may need replacement to assure the desired control of water retention.

Landscape Related Maintenance Needs

Landscape related maintenance issues of green infrastructure facilities in San Mateo County are quite numerous. Private green infrastructure maintenance does not seem to suffer as much in the form of lack of frequency of maintenance (as many private property owners have established maintenance crews that visit sites regularly), but more so the poor execution of landscape maintenance. Public green infrastructure, such as green streets, suffer from both lack of frequency and poor execution. The most significant landscape maintenance issues in the form of poor maintenance execution include:

- Inadequate or missing mulch layer, wrong type of mulch material, and incorrect placement of mulch material.
- No replacement of dead plant material/poor plant coverage.
- Exposed/broken irrigation systems and improper irrigation coverage.
- Excessive trimming of plant material and/or wrong timing to trim plant material.


URBAN RAIN DESIGN

▲ *Excessive plant trimming has caused severe plant dieback and eventual plant death.*


URBAN RAIN DESIGN

▲ *Plants within this rain garden have died due to excessive drought conditions and need to be replanted.*


URBAN RAIN DESIGN

▲ *Lack of mulch exposes the soil to erosion, causes plant stress, and can expose drip irrigation lines.*

6.1 Operations and Maintenance

Introduction

▲ *This newly installed green infrastructure facility will need regular care in the first years of establishment to ensure optimum performance and a healthy start.*

▲ *Bay-Friendly Landscape Guidelines should be embraced by both municipal staff and the general public.*

Early Maintenance Intervention for Newly Built Projects

An ounce of prevention is worth a pound of cure. The saying is true for going to the doctor as it is for maintaining green infrastructure systems. With green infrastructure quickly becoming mandatory for many municipalities, there are many new stormwater facilities being installed. It is important to make sure that there is a regular schedule of maintenance conducted during the first years of post-construction establishment to assure that these facilities have the best start in life. Having a strong maintenance plan, an agreed upon and responsible party for maintenance services, and an engaged owner of the facilities (whether private or public), is absolutely necessary.

It is recommended that within a standard agreement-based maintenance plan there be a focus on early maintenance. An early maintenance emphasis would recommend both monitoring and frequent maintenance for the first two years of a facilities life. This would include more frequent observational visits than the standard recommended maintenance plan and more robust corrective actions, if required.

Bay-Friendly Landscape Guidelines

Because green infrastructure is based upon mimicking natural hydrologic systems using a landscaped approach, it is highly recommended that maintenance staff utilize **Bay-Friendly Landscape Guidelines** as promoted by ReScape California. **Bay-Friendly Landscape Guidelines** help to minimize waste, protect air and water quality, conserve energy and water, and protect natural ecosystems. Landscape maintenance should follow an integrated approach, consistent with the principles set forth by **ReScape California** and in the **Bay-Friendly Landscape Guidelines**, www.rescapeca.org. These seven Bay-Friendly principles are:

1. Landscape Locally

The Project landscape is part of a larger natural ecosystem of the San Francisco Bay Area. The materials and methods used to maintain the Project can support the health, diversity and sustainability of the Bay.

2. Less Landscape Sent to the Landfill

Reducing waste starts with not generating plant debris in the first place by fertilizing, irrigating and pruning judiciously, grasscycling, mulching and composting plant debris. Using recycled content, salvaged, durable or local materials conserves resources and reduces the amount of energy consumed by the landscape.

3. Nurture the Soil

Create a healthy soil that supports a healthy landscape by protecting the soil from compaction and erosion, replenishing organic matter and mulching, using slow-release and organic fertilizers and minimizing use of chemicals that harm beneficial soil organisms.

4. Conserve Water

Use California's water supply efficiently by reducing irrigation requirements, irrigating according to plant need, maximizing irrigation system performance, increasing the water holding capacity of the soil and using recycled water.

5. Conserve Energy

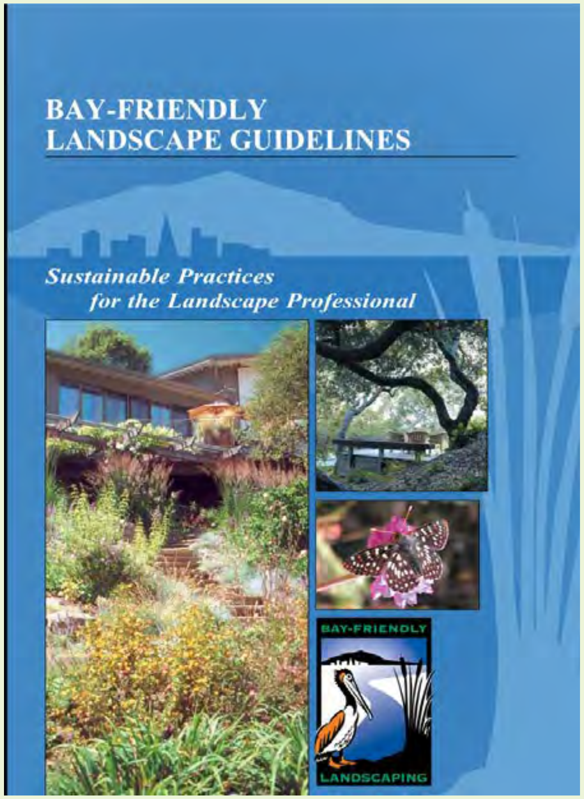
Conventional landscapes are fossil fuel consumptive. Nationally it is estimated that lawn mowers consume 400 million gallons of gas. Look for opportunities to conserve fuel and energy by choosing and maintaining materials and equipment for fuel conservation.

6. Protect Water and Air Quality

Reduce runoff, reduce contaminants in runoff through an integrated pest management (IPM) program, and increase the soil's ability to remove pollutants from runoff through steps such as mulching bare soil. Reduce air pollution by reducing fossil fuel consumption, recycling plant debris on –site and planting trees to remove CO_2 and absorb air pollutants.

7. Protect and Maintain Wildlife Habitat

The Project may provide food, water, shelter and nesting sites for birds, butterflies, beneficial insects and animals that contribute to the ecological diversity of the Bay. Methods to protect them include minimizing application of chemicals by implementing an integrated pest management (IPM) program, and conserving flowers, berries, fruits, seed heads, low branch cover, and natural vegetation in open space areas.



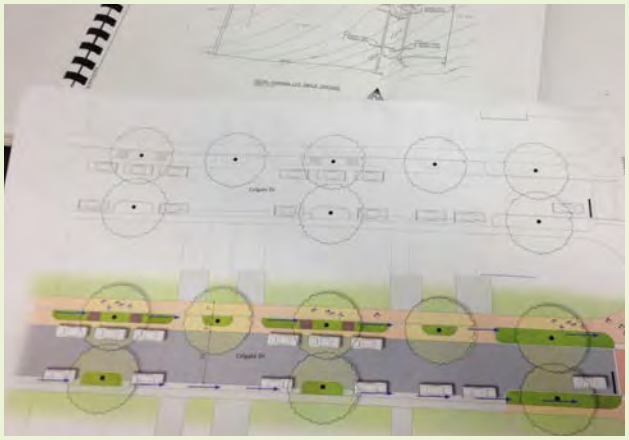
STOPWATSTE.ORG

▲ *An excellent and free resource to all is the Bay-Friendly Landscape Guidelines (See rescapeca.org to obtain).*

STOPWATSTE.ORG

▲ *The seven principles of Bay-Friendly Landscape Guidelines.*

6.1 Operations and Maintenance
Introduction



URBAN RAIN DESIGN

▲ *Obtain and review all design plans and maintenance logs prior to going to the project site for maintenance activity. Contact project designers with any questions.*

KEVIN ROBERT PERRY

▲ *Providing extensive photo documentation of after-construction condition and ongoing maintenance activities is a critical tool for observing changes at the project site.*

What To Do Before and While at the Project Site

When maintaining green infrastructure facilities, there are several things that maintenance personnel should do before going to the project site, such as:

- Check weather conditions to make sure that there are ideal conditions for maintenance. There should be no landscape maintenance when the soil is saturated to minimize the potential for soil compaction.
- Check design plans to understand design intent, plant species used, and site grading. It is also useful if digging is required and determine the location of unseen elements such as irrigation lines, underdrains, overflow pipes, etc.
- If possible, meet with the designers to talk over the project's design intent.
- Check maintenance logs to see when past maintenance has been performed, including the last scheduled maintenance activity.
- Notify property owner(s)/city agency and get permission to enter and perform maintenance activities.
- If using a volunteer crew to perform maintenance activities, coordinate with any individuals.
- Visit the site beforehand and determine what tools/safety equipment will be needed for maintenance activities.

Photo Documentation of Maintenance Activities

It is vital that photographs should be taken after the project has been completed, at the commencement of the maintenance period. Documentation of the existing conditions establishes a maintenance benchmark before damage, disrepair or neglect compromise the appearance and function of the site. Initial photographs of the site should be thorough. After the initial photo documentation, photography is only required during subsequent maintenance visits when evidence of damage, decline, deficiency or vandalism is found.
In general, take photographs with context. Photographs should be in focus, clearly show the subject and be of a high-quality image resolution, i.e. taken with a minimum 5-megapixel camera.

Comprehensive site photographs and photographs of deficiencies should be submitted to the owner in digital format. Provide the digital images in a common format such as a JPEG or PDF. All images should be submitted with a date and time stamp. Other information best submitted with the images includes: the name of the project site, the name of the photographer or an alternative contact person, and a description of the photograph's vantage point, indicating the location and direction from which it was taken.

Safety and Hazard Considerations When Performing Maintenance

Public stormwater facilities are often located within parking lots, along street corners, within medians, and in other places near moving vehicles. When maintaining these facilities, maintenance personnel are exposed to some risk of being hit by vehicles. To create a safe environment, warning signage should be placed to alert vehicles to the presence of maintenance personnel. Additionally, personnel can wear bright clothing and safety vests while working in these conditions.

Personnel should wear appropriate footwear, such as close-toed shoes not prone to slipping. Clothing should not be overly baggy to avoid fabric getting caught within machinery. Long pants are recommended. Gloves should be worn in situations when cuts, abrasions or chemical usage are likely. For instance, skin can be irritated when exposed to certain weeds. Gloves are recommended during hand weeding. Maintenance personnel should wear eye protection, preferably options with side guards, when exposed to hazards like flying debris or chemicals. Sometimes maintenance tasks require the use of power tools. Often loud, power tools necessitate ear protection in the form of ear plugs or muffs.

When working with new equipment, tools or chemicals, maintenance personnel should be trained by a qualified person in the proper usage of the item. Any equipment, tool or chemical should be implemented based on the manufacturer's instructions. Furthermore, equipment should only be used when working properly. Any defective equipment should be repaired before reinstating its use.

In the case of injury, first aid supplies should be readily available. Any injured personnel should be immediately evaluated for the necessity of ceasing work and obtaining professional medical help.

These safety considerations are not holistic. Any maintenance program responsible for the stormwater facilities should have effective safety procedures in place.

Data Logs

In addition to photo documentation, maintenance activities should be recorded in written form (i.e. a data log). Information in data logs provides a reference of maintenance activity at a site. If maintenance crews or key personnel changes, the new personnel can access maintenance history, including the types of tasks usually performed on site, typical problems encountered and solutions. Additionally, longstanding maintenance crews don't have to rely on memory to recall maintenance history.

Information typically recorded in data logs includes the following:

- Changes that have been made (i.e. dead plant replaced, irrigation sprinkler head repaired)
- Supplies needed at the next maintenance visit (i.e. quantity of mulch required to restore depleted levels)
- Notate things that need to be closely monitored over the next several site visits (i.e. a struggling shrub gradually being shaded by a maturing tree that may require replacement)

Different logs are available within this document. A comprehensive checklist and schedule of maintenance tasks that need to be completed within specific months over the course of a year is included in **Section 6.6**. In **Appendix 5**, these maintenance tasks are organized by stormwater facility type. This log lists the routine tasks, however, a separate sheet should be included to list the specific maintenance activities performed, as described above. It is useful, when available, to bring a site plan of the project. The site plan can be used to diagram the specific location at which a maintenance task has been performed (i.e. where a plant has been replaced) to supplement the written description. It is recommended that at each site visit, a data log be recorded.

CHAPTER 6

6.1 Operations and Maintenance
Introduction

URBAN RAIN DESIGN

Public works often maintain green infrastructure but are encouraged to seek specific green infrastructure training.

URBAN RAIN DESIGN

The general public can help maintain green infrastructure facilities as part of an "Adopt-a Rain Garden" campaign.

Types of Maintenance Programs

There are many types of maintenance programs to choose from when caring for green infrastructure facilities. Many property owners, cities, or agencies utilize one or multiple types of programs to assure the best possible performance of their projects. Below lists a few of the most common types of maintenance programs.

Private Maintenance Crews

One of the most common types of maintenance programs is to simply hire private landscape construction/ maintenance firms to complete maintenance activities. Using private contractors is most prevalent on private property green infrastructure projects but they are also utilized on public green infrastructure projects such as streets and parks. The advantage of using private landscape contractors is that they are professionally licensed to perform landscape maintenance, offer competitive fees for completing work, and can meet the staffing needs in providing maintenance for multiple projects.

Public Maintenance Crews

Many individual municipalities have their own city crews to perform routine maintenance on conventional public projects such as streets and parks. With new green streets being installed in San Mateo County, cities are asking park and street maintenance crews to also perform green infrastructure maintenance on top of their regular maintenance duties. While it may be easier to have "in-house" crews work on green infrastructure maintenance, limited budgets and staff shortages are common place.

Adopt-A-Rain Garden Public/Private Partnerships

Some cities have found success when facing maintenance budget shortfalls and staffing issues to coordinate with individual volunteers within the community to help maintain publicly owned green infrastructure projects. This public/private partnership, sometimes called "Adopt-a-Rain Garden" allows interested citizens to perform selective green infrastructure maintenance activities such as weeding, plant trimming, sediment and trash removal, and simple observation of performance under the guidance of city staff. This helps reduce the maintenance burden of maintaining public green infrastructure at the city level and helps promote community engagement and environmental stewardship at the individual level. This volunteer effort can also be in the form of individual businesses or agencies adopting the selective maintenance activities. This type of maintenance program will likely require at least one trained city/agency staff person in green infrastructure maintenance to coordinate the Adopt-a-Rain Garden program.

Gardening/Sustainability Clubs

Similar to the Adopt-a-Rain Garden program, having a coordinated group of individuals that help perform green infrastructure maintenance is another option to help spread out maintenance responsibilities. School, church, or UC Master Gardeners are always recruiting individuals to help with community-based volunteer efforts; and green infrastructure maintenance can be a part of this effort. This type of maintenance program will likely require at least one trained club/program staff person in green infrastructure maintenance to coordinate the group effort.

Skills Training and Employment for Disadvantaged Citizens

There are cities throughout California that are helping disadvantaged and/or homeless individuals find employment by offering paid job skills training for city beautification/maintenance. This is a great opportunity for cities to create "green jobs" while helping out neighbors in their communities. Davis, California currently offers a similar program called "Davis Pathways to Employment" that provides employment skills training and employment opportunities to persons experiencing homelessness—helping them become self-sufficient, more-connected members of the community.

Green Infrastructure Maintenance Training Opportunities

Because green infrastructure is a specialized form of landscape maintenance, it is important to have people adequately trained to perform this maintenance. Even licensed landscape contractors, while well-versed in conventional landscape maintenance, still need extra training in the nuances of green infrastructure maintenance. **The National Certification of Green Infrastructure (NCGIP)** sets national certification standards for green infrastructure construction, inspection, and maintenance workers. The program provides specific green infrastructure training in the form of workshops to interested agencies and includes a standardized exam for certification. Some cities in the Bay Area are engaging in the NCGIP certification program. See www.ngicp.org for additional inforamtion on this national program.

DAVIS ENTERPRISE

▲ *Organized groups, such as the UC Master Gardener Program can provide highly-trained volunteer personnel.*

URBAN RAIN DESIGN

▲ *The Davis "Pathways to Employment" program helps the homeless find paid work for streetscape maintenance.*

URBAN RAIN DESIGN

▲ *UC Davis students maintaining a rain garden location.*

6.2 Operations and Maintenance

Hardscape and Functional Maintenance Activities

URBAN RAIN DESIGN

▲ *A stormwater curb extension curb cut full of sediment accumulation.*

URBAN RAIN DESIGN

▲ *River rock used to minimize erosion creates pockets of sediment accumulation that is difficult to remove.*

Sediment and Trash Accumulation

Sediment is small particulate matter such as soil, small leaf debris, gravel, and road particulates that is transported into vegetated or pervious pavement stormwater facilities by means of flowing water. In addition, pollutants such as oil, grease, metals, and other compounds are often found bound to the sediment load. If left to accumulate unmaintained, the sediment will build up over time creating difficult conditions for plant growth, reduce the porosity of both vegetated or pervious pavement systems, and can impede the flow of runoff into vegetated systems.

Sediment is more prominent and problematic with street and parking lot conditions where vehicles break down leaf debris, gravel, and soil into fine dust. Some streets and/or parking lots have higher sediment loads than other based on the surrounding conditions and the amount of tree canopy cover. Building sediment from rooftops less common but does occur. In all cases, a regular schedule of maintenance, responding to the specific sediment loading conditions of the site, should be outlined in the overall maintenance plan.

One of the most common failures of stormwater facilities is having the entry points of stormwater (i.e. curb cuts, trench drains, etc.) blocked with debris. This blockage can be in the form of sediment, leaves, trash, weed growth, or a combination of these elements. It doesn't take much blockage to prohibit water from entering a landscaped area as intended. In fact, just one-quarter inch of sediment or debris build-up can prohibit the flow of runoff into a stormwater facility and render even the best designed facilities functionally useless.

The best means to remove debris from curb cuts is by using non-mechanical tools such as rakes, shovels, and by hand grabbers to lift and remove debris. Be sure to dispose of debris in an appropriate solid waste trash bin. If removing any weeds or overgrown plant material that is blocking entry points of stormwater runoff, dispose of this material in appropriate yard waste/composting bins.

Sediment Forebays

Sediment forebays are areas immediately downstream of stormwater entry points that allows sediment loads to be deposited prior to entering a landscape system. Sediment forebays are extremely important to limit the amount of sediment impacting vegetated stormwater facilities. Typically made of a concrete slab, pavers, or other hardscape structure, the sediment forebay is a smooth level area that can easily allow for a flat-bed shovel, rake, or broom to lift out sediment. Alternatively, the hardscape forebay allows for a vacuum hose (e.g. Vactor®) to suction sediment. The use of river rock, or cobble, is not recommended for a sediment forebay at stormwater entry points. While cobbles may be useful for erosion control, the uneven surface and void spaces traps sediment, provides desirable conditions for weed growth, and does not allow for easy removal of the sediment.

Sediment forebays are often recessed 2 to 3 inches below the entry area of stormwater flow to provide capacity for some sediment to build up on the hardscape slab. The size or area of sediment forebays will vary greatly depending on how much sediment load is anticipated, how concentrated the flow of water/sediment is when it arrives at the forebay, and the amount of available space.

Sediment and Trash Removal Process

Non-mechanical sediment and trash removal uses hand labor to clean vegetated systems. Using rakes, shovels, trash grabbers, and litter bags, debris is scooped out sediment forebays and, if needed, within the vegetated portion of the stormwater facility. This method is just as effective as mechanical sediment removal and it can be done with little up-front expense, training, or specialized equipment.

Sediment Disposal

Sediment often carries pollutant loads and smaller trash particles that should not be directly disposed of through conventional street-side yard waste bins but can be disposed of in trash bins. If sediment is to be removed by non-mechanical means, it should be picked up from the stormwater facility, stored in plastic buckets, brought to a garbage bin or location where it can be disposed of properly.

Maintenance Schedule

It is best if sediment and trash be removed on a monthly basis and during dry conditions to minimize the potential for compacting soil during the removal process.

Helpful Tips

In some cases, excessive sediment from off-site impervious area runoff is unintentionally carried on-site and impacts stormwater facilities. This can be common in industrial areas where there is unimproved gravel road/parking conditions. It is important to identify these problem sources of sedimentation early on, notify the municipality, and ultimately have the property owner address the stormwater runoff and sedimentation issue.

Also, regular street sweeping and leaf pickup by property owners or municipal staff can dramatically reduce the amount of sediment and small trash items from entering stormwater facilities via stormwater runoff.

Organizing regular neighborhood trash pickup, gutter sweeping, and other maintenance events can allow for an overall community service event that brings neighbors together to be good environmental stewards.

URBAN RAIN DESIGN

▲ *This stormwater planter features a concrete sediment forebay that can be cleaned easily using a flat-bed shovel.*

6.2 Operations and Maintenance

Hardscape and Functional Maintenance Activities

URBAN RAIN DESIGN

▲ *Sediment build-up within the joints of interlocking concrete pavers.*

URBAN RAIN DESIGN

▲ *The void space of pervious concrete should be free of sediment and debris by regular sweeping or blowing.*

Pervious pavement Sweeping Maintenance

Pervious pavement areas are to be kept free of all trash a debris to maintain permeability. Maintenance activities depend on the type of pervious pavement. Two of the more common types of pervious pavement will be discussed here: interlocking joint concrete pavers and pervious concrete.

Interlocking Joint Concrete Unit Pavers

Permeable pavers are typically made of an impervious material. It is the space between each paver, filled with a pervious aggregate, that constitutes the pavers' permeability. Proper maintenance of permeable pavers ensures that water may still permeate the paver joints at the designed infiltration rate.

The surface of permeable pavers must be cleaned regularly to remove fine debris and organic material that may otherwise become lodged between pavers. Sweeping and blowing are two suitable cleaning methods. Pavers may also be cleaned with water and brushes, followed by the low-pressure hosing of the surface, taking care not to dislodge aggregate-filled joints. If necessary, replace any displaced aggregate with clean aggregate.

Weed growth may occur at joints. Weeds shall be removed manually. Refer to **Section 6.3**, Hand Weeding, for weeding practices.

Despite regular surface maintenance, eventually the aggregate-filled joints may become clogged. An annual infiltration test will determine if the aggregate requires replacement. If the aggregate-filled joints are no longer draining at the intended rate, remove the aggregate to a depth approximately half an inch above the bottom of the pavers and replace with clean, similarly graded aggregate. Do not compact aggregate-filled joints and do not use soaps or detergents.

Pervious Concrete

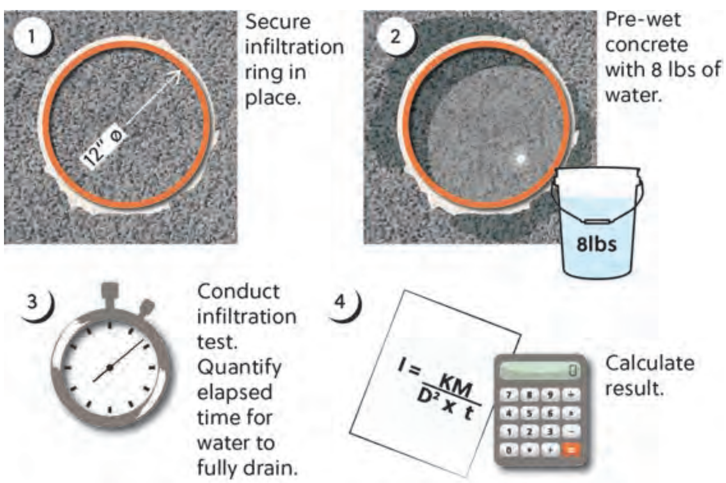
Pervious concrete is a mixture of uniform, large aggregates which bind to form a porous structure. Small pockets of space within the structure allows water to drain directly through the concrete. To maintain the permeability of pervious concrete, sediment must be removed or captured before it can infiltrate too deeply into the pervious concrete matrix.

Routine maintenance will keep pavement clear of particulates. Without regular maintenance, pavement may become severely clogged and require heavier equipment to restore its permeability. Severe storms may also prompt the need for additional maintenance.

Regular maintenance methods include sweeping or blowing. The appropriate equipment depends on the size of the site. Standard walk-behind sweepers and leaf blowers are maneuverable in small sites. Larger sites may accommodate riding or truck-mounted sweepers. Regular maintenance shall occur weekly.

An additional maintenance option is power washing. This method helps to dislodge particles within the top layers of the pervious concrete by either flushing them out of or through the pavement. Where routine sweeping or vacuuming has been neglected, power washing may be necessary to restore adequate infiltration to the pavement. Power washing shall occur periodically.

Where the above three methods fail to restore pervious concrete to its designed infiltration rate, vacuuming can help to free trapped sediment from the pavement. There is a variety of equipment options ranging from walk-behind, ride-on or track-mounted units. Vacuuming may occur annually or as needed.



Infiltration Rate Formula

$$I = \frac{K\,M}{D^2 \times t}$$

M = mass of water (lbs.)
D = diameter of infiltration ring (in.)
T = time for water to fully infiltrate starting once water hits the concrete (sec.)
K = 126,870 (constant to convert the product into

Testing Infiltration Rates

Before you start:
Ensure the surface of the pervious concrete where the test is being performed is clean and clear of debris. The infiltration ring should be 12-inch diameter PVC ring or similar.

Performing the test:

- The infiltration ring should be marked with two lines on the interior to help visualize a consistent water level. Mark the first line at 0.4 in. from the bottom of the infiltration ring. Mark the second line 0.6 in. from the bottom of the infiltration ring. Keep water head between the two marked lines during pre-wetting and wetting.
- Secure the infiltration ring in place with plumber's putty.
- Pre-wet with 8 lbs. of water and maintain the water head between the two marks. Record the elapsed time once water hits the surface of the concrete. This number will be used to determine the amount of water to use in the test. If test takes <30 seconds, use 40 lbs. for the actual test. If >30 seconds, use 8 lbs. of water.
- Perform test annually in multiple locations, ideally every 2,500 ft^2. Average the resulting infiltration rates to produce your final answer.

Per the **C.3 Regulated Projects Guide**, all pervious concrete, pervious asphalt, and interlocking pavers should have a minimum infiltration rate of 100 inches/hour when tested.

See ASTM C1701 for complete instructions.

6.2 Operations and Maintenance
Hardscape and Functional Maintenance Activities


KEVIN ROBERT PERRY

▲ *Without a hard splash pad, the soil downstream of this weir is experiencing significant erosion.*


KEVIN ROBERT PERRY

▲ *It appears that the placement of rock prevents erosion, but runoff is moving around the rock and eroding soil.*

Soil Erosion at Entry Points of Runoff

Erosion of soil and movement of mulch is commonly attributed to the lack of solid mulch material and plant root structure within the direct flow path of stormwater runoff. Stormwater flow points such as curb cuts, trench drains, roof downspouts, and downstream check dams and weirs are common areas to find evidence of soil erosion. Erosion is often exasperated in areas of moderate to steeper slopes downstream from curb cuts where water quickly moves along the soil surface.

Simply applying a layer of pea gravel mulch or installing a modular concrete splash pad downstream of check dams, weirs, or curb cuts can often remedy areas of erosion. In some cases, especially in areas of steep slopes adjacent to curb cuts, a concrete pad and side walls may need to be constructed to control the direction of water flow and dissipate energy. With any solution it is important to assure that any addition of mulch or hardscape doesn't prevent the water from entering the landscape areas. The ultimate goal is to direct and slow the water down within the landscape, not impede it from entering it.

Disconnecting roof downspouts into landscape areas such as planters, rain gardens, or even conventional landscaping is an excellent strategy in reducing stormwater runoff. However, the disconnection point between the roof downspout and landscape area is often a source point for erosion. This is also compounded with the vertical force of water moving from the building. Hence, these disconnection points should be observed frequently for erosion.

Methods for controlling water flow at building downspouts are similar to controlling water at curb cuts by providing hard surfaces for routing stormwater and/or hard surface splash zones to dissipate the vertical energy of water from the downspouts. Using concrete, metal, stone, and other hardscape materials can be added as a maintenance activity to better route and/or control the energy of water into landscape areas.

Maintenance Schedule

Routine inspection prior to the oncoming wet season, and after heavy rainfall events, should be done at curb cuts, check dams, weirs, and downspout disconnection areas to notice any signs of erosion of soil or plant damage.

▲This is a better curb cut option with hardscape walls and pea gravel mulch to control erosion.

▲A concrete splash pad and pea gravel mulch at the spill point of water reduces the potential of erosion.

▲A roof downspout uses a metal channel to direct roof stormwater into a planter area. It is critical that the planter maintains a rock mulch or concrete splash pad to dissipate the vertical energy of water spilling into the landscape area.

▲ A recessed concrete forebay at the end of a trench drain channel helps dissipate energy as water flows into the landscape.

▲ A concrete forebay at the street curb cut is placed lower than the gutter grade to disperse water flow.


▲ Smaller rock at the flow line of a vegetated swale reduces to potential of erosion.

6.2 Operations and Maintenance

Hardscape and Functional Maintenance Activities

URBAN RAIN DESIGN

▲ *This stormwater curb extension suffers from poor infiltration to the point where standing water occurs frequently enough to allow for algae growth and invasive plant species to take over the landscape.*

URBAN RAIN DESIGN

▲ *Conversely, this stormwater curb extension has no check dams and is graded to retain little stormwater. As a result, most of the runoff simply enters the inlet without any ponding of water.*

Troubleshooting Too Much Standing Water

There are many reasons why green infrastructure facilities may have too much ponded water over a given time including, but not limited to: poor native soil conditions that do not allow for infiltration, high groundwater table conditions, poor overall grading design, and construction execution that may not follow the design plans. Having any standing water several days after a storm event can cause several potential problems, such as:

- Vector control/Mosquito issues. Standing water should not remain in the treatment measures for more than five days to prevent mosquito generation. If mosquito larvae are observed, contact the County Vector Control District at (408) 918-4770 or (800) 675-1155.
- Loss of capacity for back-to-back storm events. Ideally green infrastructure facilities would be able to soak in water over a given time between storm events so that there is capacity to capture the next storm.
- Stagnant water/algae growth/root rot. Prolonged standing water can cause algae to bloom and cause anaerobic soil conditions at the root zone leading to rot and mildew on leaves.

In situations where there is too much standing water over a prolonged period of time, it may be necessary to adjust the overflow structure to retain less water and promote more evapotranspiration rather than infiltration. Also, or in addition, the soil grade may need to be raised to retain less water and the overall footprint of the green infrastructure facility may need to be expanded. This is approach is especically helpful in areas with high groundwater tables. With projects that utilize an underdrain system, there also might be an issue of runoff not being able to enter the underdrain system due to a clogged condition. Use the cleanout riser to clear any underdrains of obstructions or clogging material.

Troubleshooting Too Little Standing Water

Conversely, there are projects that simply retain too little stormwater runoff. In most instances it is due to have the overflow structure placed at too low of a grade to retain much water. It may be possible to either raise the overflow structure to increase capacity or install check dams around the overflow structure or at locations upstream to promote more water retention (See **Chapter 4**). If water is entering underdrain systems at too fast of a rate, it is also possible to install a reduced diameter orifice at the end of the system to control the amount of water enter the underdrain and force the water to move more slowly through the system.

Maintenance Schedule

Routine inspection prior to the oncoming wet season, and after heavy rainfall events, should be done at curb cuts, check dams, weirs, and downspout disconnection areas to notice any signs of erosion of soil or plant damage.

Testing Soil Infiltration Rate with a Double-Ring Infiltrometer

Supplies

- Double-ring infiltrometer: Two impermeable cylinders made of a durable material, such as PVC. See graphic for size requirements.
- Water source
- Timer
- Ruler or measuring tape
- Flat wooden board and mallet to drive cylinders into the ground

Prepare cylinders:

The small cylinder is concentric within the large cylinder. Place the wooden board across both and drive them evenly into the ground, at least 2 inches deep and at least 6 inches above the surface. The bottom of both cylinders must be at the same depth. The smaller cylinder is used to measure water drop over time. The larger cylinder minimizes lateral water movement.

During the first 30 minutes (Presoak):

- Fill both cylinders to the brim.
- Maintain water level above 4 inches for the duration.
- After 30 minutes have passed, refill the cylinders completely.

During the next 30 minutes:

- Notate the water depth at full capacity in inches.
- After 30 minutes have passed, again notate the water depth in inches.
- Determine the difference in water level in inches.

Determine the measurement interval to be used during testing:

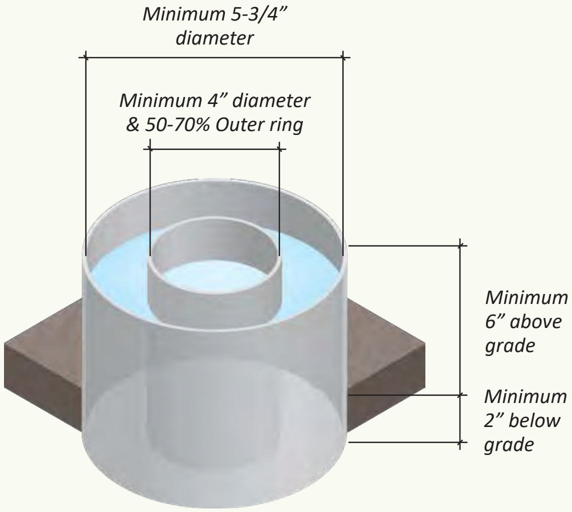
- If the difference in water level is greater than or equal to 2 inches, use 10-minute intervals.
- If the difference is less than 2 inches, use 30-minute intervals.

Test:

Obtain 8 readings or until a stabilized rate is achieved. A stabilized rate is achieved when there is a difference of one-quarter inch or less between the lowest and highest readings taken during four consecutive measurements. To take a reading:

- Fill both cylinders to the brim.
- At the appropriate interval determined during the presoak phase, obtain and record the difference in water level in the inner ring in inches.
- After each reading, stop the timer, refill the cylinders and reset the timer.

Double-Ring Infiltrometer Test



▲ *Required dimensions of a double-ring infiltrometer.*

Calculate

The final reading or the average stabilized rate, expressed in inches per hour, represents the infiltration rate.

$$\text{Soil Infiltration Rate (inches/hr)} \quad \frac{R}{I} \times \frac{60 \text{ min.}}{1 \text{ hr}}$$

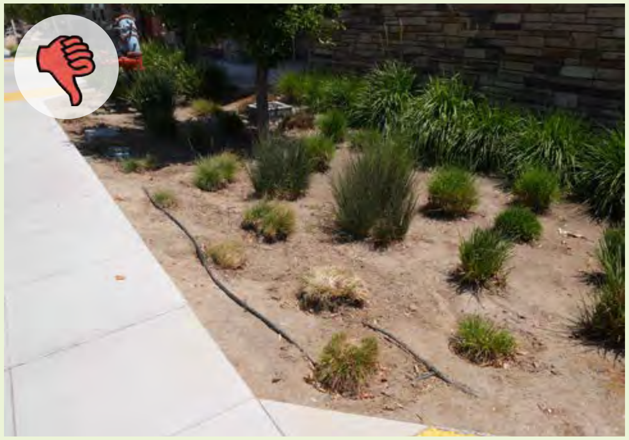
R = final reading or average stabilized readings (in.)

I = interval (min.)

Per the **C.3 Regulated Projects Guide**, rain gardens should have an infiltration rate of 5-10 inches/hour when tested.

CHAPTER 6

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities


URBAN RAIN DESIGN

▲ *A rain garden without regular mulch replacement results in plant desiccation and exposed drip irrigation lines.*


URBAN RAIN DESIGN

▲ *This green street unfortunately uses organic mulch in the flow path of water which will in time float away.*

The Benefits of Using Mulch

Mulch benefits plant health, conserves water, and reduces maintenance requirements. A mulch layer insulates the soil, keeping it cool and alleviating evaporation from its surface. With a soil that remains moist and cool, plants experience less stress. Since the soil retains more of its moisture, less water is needed to irrigate. Additionally, organic mulches such as bark mulch replenish organic material in the soil as they break down and provide a food source for beneficial soil organisms that enrich the soil. Mulch suppresses weed growth, reducing the amount of manpower required to physically remove the weeds. Desired plants then have fewer contenders for water and nutrients. Lastly, mulch shields bare soil from the erosive forces of wind and rain. Overall, mulch ensures that soil remains nurtured which in turn supports a healthy landscape. The benefits of mulch far outweigh the costs of its upkeep.

Mulch Application

Whatever the variety, mulch needs regular care to create and maintain an even and uniform appearance at each stormwater planter area. A layer of mulch, no less than 3 inches deep, needs to be sustained. Though only 3 inches of mulch is required, maintaining a deeper layer of mulch greatly reduces the labor needed to control weeds, reduces water use and helps the plants stay healthy. Mulch is not required in areas where plant foliage completely covers the soil surface. Maintain a 6 to 12-inch clearance around the base of trees and shrubs. If mulch is placed too close to a tree, excess water build-up can damage its trunk. Keep the root flare of a tree exposed. When applying a mulch layer, it is critical that the mulch material not impede the flow of water through curb cuts. Make sure that the grade of the soil is low enough to add the mulch layer, but not impede water flow.

Maintenance Schedule

Mulch levels should be monitored during scheduled site visits occur, or at a minimum of twice per year. Mulch is commonly knocked or washed out of stormwater facilities. During site visits, the disturbed mulch should be placed back into the facility or new mulch should be applied and smoothed into an even layer. After large storm events, mulch should be added or redistributed within stormwater facilities where the mulch has been reduced to less than 3 inches deep. However, if a large amount of mulch is washed out of a facility, this indicates that the incorrect type of mulch has been applied. If bark mulch or arbor mulch is routinely washed away, remove and replace with a heavier variety of mulch, such as pea gravel.

Common Types of Mulch Material

Bark mulch: Typically made from the bark of conifer trees, bark mulch is shredded or tumbled to a uniform size. It contributes to the organic material in a soil, is readily available, inexpensive and handles foot traffic well. However, in stormwater planters, it can contribute to maintenance issues as it readily floats and is easily displaced. Therefore, bark mulch is not recommended.

Composted wood mulch: Composted wood mulch is the recommended mulch for most GI measures. The Countywide trogram has a specification for composted wood mulch and a list of some mulch suppliers. See www.flowstobay.org/preventing-stormwater-pollution/with-new-redevelopment/c-3-regulated-projects/ for more information. Composted wood mulch is a recycled material and is readily available. The composting process increases the mulch density, which along with material irregularity helps the mulch "knit" together and resist floating.

Pea gravel/small-size crushed rock: Pea gravel ranges in size from a 1/8 inch to a 3/8 inch diameter. Pea gravel is an effective option for stormwater planters because of its weight. It is heavier than other mulch types which helps prevent it from washing away. Its weight makes it more difficult and costly to install; however, it will not need to be replaced as often as mulches that decay. Similar to other mulches, pea gravel helps to maintain soil moisture though it does not contribute organic material to the soil. Another maintenance consideration includes the challenge of adding or replacing plants into pea gravel mulch. Additionally, debris can be challenging to remove. Pea gravel mulch is desirable for use in stormwater planters because of its longevity and is not easily displaced from stormwater or maintenance activities.

Uniform Bark Mulch

Composted Wood Mulch

Pea Gravel

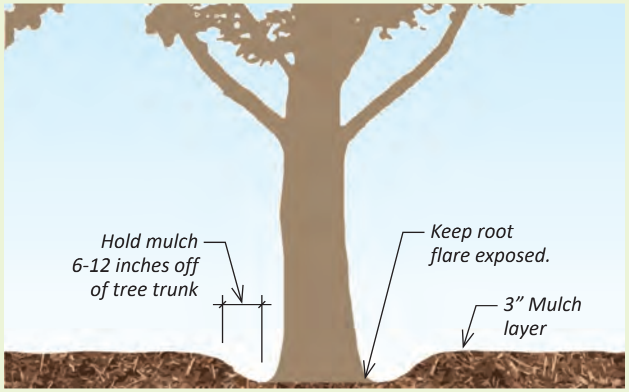
1 For wood mulch specifications please see www.flowstobay.org/preventing-stormwater-pollution/with-new-redevelopment/c-3-regulated-projects/ for more information

URBAN RAIN DESIGN

▲ *This green street uses pea gravel mulch in the flow path of water and organic mulch on upland side slopes.*

URBAN RAIN DESIGN

▲ *Pea gravel mulch used on both the side slopes and wetted area of a vegetated swale prevents erosion.*



QUADRIGA, INC.

▲ *It is recommended that a 3-inch layer of mulch be maintained throughout the year and keep a 6 to 12-inch clearance around the base of trees.*

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities


JANNEFER AN

▲ *A poorly managed irrigation schedule and/or duration causes wasteful water runoff.*


URBAN RAIN DESIGN

▲ *Poorly performing irrigation can also quickly cause plant death from under-watering or lack of coverage.*

Irrigation System Checks and Repairs

In our California climate, a well-maintained landscape system is dependent on a properly functioning irrigation system. This includes a system that applies water efficiently and is always in working order. To ensure that the landscape has the best chance to thrive both the irrigation schedule and overall functional components should be checked regularly by a qualified professional landscape contractor.

Checking Irrigation Schedule

Irrigation scheduling involves determining the frequency and duration of watering intervals. Site characteristics like weather conditions, soil infiltration rates and drainage patterns affect this determination. Plant characteristics like a species' rooting depth is also an important factor as enough water needs to be applied at each irrigation cycle to wet through the depth of the root zone. Other scheduling factors include the watering requirements for a hydrozone and the application rate and distribution uniformity of an irrigation system within that hydrozone.

Irrigation frequency (number of days/per week) should be based on seasonal evapotranspiration (ET) data (available through CIMIS). Irrigation frequency for each hydrozone shall be adjusted each month to reflect ET expected in the next month. For sites with controllers that monitor ET and adjust schedules automatically, the landscape contractor should program the controller according to manufacturer specifications, and monitor to ensure that frequency is appropriate.

Irrigation duration (number of minutes per watering) within each hydrozone shall be based on the soil infiltration rate, species water requirement and rooting depth within the hydrozone and the application rate and distribution uniformity of the irrigation system within that zone.

If irrigation runoff or ponding of water occurs, either within the landscape or crossing onto paved surfaces, the application time shall be divided into shorter time intervals and repeated as needed. Runoff indicates that plants are being over watered and is not allowed. Irrigation duration for each hydrozone is to be adjusted monthly as well.

Landscape irrigation shall be scheduled between 10 p.m. and 6:00 a.m. to avoid irrigating during times of high wind or high temperatures.

Checking Irrigation Coverage

The landscape contractor should maintain the irrigation system for optimum performance, as per manufacturer's specifications, by inspecting the entire system on an ongoing basis. This includes cleaning and adjusting all spray and bubbler heads, drip emitters and valves for proper coverage and adjusting for any and all overspray/runoff onto adjacent impermeable surfaces. Runoff of water from irrigation systems into or onto streets, sidewalks, stairs, or gutters is not permitted. The landscape contractor should immediately shut down the irrigation system and make adjustments, repairs, or replacements as soon as possible to correct the source of the runoff. Equally important, is to check irrigation coverage to ensure that plants have enough water distributed to the root zone. Plant material should be carefully observed for signs of wilting, indicating a lack of water or sudden die-off at the base of the plant indicating over-watering.

Irrigation System Repair

Any irrigation components that are damaged should be replaced or repaired as soon as possible as to not stress plants or waste water. This can only be done by frequent on-site inspection as a break in the system can occur at any time. Common minor repairs include damaged, clogged, or missing sprinkler nozzles/drip emitters, adjustments of sprinkler patterns or arcs, and the adjustment of sprinkler position (i.e. raise, lower, or straighten sprinkler heads), and breaks in drip irrigation supply and distribution lines. When repairs are needed, make sure that repair work is not performed when the soil is saturated either from rainfall, a break in the irrigation system, or an over-irrigated condition to minimize the potential for soil compaction.

Maintenance Schedule

Every month during the season of operation, the irrigation system be observed for proper schedule, coverage, and any possible repairs needed. A more extensive annual irrigation system check should be performed prior to the start of the dry season in April. When needed, adjust the irrigation controller for current water needs of plants. Irrigation system pressure should be checked and adjusted at least quarterly during season of operation. Maintain documentation of irrigation checks and as-built plans of any changes or adjustments to the system.

Irrigation Check Test

In some cases, excessive sediment from off-site impervious Once a year, at the start of the irrigation season, or as needed conduct an irrigation system check test. The following tasks should be performed:

- Ensure all flush valve/cap locations are visible.
- Ensure valve boxes are visible and can be opened.
- Clean valve boxes of dirt and debris.
- Inspect valves, filters, and pressure regulators for damage or leaks. Check wire splices.
- Flush out the irrigation system and check for proper operation of each valve zone.
- Flush irrigation laterals.
- Inspect and clean filters. Replace damaged or torn filters.
- Clean or replace plugged sprinkler nozzles.
- Make sure plants have adequate numbers of drip emitters.
- Replace irrigation controller and sensor annually, as applicable.
- Test soil sensors per manufacturer's testing instructions.

URBAN RAIN DESIGN

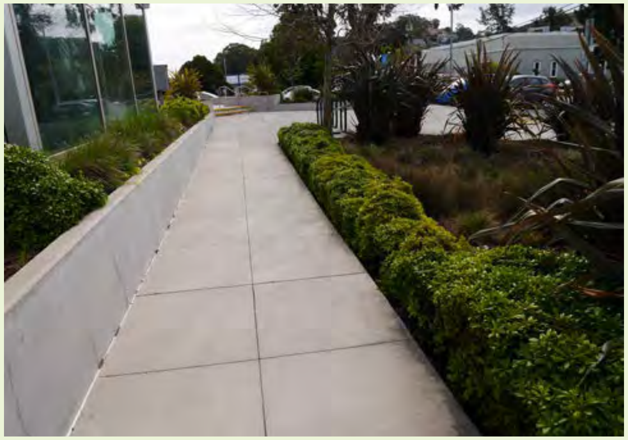
▲ *A green street with exposed drip irrigation lines and valve box is very susceptible to breakage.*

6.3 Operations and Maintenance

Landscape-Related Maintenance Activities

URBAN RAIN DESIGN

▲ *This landscape is not trimmed excessively and left to grow more informally.*



URBAN RAIN DESIGN

▲ *Even more formal planting arrangements can by trimmed lightly to achieve desired form.*

Proper Plant Trimming

Bay-Friendly Landscaping suggests that plant trimming and pruning should complement the natural form and strengthen the structural integrity of the plant. It should not be used to dominate plants. Creating straight line hedges and topping plants, especially at the wrong time of year, does more harm than good. The labor required for this type of trimming is not a cost well spent as it is endless, weakens the plant, and generates unnecessary plant debris. Selective trimming and pruning techniques of plant material can maintain adequate sight visibility, help spur new growth and flowering, and allow for better flow of stormwater throughout the landscape.

Seasonal Trimming

Pruning at different seasons triggers different responses in different species. Late winter or early spring, before bud break, is typically the best time to prune many species because new tissue forms rapidly at this time. Summer pruning tends to suppress growth of both suckers and foliage. Late summer or early fall pruning typically causes vigorous regrowth, which in some cases may not harden off by winter, leading to possible cold damage. Whenever unexpected damage from vandalism or bad weather occurs, plants should be pruned at once.

Pruning for most spring-blooming shrubs should be performed immediately after flowering to avoid reducing the floral display. For shrubs that bloom in spring from buds on one-year-old wood, prune when their flowers fade. Early summer-blooming shrubs should be pruned to early spring, prior to bud set, or in summer immediately following flowering. For shrubs that bloom in late summer or fall on current year's growth, prune in winter.

Reducing Size and Controlling Form Pruning

In general, shrubs and groundcovers should be allowed to grow unpruned to their natural size and shapes excepted of the plant variety. Shrubs and groundcovers should only be pruned as required for safety, visibility, and plant health. Deciduous shrubs require maintenance pruning to keep them healthy and in scale with their surroundings. Maintenance pruning practices should begin at the time of planting, or after rejuvenation of older shrubs. For height maintenance of mounding-type shrubs, prune only the longest branches. Make cuts well inside the shrub mass where they won't be visible. This method reduces mounding shrubs by up to one-third their size without sacrificing their shape.

Ornamental Grasses, Rushes, and Sedges Trimming

Pruning methods for ornamental grasses differ based on whether the grass is an ornamental perennial grass, an ornamental evergreen grass or a grass-like evergreen plant.

Perennial ornamental grasses need to be sheared to maintain their appearance. Foliage should remain throughout winter. Once the grass begins to push new growth, cut back foliage to a height of 6 to 8 inches. Example perennial ornamental grass species include: *Miscanthus, Pennisetum*.

Evergreen ornamental grasses should not be cut back annually. Instead, rake or comb through foliage with a rubber coated glove to remove spent foliage. When rejuvenation is required, an evergreen ornamental grass may be cut back to a height of 12 to 18 inches. Example evergreen ornamental species include: *Calamagrostis, Muhlenbergia*.

Evergreen grass-like plants may also be raked or combed with a rubber coated glove to remove spent foliage. Some species may not respond to raking or coming as their foliage, even when spent, is strongly attached at the base. For these species, stalks may need to be individually pruned out at the base of the plant. Example grass-like species include: *Dietes, Liriope, Lomandra, Phormium*.

Rushes and sedges that are commonly planted in the wetter and lowest elevation stormwater facilities, should only be trimmed to avoid the plants flopping over and creating overcrowding conditions. If trimming is required for this reason, then only trim a maximum of 1/3 off of the top of the plants per year. Trimming rushes and sedges down to the base of the plant each year will cause the plant to degenerate and die from the inside out. Example rush and sedge species include: *Juncus, Carex*.

Maintenance Schedule

During quarterly site visits, the maintenance staff should determine if pruning is required. Dead, broken or diseased branches need to be removed immediately. Shrubs and groundcovers should be trimmed back from sidewalks, curbs, and paved areas on a quarterly basis. Seasonal pruning depends on the flowering time of the shrub in question. Prune spring & winter-flowering shrubs in early summer as needed to maintain proper shape. Prune summer & fall-flowering shrubs in early winter as needed to maintain proper shape.


URBAN RAIN DESIGN

▲ *Unfortunately, many rushes and sedges are severely cut back to the ground. Eventually these plants will die.*

URBAN RAIN DESIGN

▲ *If trimming is needed for rushes, cut back foliage to maintain a height of at least 12-18 inches.*


QUADRIGA, INC.

▲ *Comb evergreen grasses with a rubber coated glove to remove spent foliage.*

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities

DANIEL SMITH (PUBLIC DOMAIN PICTURES)

▲ *A heavily pruned tree weakens the structure, reduces the canopy, and is aesthetically unpleasing.*

DIMITRY B (WIKIPEDIA)

▲ *Proper pruning of trees allows for better form, increases site visibility, and strengthens the structure of the tree.*

Tree Pruning

Trees require pruning to develop and maintain a healthy structure, to keep them free of disease and pests, and to keep roadways and walkways clear of obstructions. Young trees need to be pruned annually for up to five years after planting. Annual pruning directs tree into the appropriate form for its species and the site as well as develop a strong branch structure. For example, trees with co-dominant trunks and multiple branch attachments need to be pruned over a period of several years to correct these structural defects. The goal is to create a tree that has a strong central trunk with lateral branches spaced vertically and horizontally.

Trees of all ages need to be regularly inspected for crossing, weak, diseased or dead branches so that they may be removed. To pre-empt branch weakening, maintenance staff may also reduce end weight on heavy, horizontal branches.

No more than 20% of its live foliage should be removed or else cause unnecessary stress to a tree. When branches need to be removed or reduced, thinning cuts are preferred to heading cuts. See sidebar on the opposite page for illustrations of thinning and heading cuts. Trees should not be topped as it can cause severe injury to the tree. For the same reason, interior branches should not be stripped out, an injurious method referred to as "lion's tailing."

In addition to tree structure and health, branches need to be trimmed so that they do not impede pedestrian or vehicular traffic. Accepted clearances include a 14-foot vertical clearance over roads, a 10-foot clearance above parking spaces and an 8-foot vertical clearance over walkways. Trees should also be pruned to provide access to buildings, utilities and other sites, as needed. Besides what is listed above, trees do not require routine thinning.

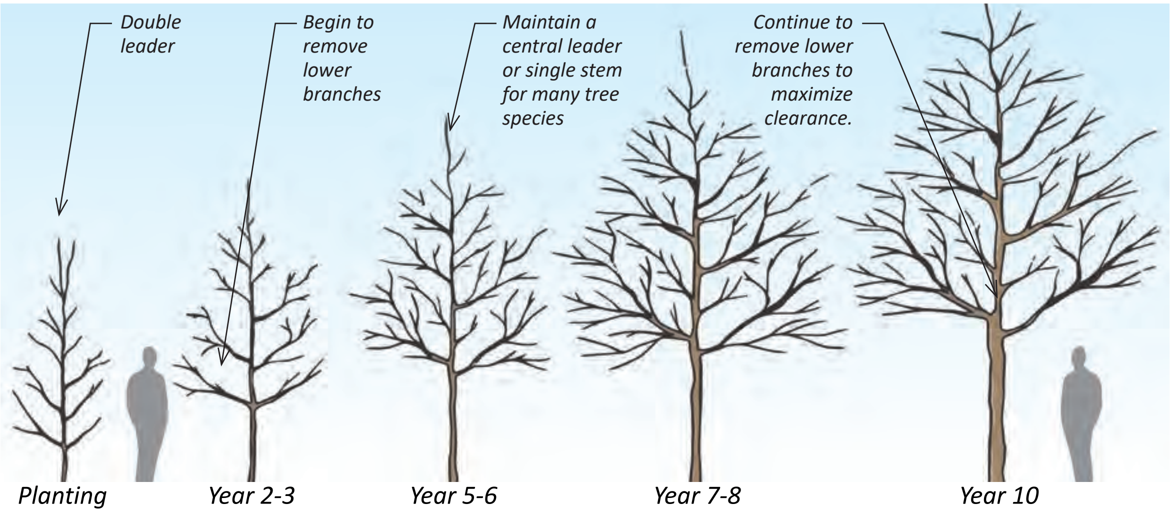
Pruning Standards

Tree pruning needs to be performed by trained, experienced personnel. While pruning occurs, the presence of an I.S.A.-certified arborist or tree worker is recommended. The arborist must have a State of California Contractor's License for Tree Service (C-61 D-49). Pruning needs to adhere with the most recent edition of the American National Standard for Pruning (A300) and the International Society of Arboriculture's Best Management Practices for Pruning.

Maintenance Schedule

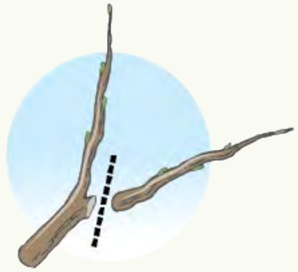
During semi-annual visits, monitor any broken or fallen branches need to be removed from trees. Also, suckers growing from the base of the tree should be removed.

Arborists will best determine the appropriate months in which tree pruning should occur. There are several occurrences that influence the scheduling. It is important to avoid times of bud break, flowering, and leaf drop. It is also key to avoid peak periods of insect and disease activity for pests to which the tree species is susceptible. Once the appropriate month is determined, annual pruning can commence. Maintenance staff should prune any tree branches that interfere with public safety and remove dead or diseased branches from the trees as described above. Additionally, stormwater planter trees require yearly pruning to encourage strong upward growth.

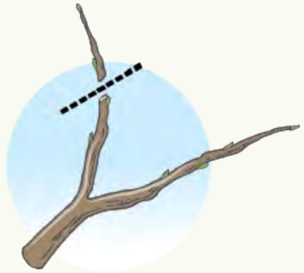


▲ *At time of planting, limit pruning. Remove only dead or broken branches. Where multiple leaders occur, reduce to a single top. Remove also narrow, V-shaped crotches. When pruning, avoid removing more than 1/3 of the total number of branches at one time. If the tree is weak, prune even less. Avoid damage to the trunk over the entire life of the tree.*

Types of Pruning Cuts



▲ Thinning cuts remove branches at their points of origin or attachment. Used in moderation, thinning cuts reduce shrub density without stimulating regrowth. Make thinning cuts just above parent or side branches and roughly parallel to them.



▲ Heading cuts stimulate growth of buds closest to the wound. The direction in which the top remaining bud is pointing will determine the direction of new growth. Make heading cuts selectively to reduce tree/shrub height and retain natural form. For heading cuts, prune a quarter inch above the bud, sloping down and away from it.

LA CITTA VITA

▲ *Creating vertical clearance under trees for vehicles and people is an important maintenance consideration.*

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities

▲ *This vegetated swale contains less than 70% coverage of plant material and needs additional plant material added.*

▲ *This rain garden achieves 100% plant coverage within the landscape.*

Plant Replacement Policy

Any trees, shrubs or groundcovers found to be dead, damaged or missing are to be replaced as soon as possible. It is also important to determine why a plant or plant(s) have died so that any potential fixable causes (i.e. lack of water, too much water, etc.) can be remedied and an appropriate replacement plant can be identified.

It is important to maintain at least a 70% plant coverage within landscaped stormwater facilities. A functioning stormwater system is dependent on the ability of its plant material to uptake water, nutrients and potential pollutants. If by visual assessment, the landscape is determined to have inadequate plant coverage, add plants until the minimum or desirable coverage is achieved. Refer to as-built drawings to determine the types of plants to be added. If drawings are not available, match additional plants to the species already present within the planter area.

If environmental conditions change, plant species selected for the original site conditions may begin to fail. For instance, shrubs planted near a young tree will receive less daylight as the tree grows into its mature canopy. If the shrub is failing and the cause is determined to be due to inadequate sunlight, select and replace with a species that is adapted to the new condition.

Plant Replacement Guidelines

A site's as-built drawings will be referred to when determining the required container size and spacing of the replacement tree, shrub or groundcover. If as-builts are not available, defer to best practices for the determination. Below lists sizing requirements and minimums.

Replacement trees must be equal in size to the originally installed tree at the time it was planted at the site. Example: if the tree was a 36-inch box size when originally planted the replacement shall be a 36-inch box size. Replacement trees will be no less than a 24-inch box size. Before it is installed, the replacement tree needs to be approved for size, health, root development, structure and appearance by the Owner's Representative. Replacement trees are to be double-staked with 2-inch diameter stakes. Once the tree trunks are larger than 2-inch caliper and the trees are able to support themselves, the stakes are to be removed. The stakes then need to be removed from the site and disposed of by a legal method. If it is possible, recycle the stakes.

Replacement shrubs must be from at least 5-gallon containers and be at least 18 inches in height when planted, unless otherwise approved by an authorized representative. Replacement groundcover, grasses or perennials must be planted at spacing per installation plan from 1-gallon containers. When replacing any plant material, it is important to determine the location of existing irrigation system components such as drip irrigation lines and spray heads as to not damage these components while digging.

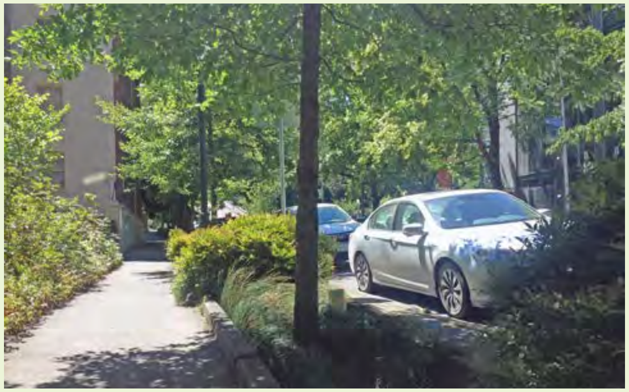
Landscape Succession

As stormwater landscapes mature over time, some plants species may outperform others from the initial installation date or plants simply die out. This is very common as the landscape is never a static system. Changing micro-climate conditions may require that selective removal and replacement of plants be made. Rarely is there a need to perform a complete replacement of plant material unless there is a significant change in the site conditions.

The most common type of plant succession is where tree canopy expands over time and begins to create increasingly shady conditions for understory shrubs, groundcovers, and grass-like plants. This should be treated as a positive aspect of landscape succession as tree canopy over parking lots, streets, and other hardscape conditions should be encouraged. However, understory plants that initially may have been planted in full sun conditions now have to adapt to part-shade to full-shade conditions. Some plant species are just not that adaptable to sun conditions and may need to be replaced. The situation can be reversed as well if a once deep shade condition (next to a tall building or under a large mature tree) changes and suddenly becomes a full-sun condition. Then shade-tolerant understory plants might need to be replaced with more sun tolerant species.

▲ *This rain garden has about 70% plant coverage which is considered the minimum for functionality.*

▲ *Planted in 2005, this green street planted a series of street trees in full-sun conditions.*



▲ *Shown in 2016, this same project's tree canopy growth is so robust that it will eventually require new re-planted shade-tolerant understory plants.*

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities


URBAN RAIN DESIGN

▲ *Without regular weeding maintenance, a stormwater landscape can quickly be overtaken by undesirable plants.*


CENTER FOR NEIGHBORHOOD TECH. (FLICKR)

▲ *Hand weeding, on a regular basis, is the most desirable method for controlling weeds.*

Hand Weeding

Weeds in planted areas, sidewalks, curbs, gutters or pavement are to be removed as the weeds emerge. Hand weeding is the preferred maintenance approach to controlling weeds over using herbicides. With weeding, a consistent weeding schedule must be maintained, so that weed growth does not reach a point where herbicide use would be required. When pulling weeds, it is critical to remove as much of the root system as possible as new weeds can grow from root remnants left behind in the soil. Dispose of weeds off-site. The regular maintenance of a mulch layer will help minimize weeds in planted areas.

The opposite page sidebar illustrates common landscape plants that readily self-sow and grow invasively in San Mateo County. These are to be removed immediately from all stormwater facilities. Refer to the California Invasive Plant Council (Cal-IPC) for more information on invasive species.

Hand Weeding Schedule

Weeding shall occur during regular site visits, or at a minimum of four times per year. All visible weeds are to be removed.

Herbicide Use

Herbicide use should be only used as a method of last resort in response to stormwater landscape taken over by weeds. If necessary, only least toxic herbicides may be used. These include:

- Fatty acid potassium salts (herbicidal soaps e.g. Safer's Superfast Weed and Grass Killer® Dr. Bronner's Peppermint Anti-Bacterial Soap)
- Acetic and citric acids (e.g. Nature's Glory Weed and Grass Killer RTU®)
- Clove, citrus, mint and thyme oil (e.g. Matran II®, Xpress®)
- Low-toxic, low-residual herbicide [e.g. glufosinate-ammonium (Finale®), pelargoic acid (Scythe®)]

Herbicide use shall follow all State restrictions and Manufacturer's directions. Do not use herbicides 48 hours before predicted rain events or use until 48 hours after rain events. Restricted chemical herbicides may not be used under any circumstances.

Pesticide Use

The term pesticide applies to insecticides, fungicides and other substances used to control pests. Pesticides are potentially hazardous to human and environmental health. The necessary precautions must be taken to ensure the protection of the public, maintenance personnel and the environment.

Bay-Friendly Landscaping emphasizes Integrated Pest Management (IPM) practices to control pests and diseases in the landscape. IPM uses cultural, mechanical, physical and biological control methods before using pesticides. Chemical controls are applied ONLY when monitoring indicates that preventative and non-chemical methods are not keeping pests below acceptable levels. Pesticides are not to be applied on a prescheduled basis. When pesticides are required, the least toxic and least persistent pesticide that will provide adequate pest control is to be applied. Least-toxic pesticides have a high LD-50, low residual and narrow range of toxicity. Refer to OMRI (Organic Material Review Institute) for a list of pesticides that meet these requirements.

Chemicals should be applied in a safe manner and according to label instructions and local, State and Federal requirements. All chemical applications should be performed by a licensed, trained technician. A Pest Control Operator license is required by the State of California. Additionally, a California Chemical Applicators license is required by maintenance personnel for chemical applications.

Chemical Use Record-Keeping and Reporting

All herbicide and pest management activities should be documented and reported to the Project Site Owner. Each record should include the following information: target pests/weeds, type and quantity of the chemical used, site of the chemical application, date the chemical was used, name of the chemical applicator, application equipment used, and prevention and other non-chemical methods of control used. The pest/weed management record will be submitted to the Owner after any application of chemicals.

A Chemical Work Report shall be completed for each chemical application. A Chemical Usage Report should be submitted to the County Agricultural Department. Copies are to be sent to the Owner's representative as part of the monthly maintenance report, if applicable.

Common Invasive Species


CDFW

Cortaderia selloana
Pampas Grass


DARYL MITCHELL

Cytisus scoparius
Scotch Broom


FOREST & KIM STARR

Genista monspessulana
French Broom


CDFW

Hedera helix
English Ivy


JOHN TANN

Ligustrum sinense
Privet


JENNIFER SNYDER

Phyllostachys spp.
Bamboo


LEONARA ENKING

Stipa tenuissima
Mexican Feathergrass


ALGOT RUNEMAN

Vinca minor
Periwinkle

6.3 Operations and Maintenance
Landscape-Related Maintenance Activities

URBAN RAIN DESIGN

▲ *A rain garden with compacted soils cannot maintain long term function.*

URBAN RAIN DESIGN

▲ *A landscape with adequate mulch reduces the potential for soil structure damage.*

General Soil Management

Landscape-based stormwater facilities depend on soils that are biologically active and held together by plant roots. Maintenance activities are to be implemented to nurture biological activity, provide organic material and protect soil from damage. The most common type of soil damage includes over-compaction and soil erosion.

Soil should be protected from compaction by assuring the pedestrian and vehicular traffic be confined to paved areas. Soil shall be protected from erosion by maintaining a vegetative cover over the soil to a possible extent and maintaining a 3-inch layer of mulch, as recommended by the **Model Water Efficient Landscape Ordinance (WELO)**. See **Section 3.1** for additional technical information on mulch applications. Also, use of leaf blowers should be minimized in planting beds to limit the movement of soil and mulch.

Soil Analysis Determines Fertilizer

A healthy landscape, consistent with Bay-Friendly Landscaping, relies on organic fertilizers and soil amendments from natural sources that release elements slowly, which is preferred. Additional amendments and fertilizers that are approved for use by the Organics Materials Research Institute (OMRI) for use in crop production are approved for use in the landscape.

Soil samples of the landscape need to be submitted annually for testing to an accredited and approved testing laboratory. A minimum of two separate agronomy reports should be prepared for the site and will include soil pH, basic and minor nutrients, salinity, organic content, percolation rate and a textural analysis. Each of the samples should consist of a composite of three shovelfuls of soil. The annual soil reports should be conducted during late winter. The types and quantities of fertilizer and/or soil amendments to be applied should be determined from the results of the soil analysis and shall be based on an 'organic' approach to soil management. Additional soil reports can be requested as required to resolve ongoing soil problems.

An appropriate amount of fertilizer should be applied to supply the specified quantity of nutrient as determined by soil analysis and/or plant tissue analysis. Fertilizer should be applied and maintained to prevent pollution of surface and groundwater and to avoid creating a nitrogen draft in the soil or toxicity to plants.

Fertilizer Application Schedule

Fertilizers shall be applied on a prescription basis only. Application frequency shall be determined by plant need and assessed through soil and/or tissue analysis. The following maximum annual number of applications are provided as a guideline:

- Trees, shrubs and woody groundcovers: once per year
- Herbaceous ground covers, perennials and grasses: two times per year

Apply granular fertilizer to planting areas in late winter or early spring. Be sure to make application prior to a moderate rainfall so the rain will wash the fertilizer in.

Soil Amendment Use

Soil should be amended based on the pH and soil chemistry recommendations of the soils report. When required, apply amendments to the exiting soil and gently work into the top 2 inches of soil, avoiding disturbing the roots of existing plans. Once amendment is complete, reapply the specified mulch layer.

Common Organic Soil Conditioners, Amendments and Fertilizers

Sphagnum Peat Moss: absorbs water, slowly releasing it for use by plant roots. It lightens clay soil, providing aeration, and adds mass to sandy soil, helping prevent the leaching of nutrients.

Compost: Made from decayed organic materials such as straw, corn cobs, food wastes, poultry litter, grass clippings, leaves, and manure. Composts improve soil structure and slowly release nutrients to plant roots.

Lime: Added to raise soil pH, reducing acidity.

Sulfur: Added to lower soil pH, increasing acidity.

Organic Granular Fertilizer: Application rates per soil report recommendations.

What Do the Three Numbers on Fertilizer Labels Mean?

The three numbers on fertilizer labels represents the value of the three primary nutrients used by plants. These macro-nutrients are nitrogen (N), phosphorus (P) and potassium (K) or NPK for short.

All plants need nitrogen, phosphorus and potassium to grow. The following is a brief description of what each of these macro-nutrients do to help plants thrive:

Nitrogen (N) – nitrogen is largely responsible for the growth of leaves on the plant.

Phosphorus (P) – Phosphorus is largely responsible for root growth and flower development.

Potassium (K) – Potassium is a nutrient that helps the overall functions of the plant perform correctly.

For each fertilizer, whether organic or chemical-based, the NPK values are shown as a ratio. Knowing the NPK values of a fertilizer can help you select one that is appropriate for your plant growth needs.

There are many different types of NPK values for fertilizers. The higher the number, the more concentrated the nutrient is in the fertilizer. For example, numbers on fertilizer listed as 20-5-5 has four times more nitrogen in it than phosphorus and potassium. A 20-20-20 fertilizer has twice as much concentration of all three nutrients than 10-10-10.

The fertilizer numbers can be used to calculate how much of a fertilizer needs to be applied to equal 1 pound of the nutrient you are trying to add to the soil. Conducting a soil test will help determine what balance of fertilizer numbers will be appropriate for the landscape's needs and deficiencies.

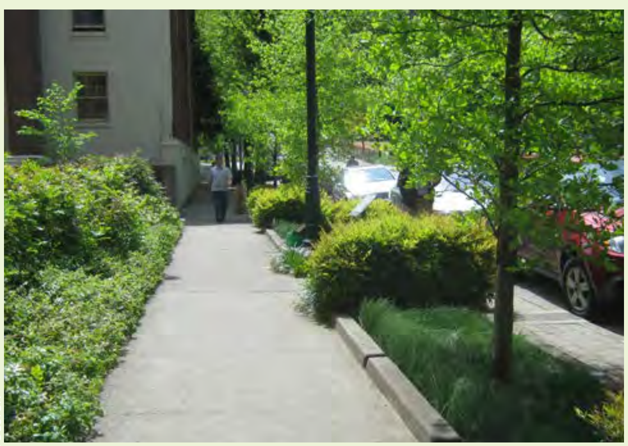
(from www.gardeningknowhow.com)

6.3 Operations and Maintenance

Landscape-Related Maintenance Activities

DAVE ELKIN-CITY OF PORTLAND

▲ *Choose low-growing plant material and place trees outside of the site distance triangle.*



URBAN RAIN DESIGN

▲ *This green street allows for street trees to be limbed up to provide adequate height clearance for pedestrians.*

Visibility Throughout Site

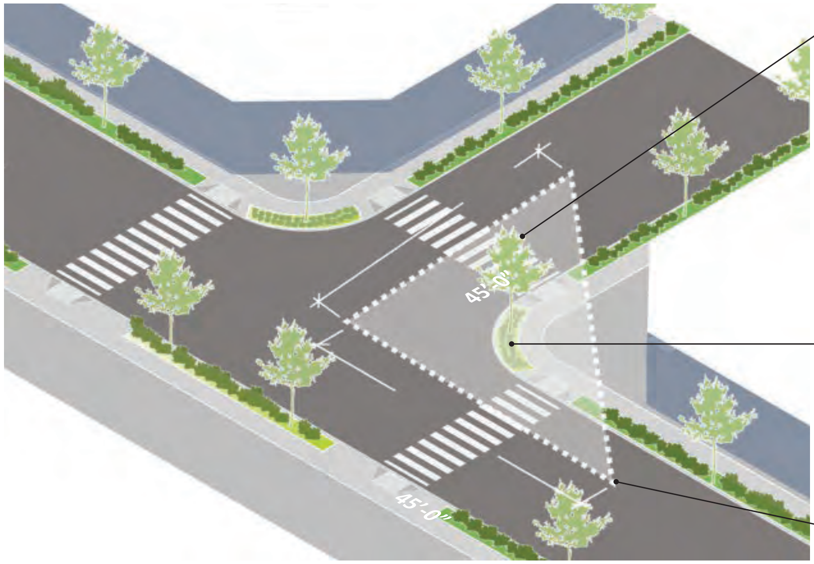
Safety in a landscape is dependent on visibility throughout a site, whether spaces be observable from the street or public areas. As a rule, there should be a window of visibility between 3 and 7 feet above the ground plane where pedestrians and/or vehicles are present. This requires shrubs, grasses and groundcovers to be kept to a height of 3 feet. The best way to achieve this, without having to rely on pruning, is to select smaller plant species and cultivars that have a maximum height less than or equal to 3 feet. Trees need to be pruned so that their lowest branches are at a height greater than or equal to 7 feet. Where height restrictions allow, plants should be maintained in their natural habit. Do not hedge, box or button plants. Refer to **Sections 6.3** and **6.4** for shrub and tree trimming guidance.

Site Triangles

Visibility needs to be maintained at street intersections to maintain pedestrian and vehicular sight lines. This area, to be kept clear of obstructions and visual impediments, is called a sight triangle. Consult Appendix A, Intersection Site Distance Evaluation Procedures, of the City of San Mateo document titled, “City of San Mateo Curb Marking Policy and Procedures,” for more information on sight triangles. This document describes the clearance size of a site triangle, dependent on the speed and location of vehicles relative to the intersection. Planting within the determined sight triangle must be lower than three feet or limbed to a height greater than 7 feet.

Aesthetics

Proper maintenance practices help secure beautiful landscape aesthetics. For instance, an ample layer of mulch creates visual uniformity and neatness in the landscape. A functioning irrigation system operates undetected; drip tubing is buried; irrigation water is contained within the landscape and plants thrive. The selective and the correct trimming of shrubs and grasses strengthens health and maintains the natural form of the plant. Similarly, a tree that has be pruned to maintain strong structure is aesthetically pleasing. Inadequate plant coverage within a stormwater facility compromises not only functionality but also compromises aesthetics. Where bare spots are conspicuous, an abundantly planted landscape appears lush. Rampant weeds detract from the landscape but consistent weeding maintains tidiness. Lastly, healthy soil secures plant health and, when required, the application of fertilizer helps plants flourish.



▲ *The plant species in this parking lot swale have been intentionally chosen to as low-growing species that help increase site visibility.*

▲ *Keeping plant material below 3 feet high at intersections provides a safe visibility triangle.*

▲ *The selective trimming of plants, allowing them to grow naturally, complements the natural form of the plant.*

6.4 Operations and Maintenance
Maintenance Quality Observation Levels

MULCH APPLICATION

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: A 3-inch layer of mulch is maintained and kept at proper distances from shrub and tree plantings.

Continued Actions: Twice yearly observation for adequate mulch coverage.

Mediocre, Modify Maintenance Routine

QUADRIGA INC.

Condition: The mulch layer is depleted. Mulch has been knocked or washed out of the landscape

Immediate Actions: Add or redistribute mulch where it has been reduced to less than 3 inches deep. Place mulch that has been knocked or washed out of planters back into place.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Mulch layer is absent.

Immediate Actions: Add a 3-inch layer of mulch. If mulch was once present, determine if a new type of mulch is needed to ensure longevity.

HAND WEEDING

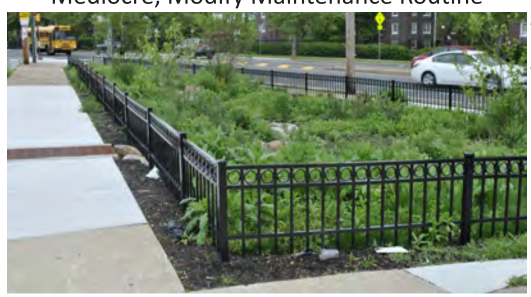
Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Little to no weeds visible within the planting area, sidewalks, gutters and pavement.

Continued Action: Quarterly hand weeding, or as necessary.

Mediocre, Modify Maintenance Routine



PHILADELPHIA WATER DEPARTMENT (FLICKR)

Condition: Several weeds can be found throughout the site.

Immediate Actions: Remove all visible weeds located in planted areas, sidewalks, gutters and pavement. Remove as much of the root system as possible. Dispose of weeds off-site.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Landscape is overrun with weeds.

Immediate Actions: Remove all visible weeds by hand, if possible. Herbicides should be used only as a last resort. Use only the least toxic herbicides. Develop a plan with the Owner before use.

PLANT COVERAGE

Good, Continue Maintenace Routine

URBAN RAIN DESIGN

Condition: Landscape achieves 100% plant coverage.

Continued Action: Monthly observation for proper coverage. Twice yearly plant addition in April and October, as necessary.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Landscape has about 70% plant coverage, achieving the minimum requirement for functionality.

Immediate Actions: If, by visual assessment, the planter is determined to have inadequate plant coverage, schedule the installation of additional plants. Refer to as-built drawings for plant species and size.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Landscape has less than 70% plant coverage.

Immediate Actions: Schedule the installation of additional plants. Refer to as-built drawings for plant species and size. Replace ill-adapted plants with a species better adapted to permanently altered environmental conditions.

PLANT HEALTH

Good, Continue Maintenance Routine

AARON VOLKENING (FLICKR)

Condition: All plants are healthy, disease-free and suited to the environmental conditions.

Continued Action: Monthly site inspection for any plants that are dead, damaged, diseased, stressed or missing.

Mediocre, Modify Maintenance Routine

CHRIS HAMBY (FLICKR)

Condition: Few plants show signs of struggle, disease, pest-infestation or are broken.

Immediate Action: Analyze struggling plants for cause of struggle and correct. Remove struggling plants unlikely to recover or plants likely to infect surrounding plants. Replace with a healthy plant.

Poor, Overhaul Maintenance Routine

CHRIS HAMBY (FLICKR)

Condition: Plants are unhealthy, damaged, missing or dead.

Immediate Action: Analyze struggling plants for cause of struggle and correct, if possible. Remove struggling plants unlikely to recover or plants likely to infect surrounding plants. Replace with a healthy plant.

6.4 Operations and Maintenance

Maintenance Quality Observation Levels

OVERALL TREE HEALTH

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Trees of all ages are healthy. Branches are strong and are pruned as necessary to reduce weight.

Continued Actions: Monthly removal of unhealthy branches and suckers, as necessary. Branch reduction once yearly in early June, as necessary.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Trees show signs of struggle, trunk/root damage, weak branches or have suckers growing.

Immediate Actions: Analyze trees for cause of struggle and correct. Remove dead, damaged or diseased branches of trees. Adjust tree grates. Provide adequate space for surface roots to grow. Remove suckers.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Trees are unhealthy, damaged, missing or dead.

Immediate Actions: Analyze trees for cause of struggle and correct. Remove trees unlikely to recover. Replace removed or missing trees with a healthy tree.

VISUAL SAFETY & PUBLIC SAFETY

Good, Continue Maintenance Routine

MONTGOMERY CO. PLANNING COMM. (FLICKR)

Condition: Visibility is maintained throughout the site including proper clearances and site triangles.

Continued Actions: Monthly observation of site visibility. Monthly removal of vegetation that interferes with public safety, as necessary.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Plant material partially obstructs visibility. Safety is compromised.

Immediate Action: Trim any tree branches or shrubs that interfere with public safety, including visibility clearances.

Poor, Overhaul Maintenance Routine

ALAN STANTON (FLICKR)

Condition: Overgrowth results in poor visibility. The site is perceived as unsafe.

Immediate Action: Trim any tree branches or shrubs that interfere with public safety, including visibility clearances.

STRUCTURAL TREE PRUNING

Good, Continue Maintenance Routine

CHRIS HAMBY (FLICKR)

Condition: Young trees are structurally pruned annually. Branch structure is strong.

Continued Action: Annual pruning of trees up to 5 years old: Prune spring- and winter-flowering shrubs and trees in June; Prune summer- and fall-flowering shrubs and trees in December

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Young trees aren't pruned annually. Branch structure is impacted.

Scheduled Action: Instate annual pruning for the remaining years of young tree development.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Young trees are never structurally pruned. Branch structure is poor and cannot be sustained.

Immediate Action: Determine if branch structure can be corrected without compromising tree health. If not, monitor branches for weaknesses necessitating removal and replacement of tree.

TRIMMING GRASSES AND GRASS-LIKE PLANTS

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Plants appear natural in appearance and are lightly trimmed to maintain at least 12 inches of height.

Continued Action: Seasonal trimming, as necessary.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Plants are overly or improperly trimmed.

Immediate Action: Stop trimming procedure to allow for plants to regenerate leaves, and evaluate future trimming procedures.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Plants are excessively and improperly pruned.

Immediate Action: If improper trimming has resulted in severely compromised plant structure or plant death, replace plants and evaluate future trimming procedures.

6.4 Operations and Maintenance

Maintenance Quality Observation Levels

TRIMMING FOR PEDESTRIAN CIRCULATION

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Plants are in scale with their surroundings and do not impede pedestrian circulation.

Continued Action: Monthly pruning, as necessary.

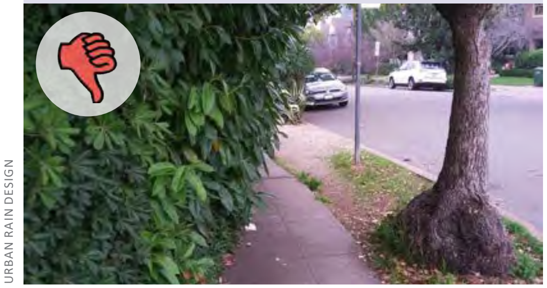
Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Slight overgrowth overlaps walkway edges.

Immediate Action: Trim shrub branches and groundcovers back from all sidewalks, curbs and paved areas. Cut the edges of groundcovers at an angle for a more natural appearance and healthier plants.

Poor, Overhaul Maintenance Routine



SEECLICKFIX.COM

Condition: Pervasive overgrowth crowds landscape area and pedestrian walks.

Immediate Action: Trim shrub branches and groundcovers back from all sidewalks, curbs and paved areas. Cut the edges of groundcovers at an angle for a more natural appearance and healthier plants.

IRRIGATION SCHEDULING

Good, Continue Maintenance Routine

CENTER FOR NEIGHBORHOOD TECH. (FLICKR)

Condition: Irrigation schedule matches the seasonal water needs of planting.

Continued Action: Quarterly adjustment of irrigation controller for current water needs of plants. Correct both frequency and duration of irrigation run times.

Mediocre, Modify Maintenance Routine

MIKE BOUCHER (FLICKR)

Condition: Mismatched irrigation schedule. Plants begin to show signs of struggle.

Immediate Action: Adjust irrigation controller for current water needs of plants. Correct both frequency and duration of irrigation run times.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Irrigation schedule severely mismatched to current watering needs. Plants are dying or dead.

Immediate Action: Adjust irrigation controller for current water needs of plants. Correct both frequency and duration of irrigation run times. Replace dying or dead plants.

IRRIGATION COMPONENTS CONDITION

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: All irrigation system components are in working order and adequately protected.

Continued Action: Monthly check during the dry season to assess condition of irrigation components.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Irrigation lines/valves are exposed and prone to damage and/or vandalism.

Immediate Action: Correct/repair any minor breaks in irrigation components.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Irrigation system components are damaged/ compromised due to exposure and damage.

Immediate Action: Replace irrigation components for proper irrigation function.

SEDIMENT LOAD MANAGEMENT AT CURB CUTS

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Sediment is removed from curb cut area on a regular basis

Continued Action: Maintain current sediment removal maintenance program.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Sediment build up is occurring but not yet impacting the flow of water entering the landscape.

Immediate Action: Remove sediment build up. Determine source of sediment load and take corrective action and/or modify maintenance program.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Sediment build up is severe enough to impede flow and inhibit landscape infiltration.

Immediate Action: Remove sediment build up. Determine source of sediment load and take corrective action and/or modify maintenance program. May need to also replace plant material and mulch/soil layers.

6.4 Operations and Maintenance

Maintenance Quality Observation Levels

TRASH REMOVAL

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Landscape is free of any large or small trash.

Continued Action: Continue monthly trash removal maintenance program.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Landscape has some trash captured, but it is of minimal size and quantity.

Immediate Action: Remove all trash. Modify maintenance schedule.

Poor, Overhaul Maintenance Routine

ALAN STANTON (FLICKR)

Condition: Landscape contains considerable amount of trash to impact aesthetics and public health.

Immediate Action: Remove all trash. Modify maintenance schedule. Locate source of trash production and take corrective actions.

PERVIOUS PAVEMENT SWEEPING

Good, Continue Maintenance Routine

CENTER FOR NEIGHBORHOOD TECH. (FLICKR)

Condition: Pervious pavement joints are free of debris and sediment.

Continued Action: Maintain current pervious pavement sweeping schedule.

Mediocre, Modify Maintenance Routine

MIKE BOUCHER (FLICKR)

Condition: Some pervious pavement joints are beginning to fill with sediment and debris slowing

Immediate Action: Remove areas of sedimentation. Adjust frequency of sweeping schedule.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Excessive build-up of sediment inhibits infiltration between pervious paver joints.

Immediate Action: Remove areas of sedimentation. May require interlocking pavers to be removed, cleaning the joints, and re-applied. Adjust frequency of sweeping schedule.

CURB CUT EROSION CONTROL

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Curb cuts are properly graded and armored for erosion control.

Continued Action: Curb cuts are maintained to control soil/mulch erosion.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Curb cuts have some erosion control measures, but are still prone to erosion.

Immediate Action: Modify curb cut construction with additional hardscape to control erosion.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: Little or no provisions for erosion control at curb cut entries.

Immediate Action: Repair or replace curb cuts to control soil/mulch erosion.

SPLASH PADS FOR EROSION CONTROL

Good, Continue Maintenance Routine

URBAN RAIN DESIGN

Condition: Splash pad at water flow point is adequately controlling erosion.

Continued Action: Splash pads adequately control erosions at water flow points.

Mediocre, Modify Maintenance Routine

URBAN RAIN DESIGN

Condition: Water flow point only uses piled rock as a splash point. Some signs of erosion/rock movement.

Immediate Action: Modify water flow points with additional hardscape/splash pad to control erosion.

Poor, Overhaul Maintenance Routine

URBAN RAIN DESIGN

Condition: No splash pad is present causing severe erosion at water flow point.

Immediate Action: Repair or replace water flow points with a splash pad to control soil/mulch erosion.

6.5 Operations and Maintenance

Annual Maintenance Actions

Ongoing Processes

1. Maintain monthly documentation of irrigation checks and as-built plans of any changes or adjustments to the system.
2. If pesticides, herbicides, etc. are used, submit a pest management record as part of a monthly maintenance report.

Observation

- Observe site for the following conditions and adjust as necessary:
  - Monitor mulch levels.
  - Check for proper irrigation coverage. Signs of improper coverage include standing water, irrigation run-off and dry spots within the landscape.
  - Check irrigation system for function and leaks. Report any evidence of damage or malfunction to the Owner.
  - Observe plant material for signs of stress, indicating excessive or insufficient watering.
  - Inspect site for any plants that are dead, damaged, diseased, stressed or missing. Remove dead and diseased plants.
  - Inspect site for proper plant coverage. If, by visual assessment, the planter is determined to have inadequate plant coverage, schedule the installation of additional plants.
  - Inspect site for any signs of disease or pest infestation where non-chemical treatments have failed. Develop a treatment plan with the Owner.
  - Inspect site for poor visibility, obstructed views and hiding spaces. Prune to maintain safety where necessary.
  - Inspect site for excessive sediment/trash build up, erosion issues, clogging of pervious pavement, and issues with water retention levels.

Mulch Layer Maintenance

- Add or redistribute mulch within planting areas where the mulch has been reduced to less than 3 inches deep. Place mulch that has been knocked or washed out of planters back and smooth into place.

Trimming & Weeding

- Remove dead, broken, damaged or diseased branches of trees and shrubs.
- Remove suckers growing from the base of trees.
- Trim shrub branches and groundcovers back from all sidewalks, curbs and paved areas. Cut the edges of groundcovers at an angle for a more natural appearance and healthier plants.
- Trim any tree branches that interfere with public safety, including visibility clearances.
- Remove all visible weeds located in planted areas, sidewalks, gutters and pavement. Remove as much of the root system as possible. Dispose of weeds off-site.

Fertilization

- Obtain a minimum of two separate agronomy reports.
- Apply granular fertilizers to planting areas, if required, per Agronomy Report to trees, shrubs, perennials and grasses. Be sure to make application prior to a moderate rainfall so the rain will wash the fertilizer in.

Irrigation

- Adjust irrigation controller for current water needs of plants. Correct both frequency and duration of irrigation run times.
- Conduct a comprehensive irrigation system test by performing the following tasks:
  - Check irrigation system pressure.
  - Ensure all flush valve/cap locations are visible.
  - Ensure valve boxes are visible and can be opened.
  - Clean valve boxes of dirt and debris.
  - Inspect valves, filters and pressure regulators for damage or leaks. Check wire splices.
  - Flush out the irrigation system and check for proper operation of each valve zone. Flush laterals.
  - Inspect and clean filters. A hose can be attached to the flush cap to keep water out of the valve box. Replace damaged or torn filters.
  - Clean or replace plugged sprinkler nozzles.
  - Make sure plants have adequate numbers of drip emitters for their size, if applicable.
  - Replace batteries to irrigation controller and sensor, as applicable.
  - Test soil sensors per manufacturer's instructions.

Structural Pruning

- Prune shrubs as needed to maintain their proper shape. Prune young trees for up to five years after planting to develop a strong branch structure.
- Reduce weight on heavy branches to pre-empt branch weakening. No more than 20% of live foliage should be removed or else cause unnecessary stress to a tree.

Plant Replacement & Addition

- Refer to as-built drawings to determine the species and size of plants to be installed. If drawings are not available, match additional plants to the species present within the planter area. Add or replace plants under the following circumstances:
  - Replace any dead or missing plants.
  - If the site is determined to lack proper plant coverage, add plants until a minimum coverage of 70% is achieved.
  - Replace ill-adapted plants with a species better adapted to a permanently altered environmental condition.

Sediment & Trash Removal

- Remove sediment/trash from curb cuts and landscape areas on a monthly basis:
  - For streets, work with adjacent property owners to sweep the gutter line to help reduce the burden of sediment flowing into street facilities.
  - Observe areas prone to clogging due to sediment loading and suggest adding forebays, etc. to help ease the removal of sediment.

Hardscape Maintenance

- Check hardscape areas such as curb cuts, weirs/checkdams, inlets for proper function and grading during the rainy season.
  - Replace/adjust hardscape features as needed.
- Clean pervious pavement on at least an annual basis.
- Perform a pervious pavement infiltration test on an annual basis.

6.6 Operations and Maintenance

Annual Landscape & Hardscape Maintenance Schedule

Maintenance Task	Frequency Description
Observation	Monthly
Mulch Layer Maintenance	Twice a year, or as necessary
Trimming & Weeding	Quarterly, or as necessary
Fertilization: Obtain agronomy reports	Once yearly in early February
Fertilization: Apply fertilizer, if required	Once yearly in late February, if required
Irrigation: Adjust irrigation controller for seasonal water needs	Quarterly
Irrigation: Conduct a comprehensive irrigation system test	Once yearly in early April
Structural Pruning: Prune shrubs to maintain shape and trees to develop branch structures	Prune spring- and winter-flowering shrubs and trees in June; Prune summer- and fall-flowering shrubs and trees in December
Structural Pruning: Reduce branch weight	Once yearly in early June, or as necessary
Plant Replacement & Addition	Twice yearly in April and October, as necessary

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
			☐					☐			
		☐			☐			☐			☐
	☐										
	☐										
		☐			☐			☐			☐
			☐								
					☐						☐
					☐						
			☐						☐		

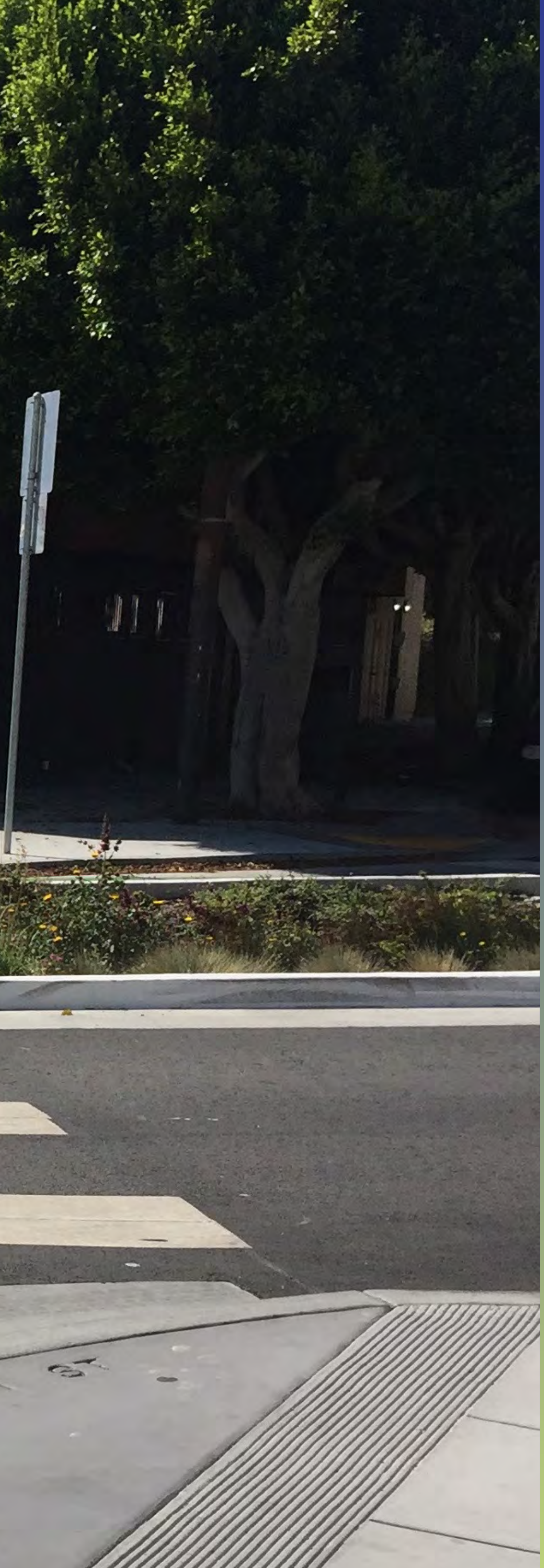
6.6 Operations and Maintenance

Annual Landscape & Hardscape Maintenance Schedule

Maintenance Task	Frequency Description
Check for structural damage/graffiti	Monthly
Remove trash and sediment throughout the facility	Monthly
Remove sediment at curb cut locations	Quarterly, or as necessary
Check curb cuts, valley gutters, roof downspouts, and other conveyance systems for proper function	Quarterly, or as necessary
Clean/Sweep/Vacuum pervious pavement	Once yearly, or as necessary
Check overflow inlets, check dams, and weirs for proper retention depths or escape routes of water	Quarterly, or as necessary
Conduct a pervious pavement infiltration test	Once yearly, or as necessary
Check for areas of erosion at curb cuts, check dams, roof downspouts, or weirs	Quarterly, or as necessary
Check for underdrain malfunction	Twice yearly in November and February as necessary
Check for areas of damage from pedestrian or vehicular traffic	Monthly

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		☐			☐			☐			☐
		☐			☐			☐			☐
									☐		
		☐			☐			☐			☐
									☐		
		☐			☐			☐			☐
	☐									☐	
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐


LORRAINE O'CONNOR D.D.S.
DENTISTRY
SF CUSTOM
Quest Diagnostics
Duncan
CD+A



Appendices

A.1 Appendix 1
Glossary

Alternative Sizing: BASMAA developed regional guidance for non-regulated green street projects with documented constraints, such as lack of space, utility conflicts, and/or other factors, based on a hydrologic modeling analysis, with sizing curves for the minimum bioretention surface area needed to provide treatment of 80% of annual runoff (per C.3.d) and design approaches to use when the C.3.d standard sizing requirements cannot be met and the project is desired to achieve treatment credit. Based on this methodology, green street bioretention facilities in some areas of the County can be sized with as low as a 2% sizing factor and still meet the C.3.d sizing requirements. Also referred to as BASMAA alternative sizing.

Bioinfiltration: The process of reducing peak runoff rates and volumes and providing stormwater treatment by directing stormwater runoff into a depressed area containing plants and specified biotreatment soil mix and allowing the runoff to infiltrate into the underlying natural soils.

Bioinfiltration Area/Planter: A term used in the **C.3 Regulated Projects Guide** of the GreenSuite for a stormwater planter that has a primary bioinfiltration function, the more general term used in this document is "Stormwater Planter".

Bioretention: The process of reducing peak runoff rates and volumes and providing stormwater treatment by directing stormwater runoff into a depressed area containing plants and specified biotreatment soil mix and by retaining and slowing down the runoff that would otherwise flow quickly into the stormwater system.

Bioretention Area/Planter: A term used in the **C.3 Regulated Projects Guide** of the GreenSuite for a stormwater planter that has a primary bioretention function, the more general term used in this document is "Stormwater Planter".

C.3: Provision of the Municipal Regional Stormwater NPDES Permit (MRP) that requires each municipality to control the discharge of stormwater pollutants and erosive flows from land development projects (Regulated Projects). It is often used as a shorthand term for green infrastructure measures that are required for new development and redevelopment sites over which a municipality has jurisdiction. For ƳƧǊŜ ŀƴŦƧǊƳŀǘƛƻƴ regarding C.3 projects, see the **C.3 Regulated Projects Guide**.

C.3 Regulated Projects Guide: The **C.3 Regulated Projects Guide** is the companion document to the Green Infrastructure Design Guide. Together, they are referred to as the GreenSuite and provide guidance pertaining to green infrastructure for the San Mateo Countywide Program. The **C.3 Regulated Projects Guide** provides guidance on the design, including sizing, of green infrastructure and LID for C.3 regulated new and redevelopment projects.

Cistern: A green infrastructure treatment measure that is used to harvest (collect) and store stormwater for subsequent use. Storage facilities can be above or below ground. Water stored in this way can be used to supplement onsite irrigation needs, or for toilet flushing.

Detention: The process of providing temporary storage of stormwater runoff in ponds, vaults, bermed areas, or depressed areas to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates. In more urban situations, detention can also be provided by using rock filled trenches or suspended paving systems directly adjacent to other treatment measures to allow them to store water and treat it over a longer period of time.

Flow Through Planters: Flow-through planters are contained landscape areas designed to capture and retain stormwater runoff, and designed as fully lined and connected via an underdrain to a stormwater system (see also Stormwater Planter).

Green Gutter: Green gutters help capture and slow stormwater runoff within very narrow and shallow


CD+A

A.1 Appendix 1
Glossary

Flow Through Planters: Flow-through planters are contained landscape areas designed to capture and retain stormwater runoff, and designed as fully lined and connected via an underdrain to a stormwater system (see also Stormwater Planter).

Green Gutter: Green gutters help capture and slow stormwater runoff within very narrow and shallow landscaped areas. As an Alternative Treatment Measure, there is limited or currently, no, credit towards C.3 requirements; however, if they are designed as a narrow stormwater planter, some credit may be possible under BASMAA's Alternative Sizing protocol.

Green Infrastructure: Stormwater infrastructure that uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural and landscaped areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood, street, or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up, storing, and/or improving the quality of water.

Green Infrastructure Alternative Treatment Measure: A type of green infrastructure that does not meet the requirements of MRP Provision C.3, but may be used as part of a green infrastructure system in some circumstances. Some alternative measures may receive some credit towards achieving TMDL reductions depending on resolution of regional discussions regarding a single approach to reduced sizing requirements. Alternative Treatment Measures include Vegetated Swale, Green Gutter, Green Wall, Rain Barrel, and Stormwater Tree.

Green Infrastructure Treatment Measure: One of the various types or forms of green infrastructure that meets the requirements of MRP Provision C.3. Also referred to as Green Infrastructure Measure or Treatment Measure. Treatment Measures include Bioretention Area/Planter, Bioinfiltration Area/Planter, Stormwater Planter, Stormwater Curb Extension, Rain Garden, Tree Well Filter, Infiltration Trench, Pervious Pavement, Green Roof, Cistern, and Subsurface Infiltration System.

Treatment Measure, there is limited or currently, no, credit towards C.3 requirements for installation of a Green Wall.

Infiltration: The process of slowing, filtering, and soaking stormwater runoff into native soil. Greater infiltration can often be achieved, as necessary, by employing a specified biotreatment soil mix and Class 2 Perm storage prior to infiltration into native soil.

Infiltration System: Infiltration systems are underground facilities and structures designed to collect and temporarily store runoff, such as a Class 2 Perm filled trench, pipe or vault, and allows the water to infiltrate into surrounding subsurface soils. In some cases, it can include an underdrain.

Infiltration Trench: A long narrow trench filled with permeable material (e.g., a stone aggregate), designed to store runoff and infiltrate through the bottom and sides of the trench into the subsurface soil. Interception: The green infrastructure function of collecting and capturing rainfall prior to rainfall contacting an impervious surface and becoming stormwater runoff.

Linked Tree Well Filter: A series of tree well filters that are linked by an infiltration trench, modular suspended pavement system, pervious pavement, or other method to provide additional area for infiltration, treatment, storage, and/or soil volume to support healthy tree growth and lifespan.

Living Shorelines: A green infrastructure technique that uses native vegetation, natural materials, and occasionally low sills to protect and stabilize shorelines. They reduce and treat runoff and nutrient pollution, minimize nstances of shoreline erosion, provide fish and wildlife habitat, and buffer shorelines from storms and tidal waves. They are a natural and low impact alternative to 'hard' shoreline infrastructure like bulkheads and rip rap.

Low Impact Development (LID): A sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional storm water management, which entails collecting and conveying storm water runoff through storm drains, pipes, or other conveyances to a centralized storm water facility, LID focuses on using site design and storm water management to maintain the site's pre-development runoff

CD+A

A.1 Appendix 1

Glossary

Linked Tree Well Filter: A series of tree well filters that are linked by an infiltration trench, modular suspended pavement system, pervious pavement, or other method to provide additional area for infiltration, treatment, storage, and/or soil volume to support healthy tree growth and lifespan.

Living Shorelines: A green infrastructure technique that uses native vegetation, natural materials, and occasionally low sills to protect and stabilize shorelines. They reduce and treat runoff and nutrient pollution, minimize nstances of shoreline erosion, provide fish and wildlife habitat, and buffer shorelines from storms and tidal waves. They are a natural and low impact alternative to 'hard' shoreline infrastructure like bulkheads and rip rap.

Low Impact Development (LID): A sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional storm water management, which entails collecting and conveying storm water runoff through storm drains, pipes, or other conveyances to a centralized storm water facility, LID focuses on using site design and storm water management to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall.

Modular Suspended Pavement Systems: Modular systems such as Strata Vault and Silva Cells that can provide additional uncompacted soil volume for tree root growth under adjacent pavement areas as well as allowing for "underground" bioretention. If used as part of the stormwater treatment system, the areas under the pavement should be installed with the required minimum 18-inch depth of specified biotreatment soil mix and underdrains as necessary.

Pervious Pavement: Pervious pavement allows rainwater to either pass through the pavement system itself or through joint openings between the pavers into an underlying Class 2 Perm bed designed to store and infiltrate rainfall. There are several kinds of Pervious Pavement, including:

> **Grate:** Depending upon the use and weight load requirements, grates can be metal, fiberglass, or another material. The size of grate openings can vary depending on the function it serves, but needs to meet ADA standards when used as a primary pedestrian path of travel.

Grid Paving: A pavement or a pavement system designed to store and infiltrate stormwater to pass through wide gaps that are cast or created within the pavement material itself, such as precast concrete and pre-molded plastic cells and filled with turf, gravel, or other materials.

Permeable Paver: Pre-manufactured pavers that allow stormwater to pass around the pavement material and into the subgrade under the pavement system. These include various interlocking pavers or other paving systems with a gap between the pavers filled with a crushed aggregate or other porous material.

Pervious Concrete: Concrete that allows stormwater to pass through gaps within the concrete.

Porous Asphalt: Asphalt that allows stormwater to pass through gaps within the asphalt mix.

Pervious Paver: Pervious pavers are-manufactured pavers that allow stormwater to pass through the pavers themselves; some manufacturers refer to this type of paver as permeable pavers which should not be confused with the permeable paver with gap joints defined above.

Porous Rubber: Made from recycled rubber and sometimes small stones, porous rubber works like pervious concrete, but can be installed over tree roots and other locations where its more flexible characteristics are a benefit.

Reinforced Grass Paving: This technique makes use of interlocking plastic or concrete cell grids to provide structural support while also allowing for some plant growth and stormwater infiltration.

Reinforced Gravel Paving: This system uses small, angular gravel without the fines and a plastic or concrete structure that helps provide support to create a rigid load-bearing surface.

Suspended Decking and Boardwalks: Suspended decking and boardwalks can be made from a variety of materials such as wood, plastic, and other materials. The gaps between the materials allow the water to flow through to the soil.

A.1 Appendix 1
Glossary

CD+A

Pollutant Removal: Pollutants are removed from stormwater runoff by a variety of techniques including filtration through soil and uptake and remediation by plants.

Rain Barrel: A small above-ground cistern, often in the shape of a barrel, used to collect rain water from roofs via roof gutters and downspouts. Rain barrels are typically used in residential applications that are not required to meet C.3.d sizing requirements. As an Alternative Treatment Measure, there is limited or currently, no, credit towards C.3 requirements for installation of a Rain Barrel.

Rain Garden: This term is often used as a synonym for bioretention or bioinfiltration areas or planters. In these SMCWPPP documents, it is used as a term for bioretention/bioinfiltration areas or planters with sloped sides and various shapes, as distinguished from the more linear stormwater planters and more contained, and specific, stormwater curb extensions.

Rainwater Harvesting: The direct capture of rainfall from an impervious surface into a storage container for future use and/or release to the landscape or for other uses such as toilet flushing. See also Cistern and Rain Barrel.

Regulated Projects: New and redevelopment projects that meet the criteria listed in the MRP under Provision C.3.b.ii that are required to treat and manage stormwater. Can be public or private projects. Also referred to as "C.3 Regulated Projects".

Site Design Measure: Site planning techniques to conserve natural spaces, limit the amount of impervious surface at new development and redevelopment projects to minimize runoff and the transport of pollutants in runoff, and/or techniques to create space for green infrastructure facilities. The MRP requires the use of site design measures for regulated projects and encourages site design measures for other projects.

Stormwater Curb Extension: A stormwater planter that is typically within the parking zone of a street or on-site parking area that captures stormwater and allows it to interact with plants and soil while also achieving complete streets goals for improving pedestrian access and safety.

Stormwater Planter: Infiltration, bioretention, and flow-through stormwater planters are contained landscape areas designed to capture and retain stormwater runoff.

Stormwater Tree: A green infrastructure alternative treatment measure consisting of a smaller sized tree well in which a curb cut is placed to allow stormwater runoff to enter from the street and infiltrate into the planter area providing water harvesting and other stormwater benefits and functions. As an Alternative Treatment Measure, there is limited or currently, no, credit towards C.3 requirements.

Subsurface Infiltration System: A green infrastructure treatment measure, also known as an infiltration gallery, with underground vaults or pipes that store and infiltrate stormwater. These systems allow infiltration into surrounding soil while preserving the land surface above for parking lots, streets, parks, and playing fields. Another type of subsurface infiltration system is an exfiltration basin or trench, which consists of a perforated or slotted pipe laid in a bed of Class 2 Perm gravel. It is similar to an infiltration basin or trench with the exception that it can be placed below paved surfaces, such as parking lots and streets. Stormwater runoff is temporarily stored in perforated pipe or coarse aggregate and allowed to infiltrate into the trench walls and bottom for disposal and treatment.

Suspended Pavement System: Systems that can provide additional uncompacted soil volume for tree root growth by supporting adjacent pavement areas as well as allowing for "underground" bioretention. The pavement can be suspended using modular units (**Modular Suspended Pavement Systems**), structural soils, or constructed suspension systems such as post and beam vaults with uncompacted soil inside the vaults under pavement.

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants from stormwater. Such processes include, but are not limited to, filtration, gravity separation, media adsorption, biodegradation, biological uptake, and infiltration.

Tree Well Filter: A small stormwater planter that has a tree planted in it – several of them may be used in series or can be used individually.

Vegetated Swale: Shallow landscaped areas designed to capture, convey,and potentially infiltrate stormwater runoff as it moves downstream. As an Alternative Treatment Measure, there is limited or currently, no, credit towards C.3 requirements for installation of Vegetated Swales.

A.2 Appendix 2
Reference Documents


CD+A

The following documents and websites are references or sources for information provided in this guide.

Chapter 1 Introduction

City of East Palo Alto. *East Palo Alto General Plan 2035*. http://www.ci.east-palo-alto.ca.us

City of San Mateo. *City of San Mateo Sustainable Streets Plan and Guidelines Document*. https://bit.ly/2QrNMDl

Clements, Janet, and Alexis St. Juliana, and Paul Davis. *The Green Edge: How Commercial Property Investment in Green Infrastructure Creates Value*. Natural Resources Defense Council, NRDC Report. December 2013.

Detweiler, M.B., P.F. Murphy, K.Y. Kim, L.C. Myers, & A. Ashai. Scheduled medications and falls in dementia patients utilizing a wander garden, *American Journal of Alzheimer's Disease and Other Dementias 24*. 2009. Pages 322-332.

Donovan, G. and B. Butry. Trees in the city: Valuing street trees in Portland, Oregon, *Landscape and Urban Planning 94(2).* 2010.

Hull, Michael Se. Nature-based Recreation, Mood Change, and Stress Restoration, *Leisure Sciences.* 1995.

Ichihara, K., and J.P. Cohen. New York City Property Values: What Is the Impact of Green Roofs on Rental Pricing? *Letters in Spatial and Resource Sciences 4* (1). 2011.

Kaplan, Rachel and Stephen Kaplan. *The Experience of Nature: A Psychological Perspective*, *Cambridge UP.* 1989.

Lovasi, G.S., and others. *Children Living in Areas with More Street Trees Have Lower Prevalence of Asthma*. 2008.

MacMullan, Ed and Sarah Reich, ECONorthwest. Prepared for Waterkeeper Alliance. *The Economics of Low-*

Impact Development: A Literature Review. 2007.

Rand Corporation. *How Neighborhoods Can Reduce the Risk of Obesity*; https://www.rand.org/pubs/research_briefs/RB9267/index1.html

San Francisco Bay Regional Water Quality Control Board, *Municipal Regional NPDES Permit (MRP 3.0)*, adopted in 2022 and amended in 2023, comprises Order Nos. R2-2022-0018 and R2-2023-0019.

San Mateo Countywide Pollution Prevention Program (SMCWPPP) provides many resources and regulator documents; www.flowstobay.org

San Mateo Countywide Water Pollution Prevention Program. Green Infrastructure Construction Phase BMP; www.flowstobay.org/construction

San Mateo Countywide Water Pollution Prevention Program. *Reasonable Assurance Analysis* (RAA); flowstobay.org/raa

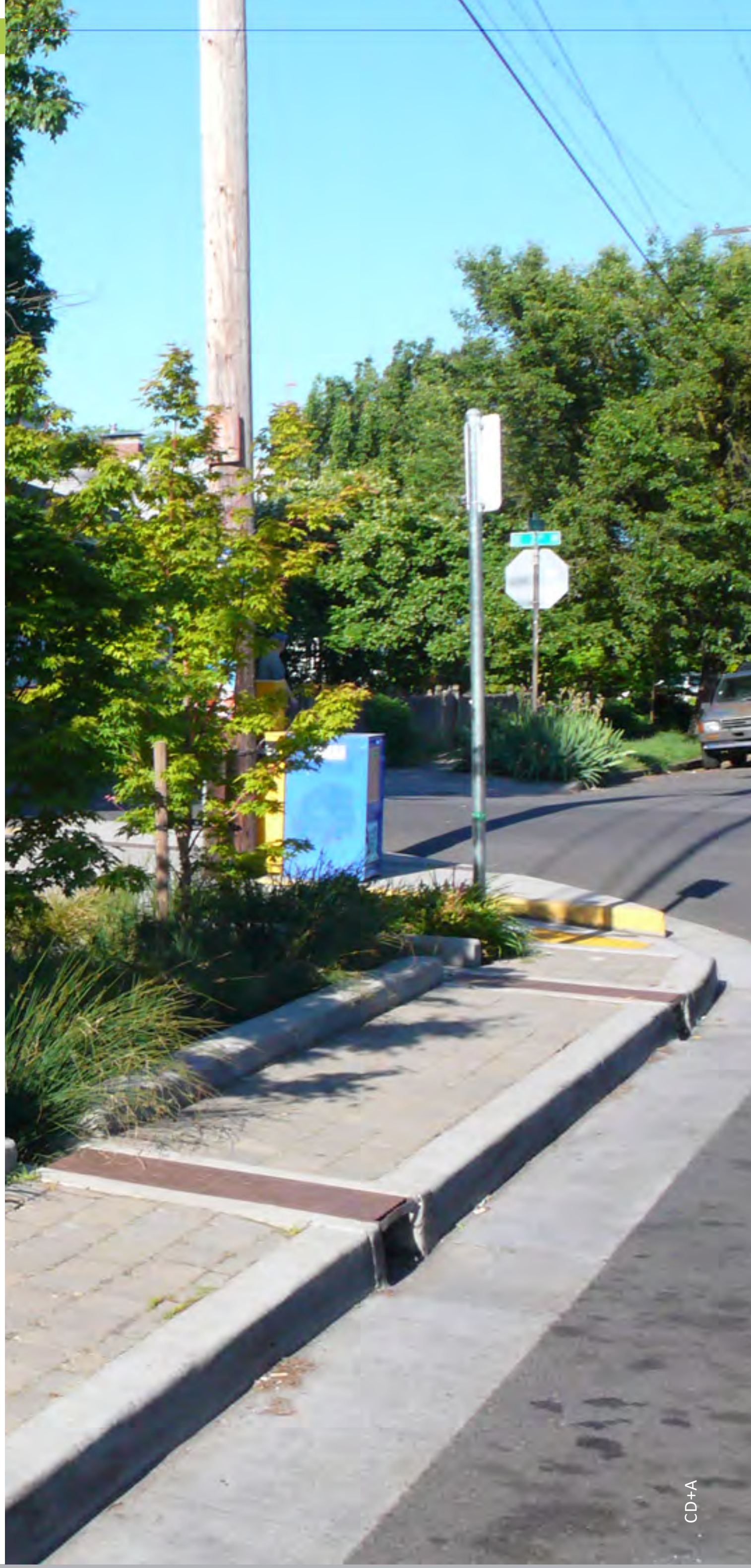
San Mateo Countywide Water Pollution Prevention Program. **C.3 Regulated Projects Guide** (formerly named as the C.3 Stormwater Technical Guidance); flowstobay.org/c3guide

SMCWPPP. *Stormwater Resource Plan* (SRP); http://ccag.ca.gov/srp/

Stratus Consulting, Inc. Prepared for the Office of Watersheds, City of Philadelphia. *A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds: Final Report*. 2009.

Ulrich, Roger S. *The Value of Trees to a Community*. Arbor Day Foundation.

Ulrich, Roger S. View through a window may influence recovery from surgery, *Science 224*. 1984. Pages 27,



CD+A

A.2 Appendix 2
Reference Documents


SANDY MATTHEWS

420. US EPA. Office of Wetlands, Oceans and Watersheds. *Economic Benefits of Runoff Controls*. 1995.

US EPA. Various public health and other benefits and case studies of green infratructure are available at https://www.epa.gov/green-infrastructure/benefits-green-infrastructure

US EPA. Using Green Roofs to Reduce Heat Islands; www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands

United States Geological Survey (USGS). Water properties: Temperature; https://water.usgs.gov/edu/temperature.html

Wachter, S. The Wharton School, University of Pennsylvania. *The Determinants of Neighborhood Transformation in Philadelphia – Identification and Analysis: the New Kensington Pilot Study*. 2004.

Wachter, S. and G. Wong. What is a Tree Worth? Green-City Strategies, Signaling and Housing Prices, *Real Estate Economics 36(2)*. 2008.

WEF Publication. Ward et al. *The Effect of Low-Impact-Development on Property Values*. 2008.

Wells, Nancy M. and Gary W. Evans. Nearby Nature a Buffer of Life Stress among Rural Children, *Environment and Behavior 35.3*. 2003.

Wolf, K.L. Social Benefits of Civic Nature, *Master Gardener*. Winter 2008.

Chapter 2 Green Infrastructure Measures and Opportunities

Bay Area Stormwater Agencies Association (BASMAA). *Harvest and Use, Infiltration and Evapotranspiration Feasbility/Infeasibility Criteria Report*. 2011.

BASMAA. *Start at the Source*. 1999. BASMAA. *Using Site Design Techniques to Meet Development Standards for Stormwater Quality: A Companion Document to Start at the Source*. 2003.

California Department of Transportation, Division of Design. Pervious Pavement Design Guidance. http://www.dot.ca.gov/design/hsd/bmp/DG-Pervious-Pvm_052716.pdf, 2016.

San Mateo Countywide Water Pollution Prevention Program. C.3 Regulated Projects Guide (formerly named as the C.3 Stormwater Technical Guidance); flowstobay.org/c3guide

Chapter 3 Design Strategies and Guidelines

Association of Bay Area Governments. Priority Conservation Area (PCA); https://abag.ca.gov/priority/conservation/

Association of Bay Area Governments. Priority Development Area (PDA); https://abag.ca.gov/priority/development/

CalRecycle. Mulch Information; https://www.calrecycle.ca.gov/organics/compostmulch

City and County of San Francisco. *Appendix B: Green Infrastructure Typical Details and Specifications*. 2016.

City of Chicago. Green Alley Program; https://www.cityofchicago.org/city/en/depts/cdot/provdrs/street/svcs/green_alleys.html

City of Philadelphia. *Green Streets Design Manual*. 2014.

City of Santa Monica. Alley Renewal Program; https://www.smgov.net/streets/alleyprogram/

National Environmental Policy Act (NEPA); https://www.epa.gov/nepa

San Francisco Bay Regional Water Quality Control Board, *Municipal Regional NPDES Permit (MRP 3.0)*, adopted in 2022 and amended in 2023, comprises Order Nos. R2-2022-0018 and R2-2023-0019.


THEWATERSHEDINSTITUTE.ORG

A.2 Appendix 2
Reference Documents

CD+A

Plan Bay Area. https://www.planbayarea.org , https://www.planbayarea.org/2040-plan/plan-details/equity-analysis

Smart Growth America, the National Complete Streets Coalition. https://smartgrowthamerica.org/program/national-complete-streets-coalition/what-are-complete-streets/

SMCWPPP. *San Mateo Countywide Stormwater Resource Plan* (SRP). http://ccag.ca.gov/srp/

State of California. *California Building Code* (CBC); http://www.bsc.ca.gov/Codes.aspx

State of California. *California Building Code* (CBC), Section 11B-303.5 Warning Curbs. https://www.dgs.ca.gov/BSC/Codes

United States Access Board. *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Rights-of-Way* (PROWAG), pending approval; https://www.access-board.gov

United States Department of Justice Civil Rights Division. *2010 American's with Disabilities Act (ADA) Standards for Accessible Design*; https://www.ada.gov

U.S. EPA. Green Streets; https://www.epa.gov/G3/learn-about-green-streets

Chapter 4 Key Design and Construction Considerations

Atlas. *Bolivar Park Smart Stormwater Capture System*; https://the-atlas.com/projects/bolivar-park-smart-stormwater-capture-project

Belden, Edward, Michael Antos, Kristy Morris, & Nancy L.C. Steele. *Sustainable Infrastructure: The Elmer Avenue Neighborhood Retrofit*. 2012. http://urbancoast.org/wp-content/uploads/2014/10/V3_13_EdwardBelden.pdf

California Stormwater Quality Association. https://www.casqa.org

City of Santa Monica. *Los Amigos Park Storm Water Harvesting and Direct Use Demonstration webpage*;

https://www.smgov.net/bebp/project.aspx?id=53687095405

City of Santa Monica. *Los Amigos Park Brochure.*

City of South San Francisco and Lotus Water. *Orange Memorial Park Water Capture Project.*

City of Redwood City. *Green Infrastructure webpage;* https://www.redwoodcity.org/departments/community-development-department/engineering-transportation/engineering/green-infrastructure

National Oceanic Atmostpheric Administration. Living Shorelines webpage; https://oceanservice.noaa.gov/facts/living-shoreline.html

Paradigm Environmental and Larry Walker Associates. *Stormwater Resource Plan for San Mateo County.* February 2017. Pages 49-50.

ReScape California. Bay-Friendly Landscape; https://rescapeca.org

ReScape California. *Our Eight Principles* ; https://www.rescapeca.org/eight-principles

San Francisco Public Utilities Commission, Water Power Sewer. *Waterwise Gardening for San Francisco*. 2015. https://sfpuc.org/learning/conserve-water/tips-requirements-publications

San Mateo Countywide Water Pollution Prevention Program. C.3 Regulated Projects Guide (formerly named as the C.3 Stormwater Technical Guidance); flowstobay.org/c3guide

StormTrap. *Bolivar Park Stormwater Project - Lakewood, CA.* Youtube, 12 December 2017, https://www.youtube.com/watch?v=yPKmM8j-D50

SMCWPPP. GreenSuite: www.flowstobay.org

Town of Atherton. *Stormwater Webpage*; https://www.ci.atherton.ca.us/247/Stormwater-and-Runoff

United States Department of Justice Civil Rights Division. *2010 ADA Standards for Accessible Design*. https://

CD+A

A.2 Appendix 2
Reference Documents

www.ada.gov regs2010/2010ADAStandards/2010ADAStandards.pdf

United States Green Business Council. Leadership in Energy and Environmental Design (LEED); https://new.usgbc.org/leed

Chapter 6 Operations and Maintenance

City of Portland, Oregon, Environmental Services. *O&M Plans by Facility Type*. 2016. https://www.portlandoregon.gov/bes/45714

City of Seattle, Washington. 2009. *Green Stormwater Operations and Maintenance Manual*. https://www.seattle.gov/util/cs/groups/public/@spu/@usm/documents/webcontent/spu02_020023.pdf

San Francisco Public Utilities Commission, Water Power Sewer. *Green Infrastructure Maintenance Guidebook*. 2018.

Appendix 3 Sustainable Streets Typical Design Details

SFPUC. *Green Infrastructure Typical Details and Specifications*: https://sfpuc.org/construction-contracts/design-guidelines-standards/stormwater-requirements

SMCWPPP. GreenSuite documents: www.flowstobay.org

Appendix 4 Sustainable Streets Specifications

Bay Area Pervious Concrete. http://www.bayareaperviousconcrete.com

Bay Area Stormwater Management Agencies Association (BASMAA). *Biotreatment Soil Media Specification*: https://basmaa.org/wp-content/uploads/2021/02/basmaa-regional-biotreatment-soil-specification-2016.pdf

California Stormwater Quality Association, *CASQA-LIDI Bioretention Details*. https://www.casqa.org/resources/california-lid-portal/standard-lid-design-plans-specifications

CalRecycle, *Product Quality and Specification: Compost and Mulch*. https://calrecycle.ca.gov/organics/compostmulch/toolbox/productquality/

City and County of Denver, Public Works. *Ultra-Urban Green Infrastructure Guidelines*, 2016.

District of Columbia, Department of Transportation. *Green Infrastructure Standards*, 2014.

Portland, Oregon. *Stormwater Management Manual Typical Details*, 2016.

Philadelphia, PA. *Green Streets Design Manual*, 2014.

San Francisco Public Utility Commission (SFPUC). https://sfwater.org

SFPUC. *Stormwater Requirements*. https://sfpuc.org/construction-contracts/design-guidelines-standards/stormwater-requirements

San Mateo Countywide Water Pollution Prevention Program. *C.3 Regulated Projects Guide* (formerly named as the *C.3 Stormwater Technical Guidance*); flowstobay.org/c3guide

United States (US) Composting Council. compostingcouncil.org

A.3 Appendix 3
Sustainable Streets Typical Design Details

Introduction

A host of sustainable street design details are available from a variety of sources. A growing number of jurisdictions have robust detailing for various types of green infrastructure, including bioretention and bioinfiltration planters and pervious pavements. A few jurisdictions have included details for green infrastructure components, which are the individual elements that comprise the green infrastructure measure, such as edge treatments (e.g.: curb, low fence), curb inlets/outlets, and check dams. The addition of these component details provides greater guidance on the design and detail of green infrastructure measures to provide safe, attractive, and functional facility design and implementation. For many of these jurisdictions, they have researched operations and maintenance of built green infrastructure and have made modifications to their details over time.

The San Mateo Countywide Program Green Infrastructure Committee (GI Committee) agreed to use the San Francisco Public Utility Commission's (SFPUC's) Green Infrastructure Typical Details as the base model details for the Countywide Program's GreenSuite. These can be obtained from the SFPUC's Stormwater Management Requirements and Design Guidelines, Green Infrastructure Typical Details, in PDF and AutoCAD file formats. San Mateo Countywide Program jurisdictions should regularly check this website to see if any new or revised details are posted and if those details are appropriate to use and integrate into their typical details. **If the jurisdiction wishes to update or expand their details, the addition of new detail(s) will need to consider and integrate modifications to the details to be consistent with that jurisdiction's regulations before they are added to the jurisdiction's standard green infrastructure details.**

SFPUC provides typical guidance for bioinfiltration and bioretention planters in different configurations and various related components such as under drains, some edge treatments, and outlets; more conceptual subsurface infiltration (large gallery and dry well); permeable pavements and their components such as edge treatments and subsurface overflow and under drains; and utility crossing and conflict related items. Planter sidewalls are also detailed; however, a licensed engineer shall always review and design planter sidewalls and retaining walls specific to each individual site's conditions and project needs. A hydrologist and geotechnical engineer should also be involved to assist with the design of the measures and facilities.

How to Use Typical Details and Specifications for Site-Specific Design[1]

These typical details and specifications were developed to be manipulated and customized for each individual project by design professionals.

As described in the San Francisco Stormwater Management Requirements and Design Guidelines, Green Infrastructure Typical Details and Specifications document, these details show typical configurations, rather than required standard configurations. This distinction is deliberate, as it is necessary for designers to use their own creative thinking, professional judgement and, above all, to be responsive to each site in order to create GI projects that are beautiful, functional, and contextual.

To ensure that the details are broadly applicable and can be adapted to many sites, wherever possible the details provide guidelines and ranges of acceptability instead of precise numeric requirements. Both the Designer Notes for each detail and the details themselves emphasize areas where the designer must exercise professional judgement to respond to the site.

For example, the Designer Notes for the bioretention planter section indicate that planter area, ponding depth, bioretention soil depth, and Class 2 Perm (gravel reservoir course) depth must be sized to meet project hydrologic performance goals. On the corresponding drawing, bioretention soil depth is shown with a minimum depth of 18 inches. Ponding depth should be between 2 and 12 inches. In these cases the details are indicating acceptable minimums and maximums but the designer must choose the bioretention soil depth and ponding depth that is appropriate for a given site and needed hydrologic function. Bioretention facilities on a site with A soils may perform very well using the minimum soil depth, while facilities sited on C soils will benefit from a deeper soil profile.

[1] Much of this section is taken directly from San Francisco Public Utility Commission's San Francisco Stormwater Management Requirements and Design Guidelines, Green Infrastructure Typical Details and Specifications, pages 1-4 and PP1.1. We wish to thank the SF PUC for their time in discussing their experiences with green infrastructure and for the use of their materials. The designer/user should review the original materials on SF PUC's website to see if any materials have been updated, and if so, base their typical details and specifications on the amended materials.

A.3 Appendix 3
Sustainable Streets Typical Design Details

CD+A

Items that are required for system function can be found in the Construction Notes, the General Utility Notes, the Layout Requirements, and the Designer Checklists. For example, the Construction Notes for the bioretention planter section include the following:

1. Avoid compaction of existing subgrade below planter during construction.
2. Scarify subgrade to a depth of 6 inches (min) immediately prior to placement of Class 2 Perm gravel storage and bioretention soil.
3. Maximum drop from top of curb to top of bioretention soil shall include considerations for bioretention soil settlement.

Usage within Construction Documents

AutoCAD drawings of typical details are available for download at flowstobay.org/CADfiles.

PDF versions of typical details are included in the following detail set and can be printed directly from this guide. Lower page ribbons and color blocks are for organization only and will not print.

Original SFPUC typical details in PDF and AutoCAD formats (in both 2007 and 2013 AutoCAD versions) may be found here. Design professionals must modify facility plan and section configurations, materials, and construction notes to address each project's site conditions and meet project performance goals. The typical details are developed as "Not for Construction" drawings. Title blocks are provided for document organization and reference only.

To ensure that your use of the construction details and notes are site-specific, please include:

- Review and adjust plans, sections, and constrquction notes for site-specific design.
- Remove the SFPUC or Countywide Program GI Title Block from the details used in your set and replace it with a title that aligns with your projects' construction document nomenclature.
- Incorporate all detail call-outs and references into the construction documents so that the contractor will have all the information required to build the project.
- Do not reference the GI typical detail sheet name and/or number (i.e., BP 2.1) as a standard detail call-out within the construction drawings.
- Do not expect contractors to conduct calculations or be responsible for missing design information.
- Some of the SFPUC details state "Optional" before an item in the detail. The use of the term "optional" is in reference to using the details for various situations. For instance, geogrid is only used for the

bottom of pervious pavements and sand filters are required in the western portions of San Francisco that have a native sandy soil condition. The user/designer will need to review the details, purpose statement, designer notes & guidelines, designer checklist, construction notes, and other information and determine when “optional” items are necessary or should be removed.

- Exchange references to San Francisco and its codes and regulations, city/county departments, SFPUC logo, and revision to other elements specific to San Francisco for each jurisdiction that will be using these details, and the appropriate department, division, standard details and specifications, codes and regulations, logo, etc. will need to be used instead.
- Remove detailing and references to combined sewer system, if one is not present in your jurisdiction.
- Exchange “biotreatment” (Countywide Program term) for “bioretention” (SFPUC term) when used in relation to soil mix.
- Level of biotreatment soil compaction to be per jurisdiction standard.
- If new details are added, it is suggested to follow the same formatting, and provide explanations for Purpose, Designer Notes & Guidelines, Layout Requirements, and Designer Checklist; and similar plan, profile, and section layout, as well as update the navigation system and key bar on the related and appropriate detail sheets.
- For courtesy, please credit the SFPUC on the details and specifications for allowing public access and to use their documents.
- Credit the source jurisdiction on other model details, as appropriate, for the adapted use of their documents.
- Specify minimum of 18 inches depth of biotreatment soil.
- Specify minimum of 12 inches of class II permeable material at bottom of facility.
- Adjust ponding depth up to 12 inches as acceptable to your jurisdiction.
- Curb cut outlets and inlets to be a minimum of 18 inches wide, unless otherwise approved by your jurisdiction.
- For structural support, compact subgrade under stormwater sidewalls (only) per engineer specifications.

CD+A

A.3 Appendix 3

Sustainable Streets Typical Design Details

Typical Detail Content

The details are organized to guide the licensed professional to the proper selection, layout, and design of green infrastructure technologies (such as permeable pavement and bioretention) and components (such as inlets, outlets, and edge treatments). The components allow the typical details to be modified to reflect specific design approaches and site conditions. The typical details include the following sections:

- Purpose
- Designer Guidelines
- Layout Requirements
- Designer Checklists
- Key Maps
- Facility Plans
- Facility Sections and Profiles
- General Notes
- General Utility Notes
- Construction Notes
- Component Details

AutoCAD detail call outs, references, and construction related notes for use by contractor shall be adjusted for use in construction drawings. Dimensional layout and edging materials should be adjusted based on proposed site design and programming.

New and Potential Future Typical Design Details

A review of the SFPUC and other national best practices in detailing green infrastructure and discussions with SFPUC staff and San Mateo County local jurisdiction have indicated that there are additional typical details that are desirable for guidance for the detailed design of green infrastructure and sustainable streets. These include:

1. Steel topped curb cut inlet
2. Energy dissipator
3. Enhanced forebay/sediment basin
4. Adding a table aligning ASTM gravel sizes to Caltrans sizing
5. Ornamental fencing around planters and tree well filters
6. Stormwater tree plan and section
7. Tree well filter plan and section
8. Concrete check dam
9. Use of trench drain to direct runoff to rear or side of stormwater planter
10. Drywell (deep)
11. Infiltration trench or basin
12. Infiltration trench or basin, with paved top surface
13. Infiltration trench or basin, with planted top surface
14. Structural soil use in tree well filters/trenches/other
15. Modular suspended pavement systems
16. Alternative sediment inlet apron/splash pad design
17. Vegetated swale plan, profile, and section
18. Additional details related to utility crossings, protection, and placement in relation to green infrastructure measures and facilities

A.3 Appendix 3
Sustainable Streets Typical Design Details

The following typical details have been developed and added as new San Mateo Countywide Program details to supplement the SF PUC green infrastructure typical detail set based on feedback received from the Countywide Program GI Committee. These details are adapted from other leading national jurisdictions that integrate green infrastructure into their streets and environments or modified from SFPUC details. Additional typical design details can be added by the Countywide Program or individual jurisdictions in the future. These files are included in the following detail set and may be obtained in AutoCAD format from flowstobay.org/CADfiles.

1. Curb cut with metal plate top (at different inlet/outlet conditions)
2. Embedded rock energy dissipator
3. Subsurface Infiltration System (Deep Dry Well, Small System)
4. Alternate biotreatment soil media (BSM) area in bioretention basins

In addition, a few of the SF PUC details have been modified to reflect San Mateo County and local MRP requirements.

Green Streets and Related Resources

Many jurisdictions throughout the country have recently developed or updated their Green Street, green infrastructure, and/or low impact development guidance documents (including policies, guidelines, standard details, and specifications) and other related plans, policies, and documents to create and implement improved street and private property design for all modes of circulation and to manage and clean stormwater runoff. The following reference documents can serve as models and/or reference, in part or in whole. Some guidance are broader green infrastructure documents that provide information to inform the development of related green streets guidance. A few that are more comprehensive include:

Philadelphia, PA – Green Streets Design Manual, 2014. The technical guidance is provided as standard detail drawings and specifications that include design and construction notes and supporting documentation, including tree well filters and various curb extensions. It has a very robust section detailing accessory components such as planter edgings (e.g.: curbs, low fence, etc.), and different curb cut designs and vehicle wheel protection at inlets. This document also provides guidance on the design of green streets. See this link for a PDF file.

District of Columbia, Department of Transportation, Green Infrastructure Standards, 2014.
Visit this link for PDF files. This comprehensive document includes standard green infrastructure construction details, specifications, plant palettes, and maintenance schedules. In addition, it provides supplemental guidance for the engineering, design, and submittal of project stormwater design and management projects, and landscape design.

CASQA – LIDI Bioretention Details, 2017.
See this link for PDF and AutoCAD files. This document provides a set of standard details for various types of green infrastructure and some specifications. The technical guidance is provided as standard detail drawings that include design and construction notes and supporting documentation.

The City and County of Denver, Public Works, Ultra-Urban Green Infrastructure Guidelines, 2016.
See this link, for a PDF file. Document provides guidance on the design and implementation of green streets as well as construction detailing for a variety of green infrastructure measures appropriate for urban streets within denser areas.

Portland, OR – Stormwater Management Manual Typical Details, 2016.
Provides details for various curb extensions, and other green infrastructure planters and elements. Details provide typical planting schemes for trees and understory plantings. PDF and CAD files are available.
See this website, Typical Details.

A.3 Appendix 3
Sustainable Streets Typical Design Details

The following index lists the typical construction details and provides active links to their PDF versions and CAD files. If printing the following construction detail PDFs, lower page number ribbons and color blocks are for organization only and will not print.

The User must verify that the correct version is being used as is required by each jurisdiction, and the most current version is being used for your project, as is required.

Legend
SFPUC GI Typical Details — 2016
SMCWPPP Typical Details **not in** SFPUC Typical Details
SMCWPPP Typical Details **Modified From** SFPUC Typical Details

Sustainable Streets Typical Details		SMCWPPP Typical Details not in SFPUC Typical Details	SMCWPPP Typical Details Modified From SFPUC Typical Details	Jump to PDF	Jump to CAD
GEN 0.1	User Guide			→	📎
	Permeable Paving				
PP 1.1	Designer Notes (1 of 2)			→	📎
PP 1.2	Designer Notes (2 of 2)			→	
PP 1.3	Key Map			→	
PP 2.1	Material Sections - Permeable Unit Pavers			→	
PP 3.1	Material Sections - Pervious Concrete			→	
PP 4.1	Material Sections - Porous Asphalt			→	
	Pavement Components				
PC 1.1	Edge Treatments - Designer Notes			→	📎
PC 1.2	Edge Treatments - Key Map			→	
PC 1.3	Edge Treatments - Vehicular Applications			→	
PC 1.4	Edge Treatments - Pedestrian Applications (1 of 2)			→	
PC 1.5	Edge Treatments - Pedestrian Applications (2 of 2)			→	
PC 1.6	Edge Treatments - Paver at Structures			→	
PC 2.1	Subsurface Check Dams - Designer Notes			→	
PC 2.2	Subsurface Check Dams			→	
PC 3.1	Subsurface Overflows - Designer Notes			→	
PC 3.2	Subsurface Overflow			→	
PC 3.3	Subsurface Underdrain			→	
PC 3.4	Underdrain Pipe			→	

Sustainable Streets Typical Details		SMCWPPP Typical Details not in SFPUC Typical Details	SMCWPPP Typical Details Modified From SFPUC Typical Details	Jump to PDF	Jump to CAD
	Bioretention Planter				
BP 1.1	Designer Notes (1 of 2)			→	
BP 1.2	Designer Notes (2 of 2)			→	
BP 2.1	Roadside Planter with Parking - Plan			→	
BP 2.2	Roadside Planter with Parking - Sections			→	
BP 3.1	Roadside Planter without Parking - Plan			→	
BP 3.2	Roadside Planter without Parking - Sections			→	
BP 4.1	Roadside Bulbout Planter - Alternative 1			→	
BP 4.2	Roadside Bulbout Planter - Alternative 2			→	
BP 4.3	Roadside Bulbout Planter - Alternative 3			→	
BP 4.4	Roadside Bulbout Planter - Alternative 4			→	
BP 4.5	Roadside Bulbout Planter - Alternative 5			→	
BP 4.6	Roadside Bulbout Planter - Alternative 6			→	
BP 5.1	Parcel Planter - Designer Notes (1 of 2)			→	
BP 5.2	Parcel Planter - Designer Notes (2 of 2)			→	
BP 5.3	Parcel Planter Plan - Alternative 1			→	
BP 5.4	Parcel Planter Plan - Alternative 2			→	
BP 5.5	Parcel Planter - Raised Planter Section			→	
BP 5.6	Parcel Planter - At Grade Planter Section			→	
BP 5.7	Parcel Planter - Planter on Structure Section			→	
	Bioretention Basin				
BB 1.1	Designer Notes			→	
BB 2.1	Roadside Section, Type 1		X	→	
BB 2.1.1	Roadside Section, Type 2	X		→	

A.3 Appendix 3

Sustainable Streets Typical Design Details

Sustainable Streets Typical Details		SMCWPPP Typical Details not in SFPUC Typical Details	SMCWPPP Typical Details Modified From SFPUC Typical Details	Jump to PDF	Jump to CAD
	Bioretention Components				
BC 1.1	Bc 1.1 Edge Treatments - Designer Notes			→	
BC 1.2	Edge Treatments - Vehicular Applications (1 of 2)			→	
BC 1.2.1	Edge Treatments - Vehicular Applications Modification (1B of 2)	X		→	
BC 1.3	Edge Treatments - Vehicular Applications (2 of 2)			→	
BC 1.4	Edge Treatments - Pedestrian Applications (1 of 2)			→	
BC 1.5	Edge Treatments - Pedestrian Applications (2 of 2)			→	
BC 1.6	Edge Treatments - Lateral Bracing (1 of 2)			→	
BC 1.7	Edge Treatments - Lateral Bracing (2 of 2)			→	
BC 2.1	Inlets - Designer Notes		X	→	
BC 2.2	Inlets - Curb Cut with Gutter Modification		X	→	
BC 2.2.1	Inlets - Curb Cut with Metal Plate Top Modification	X		→	
BC 2.3	Inlets - Curb Cut at Bulb Out			→	
BC 2.3.1	Inlets - Curb Cut at Bulb Out Modification	X		→	
BC 2.4	Inlets - Curb Cut with Trench Drain			→	
BC 2.4.1	Inlets - Curb Cut with Trench Drain with Metal Plate Top Modification	X		→	
BC 2.5	Embedded Rock Energy Dissipator	X		→	
BC 3.1	Outlets - Designer Notes		X	→	
BC 3.2	Outlets - Curb Cut			→	
BC 3.3	Outlets - Curb Cut with Trench Drain			→	
BC 3.3.1	Outlets - Curb Cut with Trench Drain w- Metal Plate Top Modification	X		→	
BC 3.4	Outlets - Overflow Structures			→	
BC 4.1	Aggregate Storage Layers			→	
BC 5.1	Underdrains - Designer Notes			→	
BC 5.2	Underdrains			→	
BC 6.1	Check Dams - Designer Notes			→	
BC 6.2	Check Dams			→	
BC 7.1	Outlet Monitoring - Designer Notes			→	
BC 7.2	Outlet Monitoring - External Access Structure			→	
BC 7.3	Outlet Monitoring - Internal Catch Basin Monitoring			→	

Sustainable Streets Typical Details		SMCWPPP Typical Details not in SFPUC Typical Details	SMCWPPP Typical Details Modified From SFPUC Typical Details	Jump to PDF	Jump to CAD
	Subsurface Infiltration				
SI 1.1	Designer Notes (1 of 2)			→	
SI 1.2	Designer Notes (2 of 2)		X	→	
SI 2.1	Infiltration Gallery - Large System - Plan			→	
SI 2.2	Infiltration Gallery - Large System - Section		X	→	
SI 3.1	Dry Well - Small System - Plan			→	
SI 3.2	Dry Well - Small System - Section		X	→	
SI 4.1	Dry Well - Deep – Plan and Section	X		→	
	General Components				
GC 1.1	Liners - Designer Notes			→	
GC 1.2	Liners - Liners and Attachments			→	
GC 2.1	Utility Crossings - Designer Notes (1 of 2)			→	
GC 2.2	Utility Crossings - Designer Notes (2 of 2)			→	
GC 2.3	Utility Crossings - Bioretention			→	
GC 2.4	Utility Crossings - Bioretention Sections (1 of 2)			→	
GC 2.5	Utility Crossings - Bioretention Sections (2 of 2)			→	
GC 2.6	Utility Crossings - Permeable Pavement			→	
GC 2.7	Utility Crossings - Pavement Sections (1 of 2)			→	
GC 2.8	Utility Crossings - Pavement Sections (2 of 2)			→	
GC 2.9	Utility Crossings - Liner Penetrations			→	
GC 2.10	Utility Crossings - Wall Penetrations (1 of 2)			→	
GC 2.11	Utility Crossings - Wall Penetrations (2 of 2)			→	
GC 2.12	Utility Crossings - Utility Trench Dam			→	
GC 3.1	Utility Conflicts - Designer Notes			→	
GC 3.2	Utility Conflicts - Street/Traffic Light Poles (1 of 2)			→	
GC 3.3	Utility Conflicts - Street/Traffic Light Poles (2 of 2)			→	
GC 3.4	Utility Conflicts - Parking Meters			→	
GC 4.1	Observation Ports - Designer Notes			→	
GC 4.2	Observation Ports - Bioretention			→	
GC 4.3	Observation Ports - Permeable Pavement			→	
G C5.1	Cleanouts			→	
GC 6.1	End-of-Block Monitoring - Designer Notes			→	
GC 6.2	End-of-Block Monitoring			→	

These typical details and specifications were developed to be manipulated and customized for each individual project by design professionals.

The SFPUC's Urban Watershed Management Program (UWMP) is proud to introduce the *San Francisco Green Infrastructure Typical Details and Specifications*. These details incorporate the latest best practices in green infrastructure (GI) design nation-wide and, at the same time, reflect the unique challenges and specific needs for designing and building GI in the City and County of San Francisco. The details were vetted through an extensive city-family review process and reflect the expertise of many members of the City Family, including Public Works, the Department of Building Inspection, the Municipal Transportation Agency, and the Planning Department.

This Appendix provides general guidance for using the details and specifications effectively during the design and construction document development process.

Bioretention in a plaza manages stormwater from the roof of a residential building in San Francisco. *Photo: Krystal Zamora*

Typical Details for Site-Specific Design

These details show **typical** configurations, rather than required **standard** configurations. This distinction is deliberate on the part of the project team, as we recognize that to create GI projects that are beautiful, functional, and contextual, designers must use their own creative thinking and professional judgement and, above all, be responsive to each site.

To ensure that the details are broadly applicable and can be adapted to many sites, wherever possible the details provide **guidelines** and **ranges of acceptability** instead of precise numeric requirements. Both the Designer Notes for each detail and the details themselves emphasize areas where the designer must exercise professional judgement to respond to the site.

For example, the Designer Notes for the bioretention planter section indicate that planter area, ponding depth, bioretention soil depth, and gravel reservoir course depth must be sized to meet project hydrologic performance goals. On the corresponding drawing, bioretention soil depth is shown with a minimum depth of 18 inches. Ponding depth should be between 2 and 6 inches. In these cases the details are indicating acceptable minimums and maximums but the designer must choose the bioretention soil depth and ponding depth that is appropriate for a given site. Bioretention facilities on a site with A soils may perform very well using the minimum soil depth, while facilities sited on C soils will benefit from a deeper soil profile.

Items that are **required** for system function can be found in the Construction Notes, the General Utility Notes, the Layout Requirements, and the Designer Checklists. For example, the Construction Notes for the bioretention planter section include the following:

1. Avoid compaction of existing subgrade below planter during construction.
2. Scarify subgrade to a depth of 6 inches (min) immediately prior to placement of gravel storage and bioretention soil.
3. Maximum drop from top of curb to top of bioretention soil shall include considerations for bioretention soil settlement.

Usage on Construction Documents

ACAD drawings of typical details are available for download at www.sfwater.org/smr. Design professionals must modify facility plan and section configurations, materials, and construction notes to address the project's site conditions and meet project performance goals. To ensure that your use of the details is site-specific, please:

- Adjust plans, sections, and construction notes for site-specific design
- Remove the SFPUC GI Title Block from the details used in your set and replace it with a title that aligns with your projects' construction document nomenclature
- Incorporate all detail call-outs and references into the construction documents so that the contractor will have all the information required to build the project

Permeable pavement along Octavia Blvd in San Francisco.
Photo: Krystal Zamora

Drought tolerant plantings can also be appropriate for vegetated roofs. Photo: Ken Kortkamp

Typical Detail Content

The details are organized to guide the licensed professional to the proper selection, layout, and design of GI technologies (such as permeable pavement and bioretention) and components (such as inlets, outlets, and edge treatments). The components allow the typical details to be modified to reflect specific design approaches and site conditions. The typical details include the following sections:

- Purpose
- Designer Guidelines
- Layout Requirements
- Designer Checklists
- Key Maps
- Facility Plans
- Facility Sections and Profiles
- General Notes
- General Utility Notes
- Construction Notes
- Component Details

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES

APPENDIX B:

GREEN INFRASTRUCTURE TYPICAL DETAILS

(SEPTEMBER 2016, VERSION 2.0)

San Francisco Water Power Sewer

Services of the San Francisco Public Utilities Commission

SHEET NO.	SHEET TITLE
	GENERAL INFORMATION
GEN 0.1	USER GUIDE
	PERMEABLE PAVEMENT (PP)
PP 1.1	DESIGNER NOTES (1 OF 2)
PP 1.2	DESIGNER NOTES (2 OF 2)
PP 1.3	KEY MAP
PP 2.1	MATERIAL SECTIONS - PERMEABLE UNIT PAVERS
PP 3.1	MATERIAL SECTIONS - PERVIOUS CONCRETE
PP 4.1	MATERIAL SECTIONS - POROUS ASPHALT
	PAVEMENT COMPONENTS (PC)
PC 1.1	EDGE TREATMENTS - DESIGNER NOTES
PC 1.2	EDGE TREATMENTS - KEY MAP
PC 1.3	EDGE TREATMENTS - VEHICULAR APPLICATIONS
PC 1.4	EDGE TREATMENTS - PEDESTRIAN APPLICATIONS (1 OF 2)
PC 1.5	EDGE TREATMENTS - PEDESTRIAN APPLICATIONS (2 OF 2)
PC 1.6	EDGE TREATMENTS - PAVER AT STRUCTURES
PC 2.1	SUBSURFACE CHECK DAMS - DESIGNER NOTES
PC 2.2	SUBSURFACE CHECK DAMS
PC 3.1	SUBSURFACE OVERFLOWS - DESIGNER NOTES
PC 3.2	SUBSURFACE OVERFLOW
PC 3.3	SUBSURFACE UNDERDRAIN
PC 3.4	UNDERDRAIN PIPE
	BIORETENTION PLANTER (BP)
BP 1.1	DESIGNER NOTES (1 OF 2)
BP 1.2	DESIGNER NOTES (2 OF 2)
BP 2.1	ROADSIDE PLANTER WITH PARKING - PLAN
BP 2.2	ROADSIDE PLANTER WITH PARKING - SECTIONS
BP 3.1	ROADSIDE PLANTER WITHOUT PARKING - PLAN
BP 3.2	ROADSIDE PLANTER WITHOUT PARKING - SECTIONS
BP 4.1	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 1
BP 4.2	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 2
BP 4.3	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 3
BP 4.4	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 4
BP 4.5	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 5
BP 4.6	ROADSIDE BULBOUT PLANTER - ALTERNATIVE 6
BP 5.1	PARCEL PLANTER - DESIGNER NOTES (1 OF 2)
BP 5.2	PARCEL PLANTER - DESIGNER NOTES (2 OF 2)
BP 5.3	PARCEL PLANTER PLAN - ALTERNATIVE 1
BP 5.4	PARCEL PLANTER PLAN - ALTERNATIVE 2
BP 5.5	PARCEL PLANTER - RAISED PLANTER SECTION
BP 5.6	PARCEL PLANTER - AT GRADE PLANTER SECTION
BP 5.7	PARCEL PLANTER - PLANTER ON STRUCTURE SECTION
	BIORETENTION BASIN (BB)
BB 1.1	DESIGNER NOTES
BB 2.1	ROADSIDE SECTION
BB 2.2	PARCEL SECTION
	BIORETENTION COMPONENTS (BC)
BC 1.1	EDGE TREATMENTS - DESIGNER NOTES
BC 1.2	EDGE TREATMENTS - VEHICULAR APPLICATIONS (1 OF 2)
BC 1.3	EDGE TREATMENTS - VEHICULAR APPLICATIONS (2 OF 2)
BC 1.4	EDGE TREATMENTS - PEDESTRIAN APPLICATIONS (1 OF 2)
BC 1.5	EDGE TREATMENTS - PEDESTRIAN APPLICATIONS (2 OF 2)
BC 1.6	EDGE TREATMENTS - LATERAL BRACING (1 OF 2)
BC 1.7	EDGE TREATMENTS - LATERAL BRACING (2 OF 2)
BC 2.1	INLETS - DESIGNER NOTES
BC 2.2	INLETS - CURB CUT WITH GUTTER MODIFICATION
BC 2.3	INLETS - CURB CUT AT BULB OUT
BC 2.4	INLETS - CURB CUT WITH TRENCH DRAIN
BC 3.1	OUTLETS - DESIGNER NOTES
BC 3.2	OUTLETS - CURB CUT
BC 3.3	OUTLETS - CURB CUT WITH TRENCH DRAIN
BC 3.4	OUTLETS - OVERFLOW STRUCTURES
BC 4.1	AGGREGATE STORAGE LAYERS
BC 5.1	UNDERDRAINS - DESIGNER NOTES
BC 5.2	UNDERDRAINS
BC 6.1	CHECK DAMS - DESIGNER NOTES
BC 6.2	CHECK DAMS
BC 7.1	OUTLET MONITORING - DESIGNER NOTES
BC 7.2	OUTLET MONITORING - EXTERNAL ACCESS STRUCTURE
BC 7.3	OUTLET MONITORING - INTERNAL CATCH BASIN MONITORING
	SUBSURFACE INFILTRATION (SI)
SI 1.1	DESIGNER NOTES (1 OF 2)
SI 1.2	DESIGNER NOTES (2 OF 2)
SI 2.1	INFILTRATION GALLERY - LARGE SYSTEM - PLAN
SI 2.2	INFILTRATION GALLERY - LARGE SYSTEM - SECTION
SI 3.1	DRY WELL - SMALL SYSTEM - PLAN
SI 3.2	DRY WELL - SMALL SYSTEM - SECTION
	GENERAL COMPONENTS (GC)
GC 1.1	LINERS - DESIGNER NOTES
GC 1.2	LINERS - LINERS AND ATTACHMENTS
GC 2.1	UTILITY CROSSINGS - DESIGNER NOTES (1 OF 2)
GC 2.2	UTILITY CROSSINGS - DESIGNER NOTES (2 OF 2)
GC 2.3	UTILITY CROSSINGS - BIORETENTION
GC 2.4	UTILITY CROSSINGS - BIORETENTION SECTIONS (1 OF 2)
GC 2.5	UTILITY CROSSINGS - BIORETENTION SECTIONS (2 OF 2)
GC 2.6	UTILITY CROSSINGS - PERMEABLE PAVEMENT
GC 2.7	UTILITY CROSSINGS - PAVEMENT SECTIONS (1 OF 2)
GC 2.8	UTILITY CROSSINGS - PAVEMENT SECTIONS (2 OF 2)
GC 2.9	UTILITY CROSSINGS - LINER PENETRATIONS
GC 2.10	UTILITY CROSSINGS - WALL PENETRATIONS (1 OF 2)
GC 2.11	UTILITY CROSSINGS - WALL PENETRATIONS (2 OF 2)
GC 2.12	UTILITY CROSSINGS - UTILITY TRENCH DAM
GC 3.1	UTILITY CONFLICTS - DESIGNER NOTES
GC 3.2	UTILITY CONFLICTS - STREET/TRAFFIC LIGHT POLES (1 OF 2)
GC 3.3	UTILITY CONFLICTS - STREET/TRAFFIC LIGHT POLES (2 OF 2)
GC 3.4	UTILITY CONFLICTS - PARKING METERS
GC 4.1	OBSERVATION PORTS - DESIGNER NOTES
GC 4.2	OBSERVATION PORTS - BIORETENTION
GC 4.3	OBSERVATION PORTS - PERMEABLE PAVEMENT
GC 5.1	CLEANOUTS
GC 6.1	END-OF-BLOCK MONITORING - DESIGNER NOTES
GC 6.2	END-OF-BLOCK MONITORING

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

SHEET INDEX

DWG NO.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

USER GUIDE: HOW TO USE THESE GI TYPICAL DETAILS

THESE TYPICAL DETAILS AND SPECIFICATIONS WERE DEVELOPED TO BE REVISED AND CUSTOMIZED FOR EACH INDIVIDUAL PROJECT BY DESIGN PROFESSIONALS.

THEY SHOW **TYPICAL** CONFIGURATIONS, RATHER THAN A REQUIRED CITY **STANDARD** CONFIGURATION. THIS DISTINCTION IS DELIBERATE. WE RECOGNIZE THAT TO CREATE GI PROJECTS THAT ARE FUNCTIONAL, CONTEXTUAL, AND AESTHETIC, DESIGN PROFESSIONALS MUST USE THEIR PROFESSIONAL JUDGMENT AND CREATIVE THINKING TO BE RESPONSIVE TO EACH SITE-SPECIFIC CONDITION.

ACAD DRAWINGS OF THESE TYPICAL DETAILS ARE PROVIDED SUCH THAT THE DESIGN PROFESSIONALS MUST MODIFY THE PLAN, SECTIONS, CALL-OUTS, AND/OR CONSTRUCTION NOTES TO ADDRESS THE PROJECTS SITE-SPECIFIC CONDITIONS.

CONTENT

THESE TYPICAL DETAILS ARE FORMATTED, ORGANIZED, AND DEVELOPED WITH THE NECESSARY INFORMATIONAL TOOLS TO GUIDE THE DESIGN PROFESSIONAL THROUGH THE PROPER SELECTION, LAYOUT, AND DESIGN OF **GI BEST MANAGEMENT PRACTICES (BMPS)** AND THE SELECTION OF APPROPRIATE SITE-SPECIFIC BMP **COMPONENT DETAILS** (I.E. INLETS, OUTLETS, AND EDGE TREATMENTS, ETC.). THESE TYPICAL DETAILS PROVIDE THE FOLLOWING ORGANIZATION:

PURPOSE: SUMMARY OF EACH FACILITY'S INTENDED PERFORMANCE AND FUNCTION.

DESIGNER NOTES & GUIDELINES: TECHNICAL DESIGN REQUIREMENTS AND/OR SIZING CRITERIA GUIDELINES ARE PROVIDED SUCH THAT EACH FACILITY IS DESIGNED AND APPROPRIATELY CUSTOMIZED BY THE DESIGN PROFESSIONAL.

LAYOUT REQUIREMENTS: TECHNICAL INFORMATION, DESIGN REQUIREMENTS, AND REFERENCE TO RELATED CITY REQUIREMENTS.

DESIGNER CHECKLIST: TECHNICAL DESIGN INFORMATION THAT **MUST** BE DETERMINED AND SHOWN IN THE CONSTRUCTION DOCUMENTS TO ENSURE PROPER DESIGN AND CONSTRUCTABILITY.

BMP PLANS: TYPICAL PLAN VIEW WITH GENERAL CONFIGURATION FOR PROPER FUNCTION. DIMENSIONAL LAYOUT AND EDGING MATERIALS SHOULD BE ADJUSTED BASED ON PROPOSED SITE DESIGN AND PROGRAMING. **[ADJUST ACAD DETAIL CALL-OUTS AND REFERENCES FOR USE IN CDs]**

BMP SECTIONS AND PROFILES: A TYPICAL SECTION AND/OR PROFILE WITH GENERAL CONFIGURATION FOR PROPER FUNCTION. DIMENSIONAL LAYOUT AND EDGING MATERIALS SHOULD BE ADJUSTED BASED ON PROPOSED SITE DESIGN AND PROGRAMING. **[ADJUST ACAD DETAILS CALL-OUTS AND REFERENCES FOR USE IN CDs]**

CONSTRUCTION NOTES: CONSTRUCTION RELATED NOTES FOR USE BY THE CONTRACTOR. **[ADJUST ACAD NOTES FOR USE IN CDs]**

NAVIGATION

THE TYPICAL DETAILS HAVE BEEN DEVELOPED WITH A NAVIGATION SYSTEM AND KEY BAR TO ASSIST THE DESIGN PROFESSIONALS WITH LINKING THE SPECIFIC BMP TO RELEVANT DESIGN NOTES AND POSSIBLE DETAIL COMPONENTS. EXAMPLE KEY BAR:

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

USE ON CONSTRUCTION DOCUMENTS

DESIGN PROFESSIONALS USING THE AUTOCAD DRAWINGS **MUST REVIEW AND ADJUST THE DETAILS AND CONSTRUCTION NOTES TO ADDRESS THEIR SITE-SPECIFIC CONDITIONS**. TO ALLOW FOR SITE-SPECIFIC DESIGN ADJUSTMENTS THE TYPICAL DETAILS ARE DEVELOPED AS **"NOT FOR CONSTUCTION"** DRAWINGS. TITLE BLOCKS ARE PROVIDED FOR DOCUMENT ORGANIZATION AND REFERENCE ONLY.

- **DO NOT** INCLUDE THE NON-ADJUSTED DETAIL WITH TITLE BLOCK WITHIN THE CONSTRUCTION DOCUMENTS.
- **DO NOT** INCLUDE NON-ADJUSTED DETAIL PLANS, SECTIONS, OR CONSTRUCTION NOTES WITHIN THE CONSTRUCTION DOCUMENTS.
- **DO NOT** REFERENCE THE GI TYPICAL DETAIL SHEET NAME AND/OR NUMBER (I.E. **BP 2.1**) AS A STANDARD DETAIL CALL-OUT WITHIN THE CDs.
- **DO NOT** EXPECT CONTRACTORS TO CONDUCT CALCULATIONS OR BE RESPONSIBLE FOR MISSING DESIGN INFORMATION.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

USER GUIDE

DWG NO. GEN 0.1

PURPOSE:

PERMEABLE PAVEMENT (PAVEMENT) CONTROLS PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF VIA INFILTRATION THROUGH THE PAVEMENT SURFACE, STORAGE IN THE PAVEMENT SECTION, INFILTRATION INTO NATIVE SOIL, AND OVERFLOW THROUGH OPTIONAL SUBSURFACE OUTLETS. RUNOFF IS TREATED AS IT FILTERS THROUGH THE PAVEMENT SECTION, AND INFILTRATES INTO UNDERLYING NATIVE SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN, SECTION DRAWINGS, AND CALCULATE DEPTH TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. ALL PAVEMENT SYSTEMS MUST BE DESIGNED BY A LICENSED ENGINEER IN ACCORDANCE WITH THE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES BASED ON SITE-SPECIFIC CONDITIONS INCLUDING TRAFFIC LOADS AND SUBGRADE CONDITIONS. PAVEMENT SECTIONS SET FORTH IN THESE TYPICAL DETAILS ARE PROVIDED TO REPRESENT THE ANTICIPATED RANGE OF DESIGN REQUIREMENTS, BASED ON "GOOD" AND "POOR" SOIL CHARACTERIZATIONS NORMALLY ENCOUNTERED IN SAN FRANCISCO. **ACTUAL SECTION DEPTHS MUST BE DETERMINED AS DESCRIBED IN GUIDELINE #3, BELOW** . SEE TABLES BELOW FOR TRAFFIC LOADING AND EFFECTIVE ROADBED SOIL RESILIENT MODULUS ASSUMPTIONS USED IN DEVELOPING THESE TYPICAL SECTIONS.
3. TRAFFIC LOADING ASSUMPTIONS:

DESIGN ASSUMPTION	MODERATE VEHICULAR	LIGHT VEHICULAR	PEDESTRIAN
EQUIVALENT SINGLE AXLE LOADS*	2,000,000	40,000	800
TRAFFIC INDEX (TI)**	10	6.5	4
* SEE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES FOR DEFINITIONS			
** SEE CALTRANS HIGHWAY DESIGN MANUAL FOR DEFINITIONS			

SUBGRADE ASSUMPTIONS:

DESIGN ASSUMPTION	GOOD SOILS	POOR SOILS
EFFECTIVE ROADBED SOIL RESILIENT MODULUS, M_R (PSI)*	6,800	3,700
CALIFORNIA R-VALUE **	33.3	15.6
DRAINAGE COEFFICIENT, m *	1.15	0.75
LAYER COEFFICIENT, a * FOR OPEN GRADED AGGREGATE BASE	0.08	
* SEE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES FOR DEFINITIONS		
** SEE CALTRANS HIGHWAY DESIGN MANUAL FOR DEFINITIONS		

4. GEOTECHNICAL EVALUATION OF SUBGRADE SOILS TO VERIFY THEIR STRUCTURAL SUITABILITY FOR PERMEABLE PAVEMENT INSTALLATIONS IS REQUIRED. INFILTRATION TESTING REQUIREMENTS ARE SUBJECT TO DIFFERENT THRESHOLDS. REFER TO SAN FRANCISCO STORMWATER MANAGEMENT REQUIREMENTS FOR GUIDANCE.
5. THE PERMEABLE PAVEMENT FACILITY MUST BE DESIGNED TO PROVIDE SUFFICIENT SUBSURFACE STORAGE IN THE PAVEMENT SECTION TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS. THE SECTION THICKNESS WILL BE A FUNCTION OF THE SUBGRADE INFILTRATION RATE (DRAINAGE COEFFICIENT), SUBGRADE SLOPE, AND THE HEIGHT AND SPACING OF SUBSURFACE CHECK DAMS. SEE **PC 2.1** AND **PC 2.2**.
6. ENTIRE PAVEMENT BASE SECTION MAY BE USED TO MEET SUBSURFACE STORAGE REQUIREMENTS.
7. SUBSURFACE STORAGE DRAWDOWN TIME (I.E. TIME FOR MAXIMUM SUBSURFACE STORAGE VOLUME TO INFILTRATE INTO SUBGRADE AFTER THE END OF A STORM) SHOULD NOT EXCEED 48 HOURS. DRAWDOWN TIME IS CALCULATED AS THE MAXIMUM SUBSURFACE PONDING DEPTH DIVIDED BY THE NATIVE SOIL INFILRATION RATE.
8. THE DESIGNER MUST ENSURE THAT THE PAVEMENT EDGES ARE RESTRAINED AND THAT WATER IS CONTAINED IN THE PAVEMENT SECTION AS NEEDED TO PROTECT ADJACENT PAVEMENT SECTIONS OR STRUCTURES. SEE EDGE TREATMENTS (**PC 1.1** THROUGH **PC 1.6**) FOR GUIDANCE ON DESIGN OF THESE COMPONENTS.
9. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. REFER TO **GC 2.1** - **GC 2.12** FOR UTILITY CROSSING DETAILS AND **GC 1.4** - **GC 4.4** FOR UTILITY CROSSING CONFLICT DETAILS.

RELATED COMPONENTS	
EDGE TREATMENTS:	PC 1.1 - PC 1.6
CHECK DAMS:	PC 2.1 - PC 2.2
OVERFLOWS:	PC 3.1 - PC 3.3
LINERS:	GC 1.1, GC 1.2
UTILITY CROSSINGS:	GC 2.1 - GC 2.12
OBSERVATION PORTS:	GC 3.1, GC 3.3
UTILITY CONFLICTS:	GC 4.1 - GC 4.4
CLEANOUTS:	GC 5.2

RELATED SPECIFICATIONS	CSI NO.
PERMEABLE/POROUS UNIT PAVERS: - PERMEABLE /POROUS UNIT PAVERS - JOINT FILLER AGGREGATE - PAVEMENT BASE - EDGE RESTRAINTS - GEOTEXTILE FOR SOIL SEPARATION	32 14 43
PERVIOUS CONCRETE PAVEMENT: - PERVIOUS CONCRETE - PAVEMENT BASE - GEOTEXTILE FOR SOIL SEPARATION	32 13 43
POROUS ASPHALT PAVEMENT: - POROUS ASPHALT - PAVEMENT BASE - GEOTEXTILE FOR SOIL SEPARATION	32 12 43

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES		KEY MAP	SECTIONS		
PP 1.1	PP 1.2	PP 1.3	PP 2.1	PP 3.1	PP 4.1

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

PERMEABLE PAVEMENT

DESIGNER NOTES (1 OF 2)

DWG NO. PP 1.1

LAYOUT REQUIREMENTS:

1. ALL PERMEABLE PAVEMENT APPLICATIONS SHALL CONFORM TO THE CURRENT CITY OF SAN FRANCISCO PUBLIC WORKS PERMEABLE PAVEMENT DIRECTORS ORDER [PENDING COMPLETION]. THE DESIGN MUST COMPLY WITH SAN FRANCISCO PUBLIC WORKS STANDARD ACCESSIBILITY REQUIREMENTS.
2. THE PREFERRED AND ALLOWED CATCHMENT AREA CONTRIBUTING RUN-ON TO A PERMEABLE PAVEMENT FACILITY IS PROVIDED IN THE FOLLOWING TABLE:

WEARING COURSE	PREFERRED RUN-ON RATIO	MAXIMUM RUN-ON RATIO** (AREA CONTRIBUTING RUN-ON: PERMEABLE PAVEMENT AREA)
PERVIOUS CONCRETE AND POROUS ASPHALT	MINIMAL	3:1
PERMEABLE UNIT PAVERS (≥ 1/2" GAPS) [PARCEL ONLY] *	0:1	3:1
PERMEABLE UNIT PAVERS (≥ 3/8" GAPS) *	0:1	2:1
PERMEABLE UNIT PAVERS (≥ 1/4" GAPS)	0:1	1:1
POROUS PAVERS	0:1	0:1 (NO RUN-ON)

*PAVERS WITH 3/8 INCH OR 1/2 INCH GAPS SHALL BE PERMEABLE INTERLOCKING CONCRETE PAVERS WITH INTEGRATED PRECAST INTERLOCKING SPACER.

**THE DESIGNER AND OWNER SHOULD CONSIDER THE INCREASED MAINTENANCE REQUIREMENTS ASSOCIATED WITH HIGHER RUN-ON RATIOS WHEN DESIGNING THE FACILITY.

3. WHEN DESIGNED TO ACCEPT RUN-ON FROM OTHER CATCHMENT AREAS, PERMEABLE PAVEMENT AREAS MUST BE PROTECTED FROM SEDIMENTATION WHICH CAN CAUSE CLOGGING AND DIMINISHED FACILITY PERFORMANCE. THE FOLLOWING REQUIREMENTS APPLY FOR RUN-ON CONTRIBUTIONS:
   - RUN-ON FROM LAWN, LANDSCAPE OR OTHER ERODIBLE SURFACES IS DISCOURAGED. IF MINOR RUN-ON FROM LAWN OR LANDSCAPE AREAS IS UNAVOIDABLE, THOSE ERODIBLE AREAS MUST BE FULLY STABILIZED.
   - CONCENTRATED RUN-ON (E.G., DIRECT DISCHARGE FROM A DOWNSPOUT) SHOULD BE DISPERSED PRIOR TO DISCHARGE TO A PERMEABLE PAVEMENT FACILITY. ACCEPTABLE METHODS INCLUDE SHEET FLOW OR SUBSURFACE DELIVERY TO THE STORAGE RESERVOIR. IF SUBSURFACE DELIVERY IS USED, PRIMARY SETTLING IS REQUIRED (E.G., VIA SAND TRAP) FOLLOWED BY DISTRIBUTION TO STORAGE RESERVOIR (E.G., VIA PERFORATED PIPE).
4. WEARING COURSE SHALL BE SET FLUSH (± 3/16 INCH) WITH ADJACENT WALKING SURFACES.
5. WEARING COURSE SHALL HAVE A MINIMUM SURFACE SLOPE OF 0.5% TO ALLOW FOR SURFACE OVERFLOW AND A MAXIMUM SURFACE SLOPE AS LISTED BELOW:
   a. POROUS ASPHALT SURFACE: = 5 PERCENT SLOPE
   b. PERVIOUS CONCRETE SURFACE: = 10 PERCENT SLOPE
   c. PERMEABLE UNIT PAVERS: = 12 PERCENT SLOPE (PER MANUFACTURER'S RECOMMENDATION)
6. WHILE THERE IS NO MAXIMUM SLOPE FOR THE SUBGRADE UNDER THE PERMEABLE PAVEMENT COURSES, THERE MAY BE ENGINEERING CHALLENGES ASSOCIATED WITH SUBSURFACE CHECK DAM REQUIREMENTS ON SUBGRADE SLOPES EXCEEDING 5%. SEE SUBSURFACE CHECK DAMS (**PC 2.1** AND **PC 2.2**).

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PERMEABLE PAVEMENT SPECIFICATIONS AND/OR PAVER TYPE AND GAP WIDTH
- ☐ PERMEABLE PAVEMENT WIDTH AND LENGTH
- ☐ ELEVATIONS AND CONTROL POINTS AT EVERY CORNER OR POINT OF TANGENCY
- ☐ THICKNESS OF EACH LAYER IN THE PAVEMENT SECTION
- ☐ JOINT SPACING AND TYPE
- ☐ SUBGRADE SLOPE
- ☐ SUBSURFACE CHECK DAM SPACING, HEIGHT, AND TYPE
- ☐ ELEVATIONS OF EACH PIPE INLET AND OUTLET INVERT
- ☐ TYPE AND DESIGN OF PERMEABLE PAVEMENT COMPONENTS (E.G., EDGE TREATMENTS, OUTLETS, UNDERDRAINS, etc.)

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES		KEY MAP	SECTIONS		
PP 1.1	PP 1.2	PP 1.3	PP 2.1	PP 3.1	PP 4.1

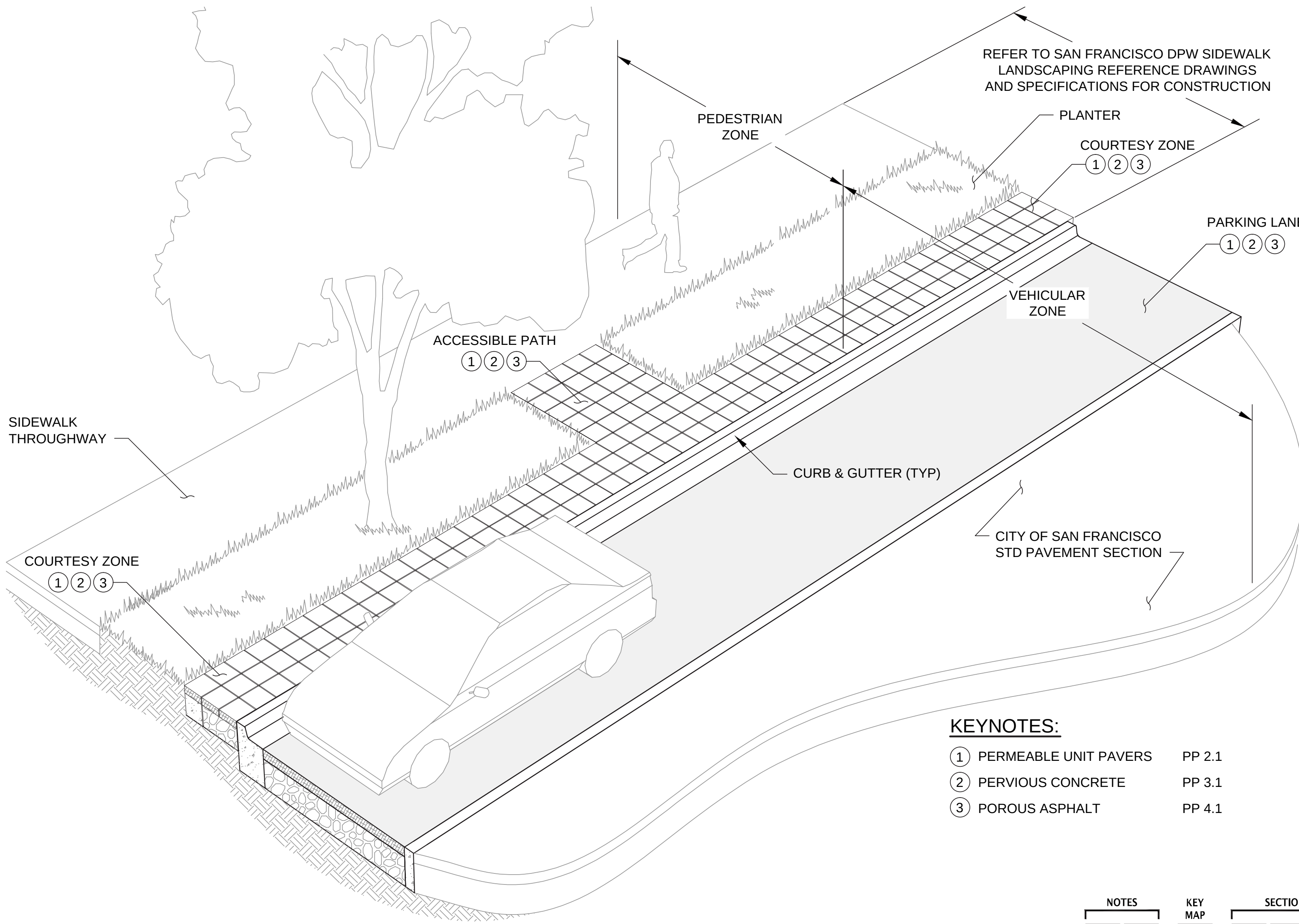
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PERMEABLE PAVEMENT
DESIGNER NOTES (2 OF 2)

DWG NO. PP 1.2



NOT FOR CONSTRUCTION - REFER TO USER GUIDE

KEYNOTES:

1	PERMEABLE UNIT PAVERS	PP 2.1
2	PERVIOUS CONCRETE	PP 3.1
3	POROUS ASPHALT	PP 4.1

NOTES		KEY MAP	SECTIONS		
PP 1.1	PP 1.2	PP 1.3	PP 2.1	PP 3.1	PP 4.1

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

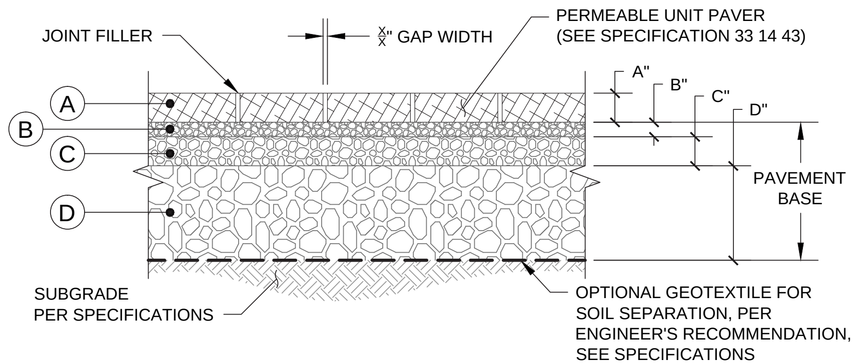
VERSION 2.0

REVISED

PERMEABLE PAVEMENT

KEY MAP

DWG NO. **PP 1.3**



PERMEABLE UNIT PAVERS (1)

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	PERMEABLE UNIT PAVERS	3 1/8	3 1/8	3 1/8	3 1/8	3 1/8	3 1/8
B	LEVELING COURSE ASTM NO. 8	2	2	2	2	2	2
C	BASE COURSE ASTM NO. 57	6	6	6	4	4	4
D	RESERVOIR COURSE ASTM NO. 2, 3, OR 57	22	28	-	10	-	-

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

TYPICAL JOINT FILLER AGGREGATE SIZE:

GAP WIDTH (IN)	JOINT FILLER AGGREGATE *
3/8 OR 1/2	ASTM NO. 8
1/4	ASTM NO. 9 OR 89
1/8	ASTM NO. 10 **

* PROVIDED FOR REFERENCE ONLY, FOLLOW MANUFACTURER'S RECOMMENDATIONS

** FOR POROUS PAVERS ONLY, ASTM NO. 20 SAND NOT ALLOWED PER MANUFACTURERS RECOMMENDATIONS.

CONSTRUCTION NOTES:

1. SEE PERMEABLE/POROUS UNIT PAVER SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR PERMEABLE/POROUS UNIT PAVER FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: PP 1.1 | PP 1.2
KEY MAP: PP 1.3
SECTIONS: PP 2.1 | PP 3.1 | PP 4.1

San Francisco Water Power Sewer

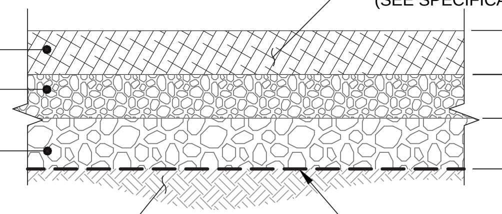
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PERMEABLE PAVEMENT
MATERIAL SECTIONS
PERMEABLE UNIT PAVERS

DWG NO. PP 2.1



PERVIOUS CONCRETE 1

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	PERVIOUS CONCRETE	9	9.5	6.5	7	4.5	5
B	BASE COURSE ASTM NO. 3 OR 57	6	6	6	6	6	6
C	OPTIONAL RESERVOIR COURSE ASTM NO. 2, 3, OR 57	-	-	-	-	-	-

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

CONSTRUCTION NOTES:

1. SEE PERVIOUS CONCRETE SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR PERVIOUS CONCRETE FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: PP 1.1 | PP 1.2
KEY MAP: PP 1.3
SECTIONS: PP 2.1 | PP 3.1 | PP 4.1

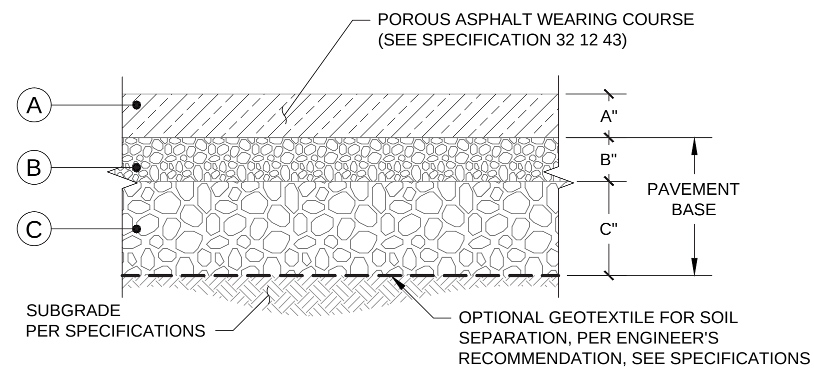
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PERMEABLE PAVEMENT
MATERIAL SECTIONS
PERVIOUS CONCRETE

DWG NO. PP 3.1



POROUS ASPHALT 1

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	POROUS ASPHALT	6	8	4	4	3	4
B	BASE COURSE ASTM NO. 57	6	6	5	4	6	4
C	RESERVOIR COURSE ASTM NO. 2, 3, OR 57	10	19	-	11	-	8

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

CONSTRUCTION NOTES:

1. SEE POROUS ASPHALT SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR POROUS ASPHALT FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: PP 1.1 | PP 1.2
KEY MAP: PP 1.3
SECTIONS: PP 2.1 | PP 3.1 | PP 4.1

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

PERMEABLE PAVEMENT

MATERIAL SECTIONS

POROUS ASPHALT

DWG NO. PP 4.1

PURPOSE:

EDGE TREATMENTS ARE USED TO STABILIZE THE EDGE OF THE PERMEABLE PAVEMENT AND CONTAIN WATER WITHIN THE PERMEABLE PAVEMENT SECTION.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. ALL EDGE TREATMENT SYSTEMS MUST BE DESIGNED BY A LICENSED ENGINEER BASED ON SITE SPECIFIC CONDITIONS.
3. MINIMUM EDGE TREATMENT EMBEDMENT KEY DEPTHS ARE SPECIFIED TO PREVENT LATERAL SEEPAGE UNDER THE EDGE TREATMENT AND INTO ADJACENT PAVEMENT SECTIONS. DEEPER EMBEDMENT MAY BE REQUIRED UNDER SOME CONDITIONS.
4. FOR DEEP PAVEMENT SECTIONS, EDGE TREATMENT NOT REQUIRED TO EXTEND MORE THAN 12 INCHES BELOW WEARING COURSE PROVIDED REQUIREMENTS AT INTERFACE WITH IMPERMEABLE PAVEMENTS ARE SATISFIED.
5. USE THE EDGE TREATMENT KEY MAP ON **PC 1.2** AND CURRENT CITY OF SAN FRANCISCO PUBLIC WORKS PERMEABLE PAVEMENT DIRECTORS ORDER [PENDING COMPLETION] TO IDENTIFY WHERE EACH TYPE OF EDGE TREATMENT IS REQUIRED OR ALLOWED.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ EDGE TREATMENT TYPE AND MATERIAL
- ☐ EDGE TREATMENT WIDTH AND HEIGHT
- ☐ EMBEDMENT KEY DEPTH IF DIFFERENT THAN THE PROVIDED MINIMUMS

EDGE TREATMENTS							SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS					NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6		PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

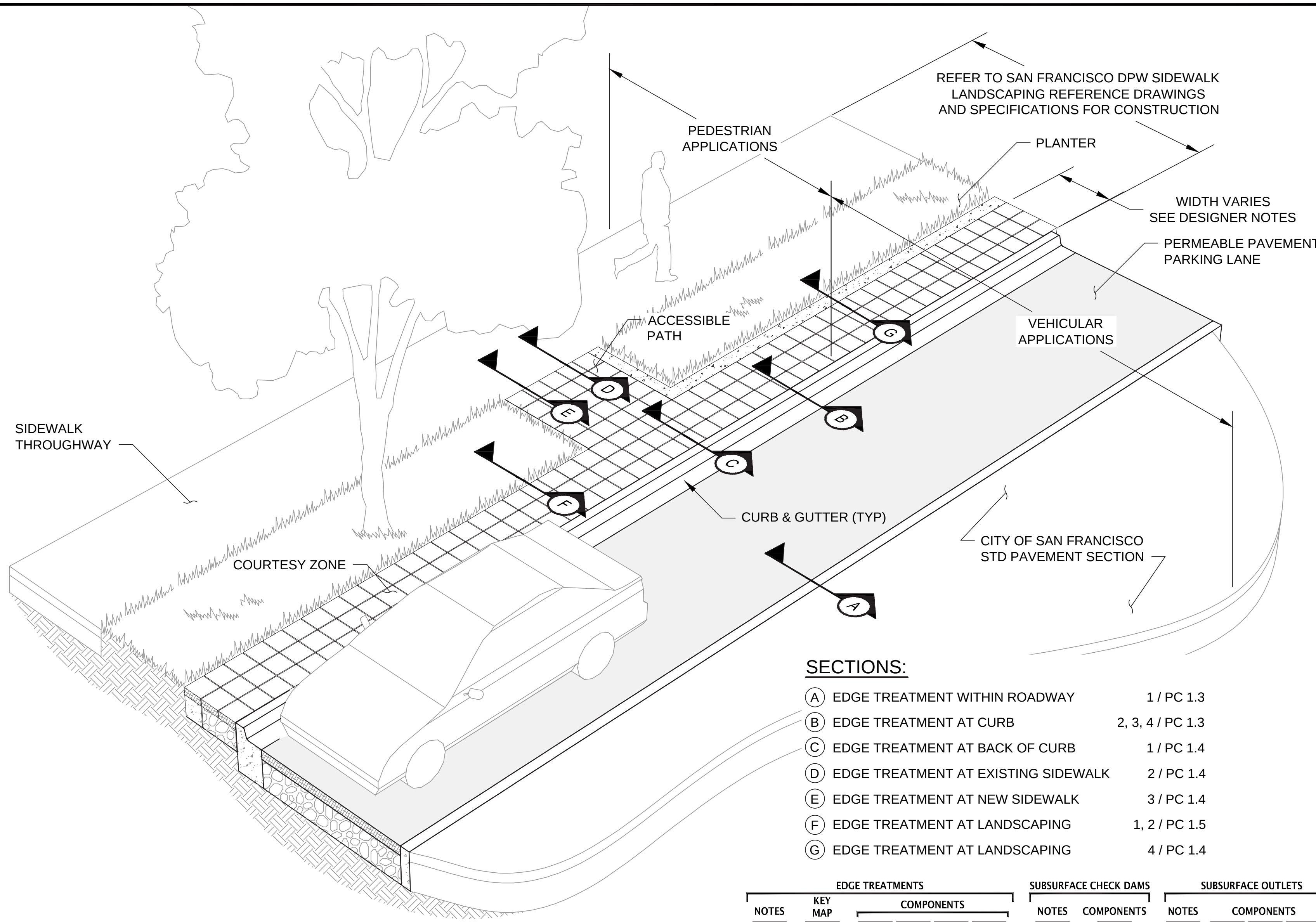
REVISED

PAVEMENT COMPONENTS

EDGE TREATMENT DESIGNER NOTES

DWG NO. PC 1.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



NOT FOR CONSTRUCTION - REFER TO USER GUIDE

SECTIONS:

A	EDGE TREATMENT WITHIN ROADWAY	1 / PC 1.3
B	EDGE TREATMENT AT CURB	2, 3, 4 / PC 1.3
C	EDGE TREATMENT AT BACK OF CURB	1 / PC 1.4
D	EDGE TREATMENT AT EXISTING SIDEWALK	2 / PC 1.4
E	EDGE TREATMENT AT NEW SIDEWALK	3 / PC 1.4
F	EDGE TREATMENT AT LANDSCAPING	1, 2 / PC 1.5
G	EDGE TREATMENT AT LANDSCAPING	4 / PC 1.4

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

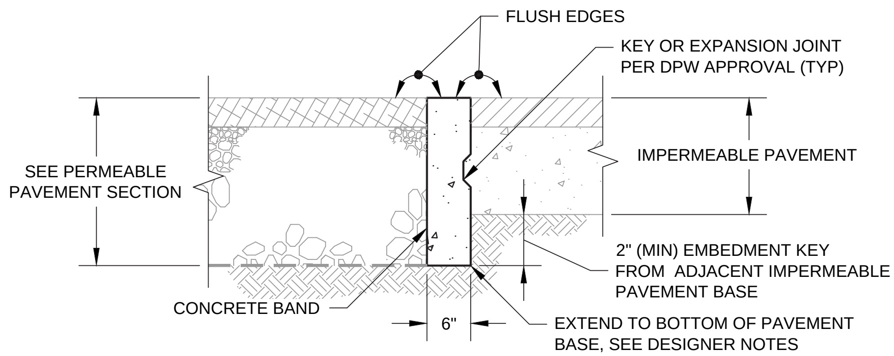
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

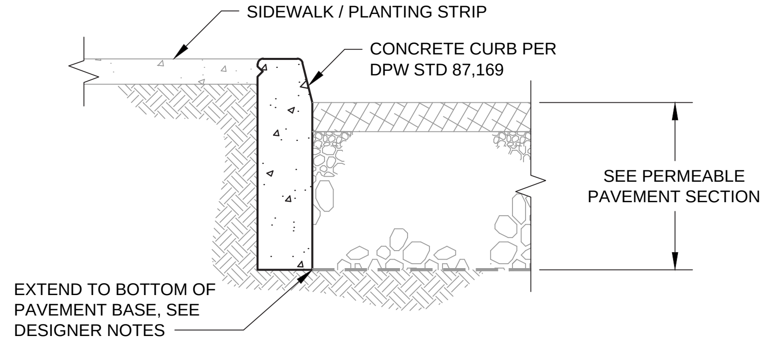
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS
EDGE TREATMENT KEY MAP

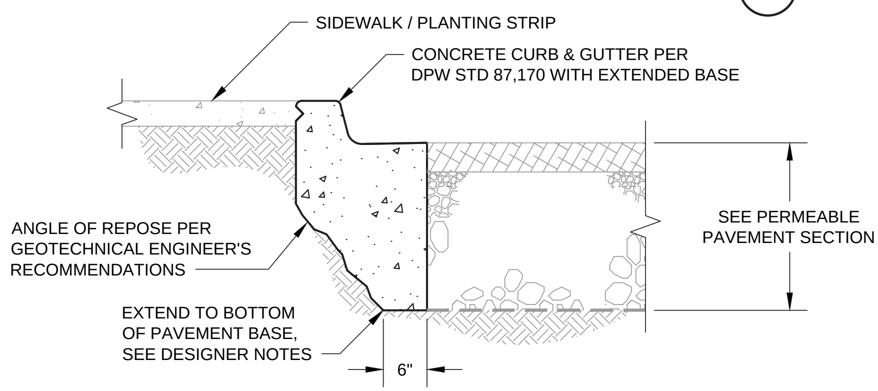
DWG NO. PC 1.2



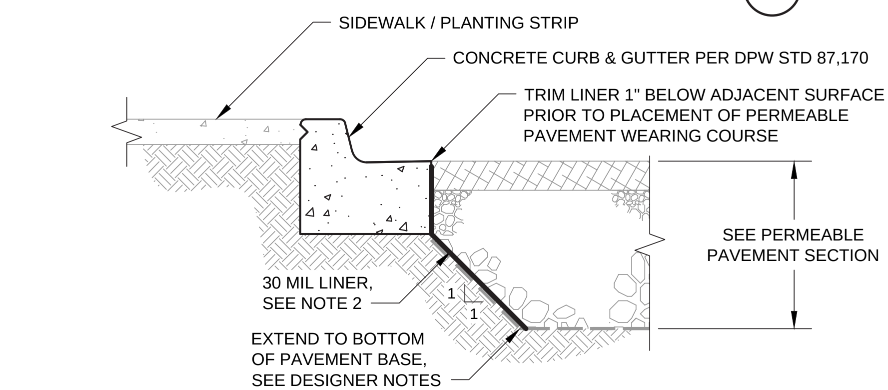
CONCRETE BAND WITHIN PAVED AREA (1)



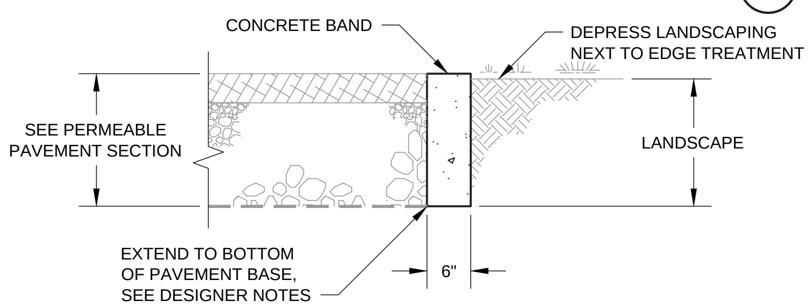
DEEPENED STANDARD CURB (2)



DEEPENED STANDARD CURB AND GUTTER (3)



IMPERMEABLE LINER AT STANDARD CURB AND GUTTER (4)



CONCRETE BAND AT LANDSCAPE (5)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM 17.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

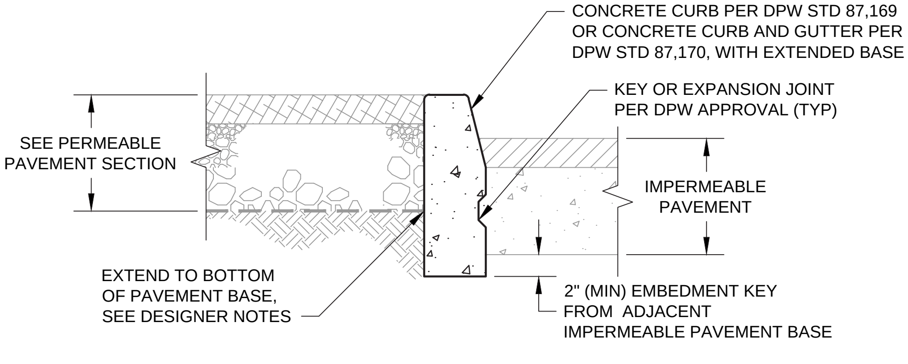
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

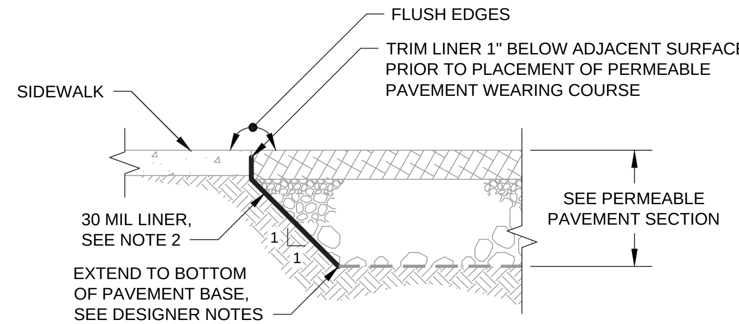
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS
EDGE TREATMENTS
VEHICULAR APPLICATIONS

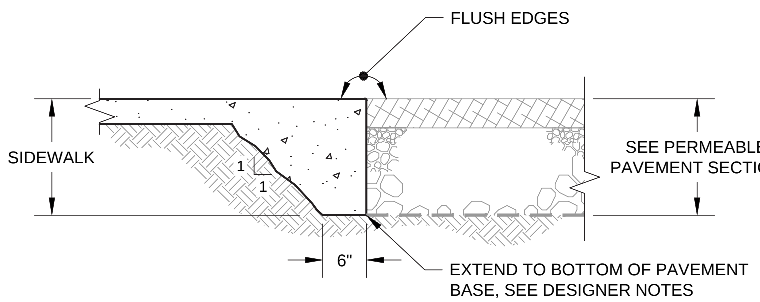
DWG NO. PC 1.3



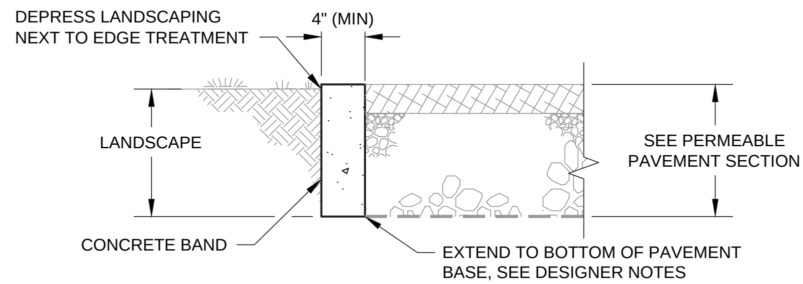
DEEPENED STANDARD CURB / CURB AND GUTTER (1)



IMPERMEABLE LINER AT EXISTING SIDEWALK (2)



THICKENED EDGE AT NEW SIDEWALK (3)



CONCRETE BAND AT LANDSCAPE (4)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM 17.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

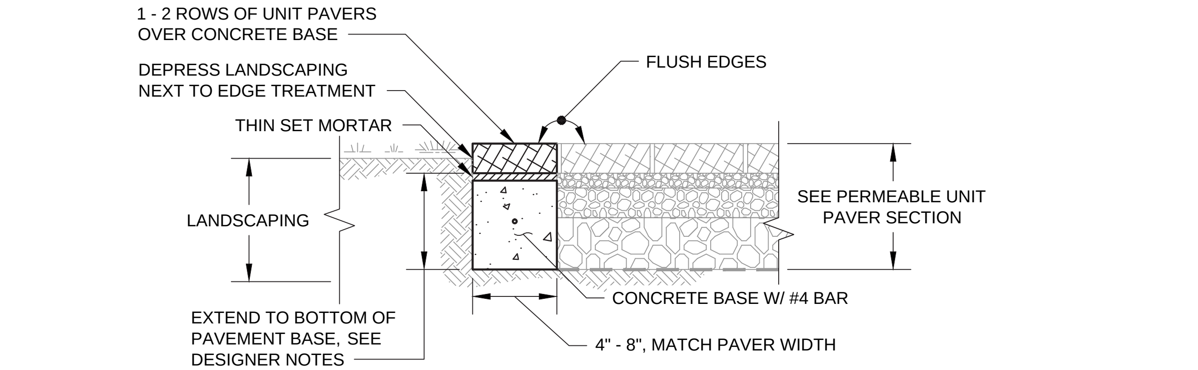
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

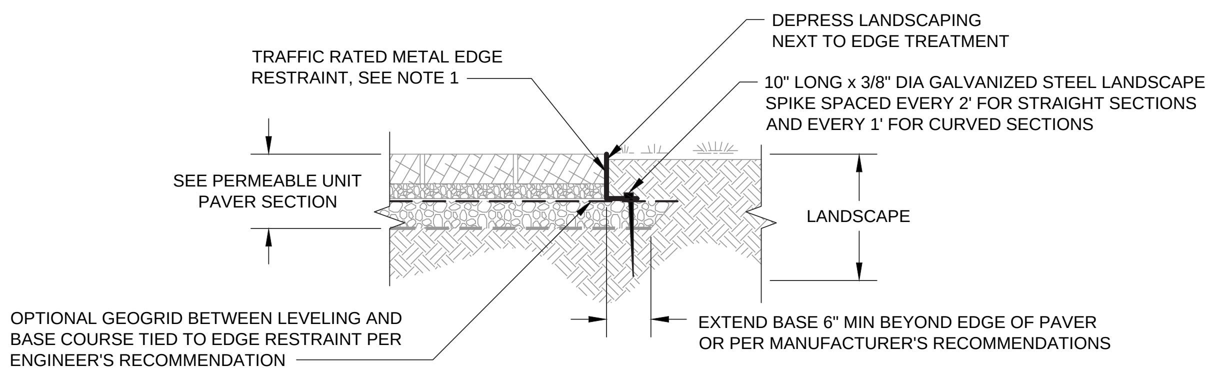
DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

PAVEMENT COMPONENTS
EDGE TREATMENTS
PEDESTRIAN APPLICATIONS (1 OF 2)

DWG NO. **PC 1.4**



MORTARED PAVER AT LANDSCAPING (1)



METAL PAVER EDGE AT LANDSCAPING (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. COORDINATE WITH SAN FRANCISCO PUBLIC WORKS IF STEEL IS REQUIRED IN RIGHT OF WAY.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

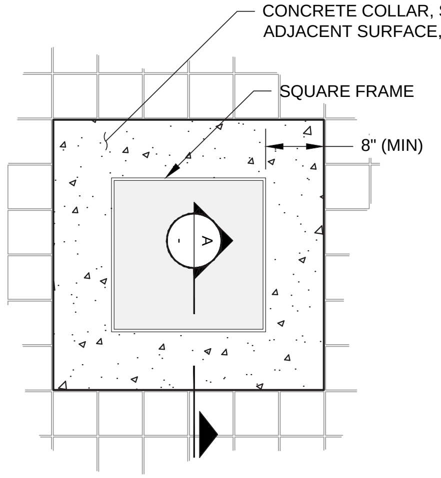
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

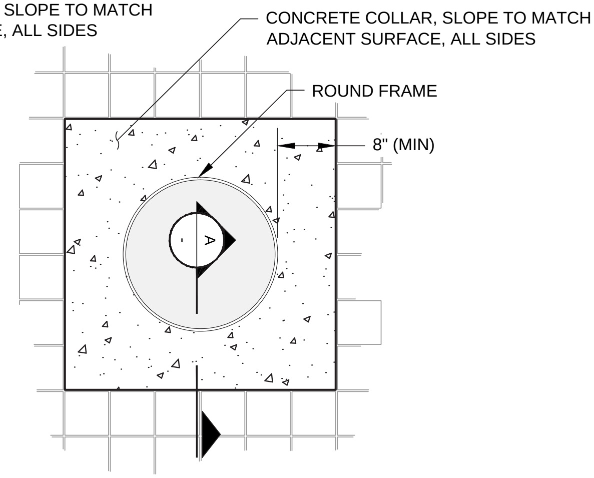
PAVEMENT COMPONENTS

EDGE TREATMENTS
PEDESTRIAN APPLICATIONS (2 OF 2)

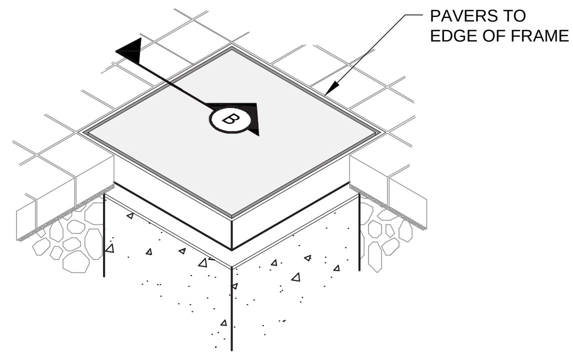
DWG NO. PC 1.5



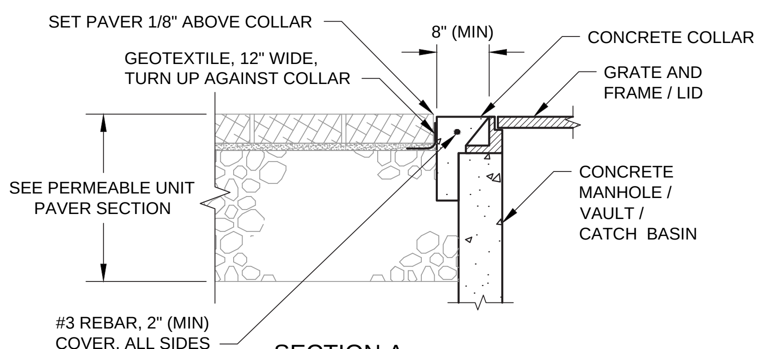
PLAN - SQUARE FRAME



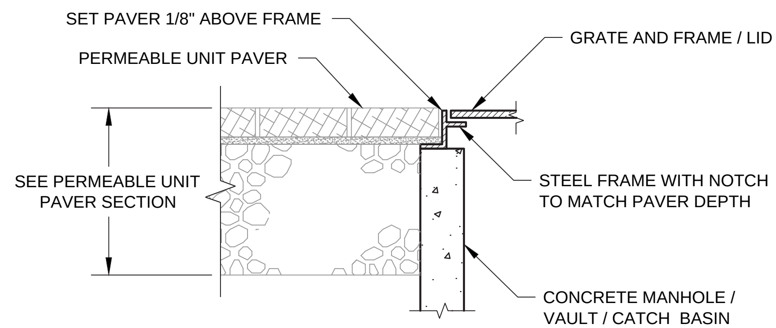
PLAN - ROUND FRAME



ISOMETRIC - SQUARE FRAME



SECTION A



SECTION B

PERMEABLE UNIT PAVER EDGE AT STRUCTURE -
VEHICULAR APPLICATIONS (1)

PERMEABLE UNIT PAVER EDGE AT STRUCTURE -
PEDESTRIAN APPLICATIONS (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS
EDGE TREATMENTS
PAVER AT STRUCTURES

DWG NO. PC 1.6

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

PERMEABLE PAVEMENT FACILITIES MUST BE DESIGNED TO PROVIDE SUBSURFACE STORAGE OF STORMWATER TO ALLOW TIME FOR THE WATER TO INFILTRATE INTO THE UNDERLYING SOIL. SLOPED FACILITIES ON POOR SOILS HAVE AN INCREASED POTENTIAL FOR LATERAL FLOWS THROUGH THE STORAGE RESERVOIR COURSE ALONG THE TOP OF THE RELATIVELY IMPERMEABLE SUBGRADE SOIL. THIS REDUCES THE STORAGE AND INFILTRATION CAPACITY OF THE PAVEMENT SYSTEM. SUBSURFACE DETENTION STRUCTURES, OR CHECK DAMS, CAN BE INCORPORATED INTO THE SUBGRADE AND ALIGNED PERPENDICULAR TO THE LONGITUDINAL SUBGRADE SLOPE TO CREATE PONDING IN THE AGGREGATE STORAGE RESERVOIR COURSE TO DETAIN SUBSURFACE FLOW, INCREASE INFILTRATION, AND REDUCE STRUCTURAL PROBLEMS ASSOCIATED WITH SUBGRADE EROSION ON SLOPES.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. WHILE THE DESIGNER MUST DETERMINE IF CHECK DAMS ARE NECESSARY BASED ON SITE-SPECIFIC CONDITIONS, SOME GENERAL GUIDELINES ARE PROVIDED BELOW:

SUBGRADE SOILS	SUBGRADE SLOPE	RUNON FROM OTHER AREAS	CHECK DAM REQUIRED
TYPE A/B	ANY	ALLOWED	NO
TYPE C/D	≤ 2%	NOT ALLOWED	NO
	≤ 2%	ALLOWED	NO*
	> 2%	ALLOWED	YES

* RECOMMENDED FOR SUBSURFACE FLOW PATHS OVER 50 FEET

3. THE DESIGNER MUST ESTABLISH THE HEIGHT AND SPACING OF THE CHECK DAMS BASED ON THE SUBGRADE SLOPE AND THE STORAGE DEPTH REQUIRED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS. THE AVERAGE DEPTH OF SUBSURFACE STORAGE ACROSS THE FACILITY AREA MUST MEET THE REQUIRED STORAGE DEPTH. REFER TO CHECK DAM SPACING GUIDANCE ON THIS DRAWING FOR CHECK DAM SPACING CALCULATIONS.
4. MAXIMUM CHECK DAM HEIGHT IS GOVERNED BY 48 HOUR DRAWDOWN REQUIREMENT AND NATIVE SOIL INFILTRATION RATE. SEE **PP 1.1** FOR ADDITIONAL GUIDANCE.
5. THE AREA OF SUBBASE COVERED BY IMPERMEABLE CHECK DAM MATERIAL SHOULD BE EXCLUDED FROM HYDROLOGIC PERFORMANCE CALCULATIONS WHEN THE AREA IS SIGNIFICANT (GREATER THAN 10 PERCENT) RELATIVE TO THE PAVEMENT AREA.
6. THE DESIGNER MUST ENSURE THAT THE RESERVOIR COURSE DEPTH IS SUFFICIENT TO ACCOMMODATE THE HEIGHT OF THE CHECK DAMS WITH THE REQUIRED MINIMUM CLEARANCE.
7. CONVEYANCE CALCULATIONS ARE REQUIRED TO EVALUATE THE NEED FOR SUBSURFACE OUTLETS (E.G., PERFORATED OVERFLOW PIPES SET AT THE DESIGN SUBSURFACE PONDING DEPTH) AND DOWNSLOPE OVERFLOW SYSTEM. REFER TO **PC 3.1**.
8. LOCATE CHECK DAMS TO MINIMIZE IMPACT TO UTILITY ACCESS.
9. LOCATE PERVIOUS CONCRETE CONTROL JOINTS AT CHECK DAM LOCATIONS WHEN CHECK DAM EXTENDS INTO THE STRUCTURAL PAVEMENT SECTION.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ CHECK DAM TYPE AND MATERIAL
- ☐ CHECK DAM ELEVATION, HEIGHT, AND WIDTH
- ☐ CHECK DAM SPACING
- ☐ CHECK DAM CLEARANCE (MEASURED FROM BOTTOM OF WEARING COURSE)

CHECK DAM SPACING GUIDANCE:

TYPICAL MAXIMUM SPACING, $L_{SPACING,\ MAX}$ (FEET) :

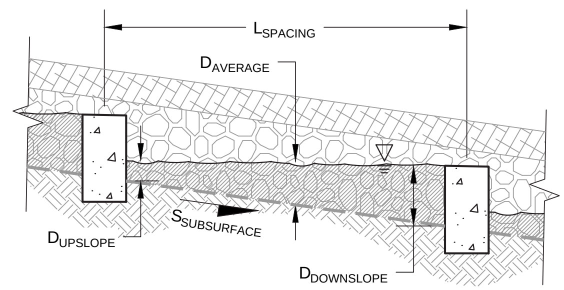
$$L_{SPACING,\ MAX} = D_{DOWNSLOPE} \div S_{SUBSURFACE}$$

$D_{DOWNSLOPE}$ = DOWNSLOPE STORAGE DEPTH (I.E. CHECK DAM HEIGHT) (FEET)
$S_{SUBSURFACE}$ = SUBSURFACE SLOPE (FT/FT)

SPACING, $L_{SPACING}$ (WHEN $L_{SPACING} \leq L_{SPACING,\ MAX}$) :

$$L_{SPACING} = \frac{2\,(D_{AVERAGE} - D_{DOWNSLOPE})}{-\,S_{SUBSURFACE}}$$

$D_{AVERAGE}$ = AVERAGE STORAGE DEPTH (FEET)



EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

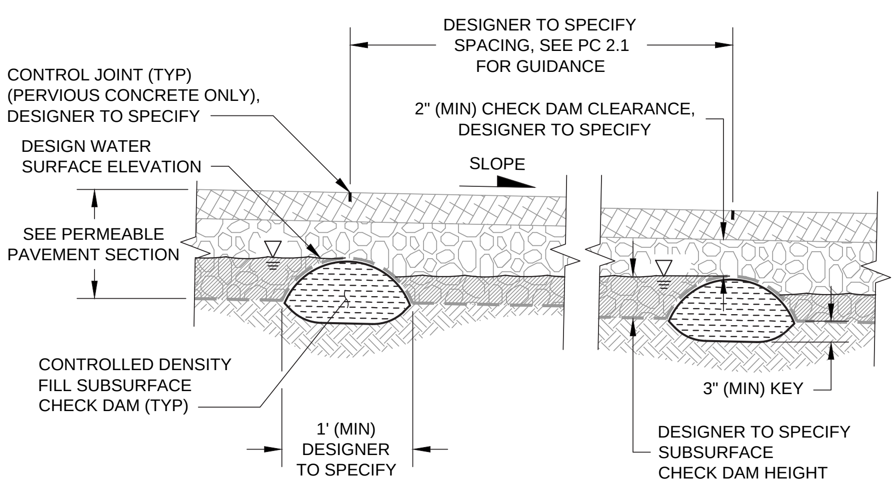
GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

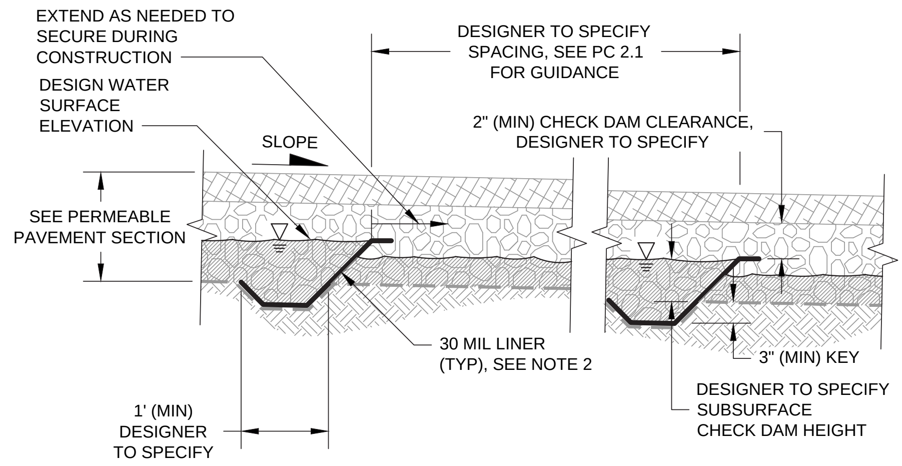
PAVEMENT COMPONENTS
SUBSURFACE CHECK DAMS
DESIGNER NOTES

DWG NO. PC 2.1

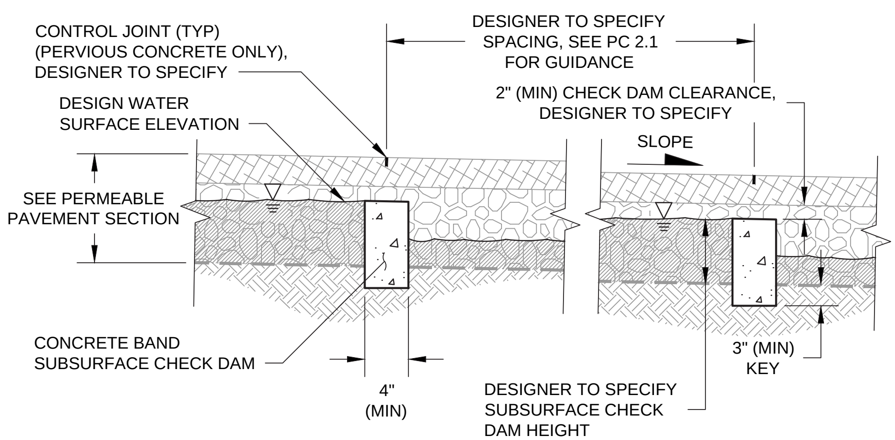
NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONTROLLED DENSITY FILL SUBSURFACE CHECK DAM (1)



IMPERMEABLE LINER SUBSURFACE CHECK DAM (2)



CONCRETE BAND SUBSURFACE CHECK DAM (3)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CHECK DAMS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM 17.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS
SUBSURFACE CHECK DAMS

DWG NO. PC 2.2

PURPOSE:

PERMEABLE PAVEMENT SUBSURFACE OVERFLOWS AND/OR UNDERDRAINS ARE DESIGNED TO CONVEY EXCESS FLOW TO AN APPROVED DISCHARGE POINT. FOR **SUBSURFACE OVERFLOW** CONFIGURATIONS, THE OVERFLOW RISER ELEVATION IS SET AT THE MAXIMUM DESIGN PONDING DEPTH IN THE PAVEMENT BASE. FOR **SUBSURFACE UNDERDRAIN** CONFIGURATIONS, THE CHECK DAM IS SET AT THE MAXIMUM DESIGN PONDING DEPTH IN THE PAVEMENT BASE, AND THE UNDERDRAIN IS LOCATED IN AN UNDERDRAIN TRENCH. WATER BELOW THE OVERFLOW RISER OR CHECK DAM ELEVATION IS TEMPORARILY STORED AND INFILTRATED INTO THE UNDERLYING SUBGRADE. UNDERDRAINS ARE ONLY RECOMMENDED WHEN AN AVAILABLE DAYLIGHT CONDITION EXISTS.

DESIGNER NOTES & GUIDELINES:

1. DESIGNERS MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. OVERFLOW / UNDERDRAIN PIPES MUST BE LOCATED AT AN ELEVATION HIGHER THAN THE SEWER HYDRAULIC GRADE LINE TO PREVENT BACK FLOW INTO THE PAVEMENT SECTION.
3. OVERFLOW IS TYPICALLY PROVIDED BY A SUBSURFACE SLOTTED OVERFLOW PIPE(S) WITH DOWNSTREAM OUTLET CONTROL OR UPSTREAM CHECK DAMS SET AT THE DESIGN PONDING ELEVATION.
4. EMERGENCY OVERFLOW FOR LARGE STORM EVENTS CAN BE PROVIDED BY SURFACE SHEET FLOW UPON INUNDATION OF THE PAVEMENT SECTION (REQUIRES SURFACE CONVEYANCE SYSTEM OR OTHER RUNOFF COLLECTION METHOD).
5. THE DESIGNER MUST CONSIDER THE FLOW PATH OF WATER WHEN THE PERMEABLE PAVEMENT SECTION IS FULLY SATURATED TO THE MAXIMUM DESIGN DEPTH TO CONFIRM THERE ARE NO UNANTICIPATED DISCHARGE LOCATIONS (E.G., INTERSECTING UTILITY TRENCHES) AND TO ENSURE THE DESIGN PROVIDES EMERGENCY OVERFLOW CONVEYANCE TO AN APPROVED DISCHARGE POINT.
6. CONVEYANCE CALCULATIONS ARE REQUIRED TO DESIGN THE OVERFLOW / UNDERDRAIN PIPE DIAMETER AND PIPE SPACING TO SATISFY SAN FRANCISCO DPW HYDRAULIC REQUIREMENTS.
7. IF SITE CONSTRAINTS NECESSITATE USE OF OVERFLOW PIPE IN AN AREA SUBJECT TO VEHICULAR TRAFFIC OR OTHER LOADING, APPROPRIATE COVER DEPTH AND PIPE MATERIAL MUST BE DESIGNED.
8. WEARING COURSE MAY BE USED TO FULFILL MINIMUM COVER REQUIREMENTS PROVIDED WEARING COURSE IS RIGID PAVEMENT.
9. OPTIONAL OBSERVATION PORTS CAN BE USED TO DETERMINE WHETHER AN OVERFLOW / UNDERDRAIN IS DEWATERING PROPERLY. REFER TO **GC 3.1- GC 3.3**.
10. OVERFLOW / UNDERDRAIN PIPES MUST BE EQUIPPED WITH CLEANOUTS. REFER TO **GC 5.2**.
11. INSTALL OVERFLOW PIPES AT DOWNGRADIENT END OF PAVEMENT. OVERFLOWS NOT REQUIRED AT EACH CHECK DAM LOCATIONS.
12. PIPE MATERIAL SHALL BE DESIGNED PER SAN FRANCISCO ENVIRONMENTAL CODE (CHAPTER 5, SECTION 509 AND CHAPTER 7, SECTION 706).
13. AN OUTLET ORIFICE CONTROL DEVISE MAY BE INSTALLED TO FURTHER DETAIN OUTFLOW AND MAXIMIZE INFILTRATION. ENGINEER SHALL DESIGN, DETAIL, SPECIFY, AND CONDUCT SUPPLEMENTAL PERFORMANCE CALCULATIONS AS NEEDED.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ OVERFLOW / UNDERDRAIN PIPE MATERIAL, DIAMETER, AND COVER DEPTH
- ☐ OVERFLOW / UNDERDRAIN PIPE INVERT ELEVATION AND SLOPE
- ☐ OVERFLOW / UNDERDRAIN PIPE ALIGNMENT AND DISCHARGE LOCATION

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

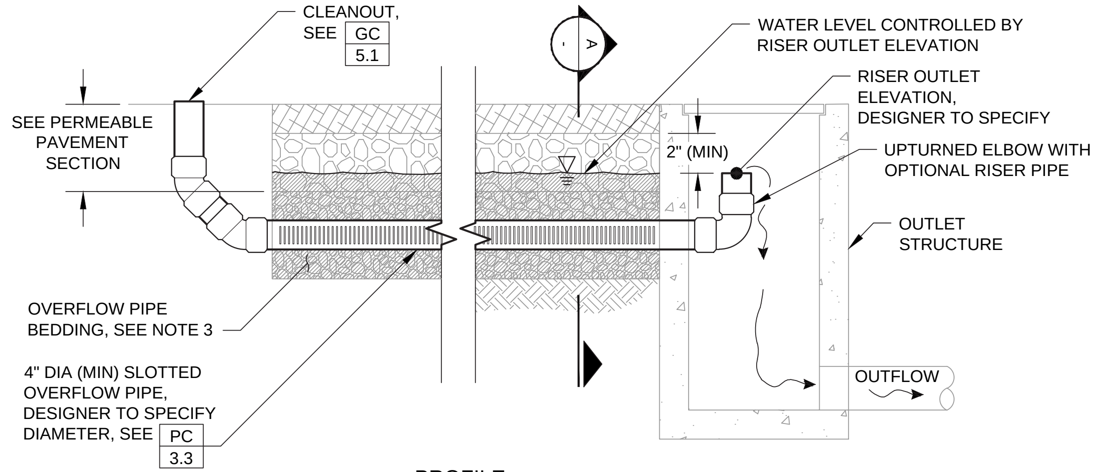
GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS
SUBSURFACE OVERFLOWS
DESIGNER NOTES

DWG NO. PC 3.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

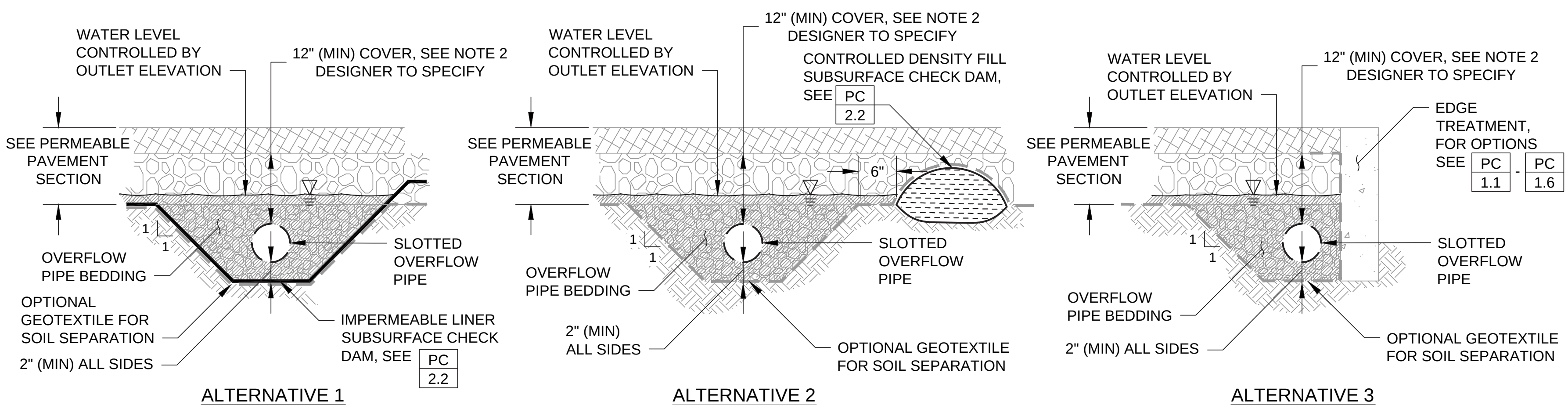


PROFILE

OVERFLOW CONTROL STRUCTURE WITH RISER (1)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LOCATE OVERFLOW PIPE BELOW STRUCTURAL PAVEMENT BASE DEPTH.
3. OVERFLOW PIPE BEDDING SHALL BE ASTM NO. 57 CONFORMING TO THE REQUIREMENTS OF GRAVEL BASE MATERIAL FOR PAVEMENTS, UNLESS OTHERWISE SPECIFIED.



OVERFLOW PIPE TRENCH SECTION (A)

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

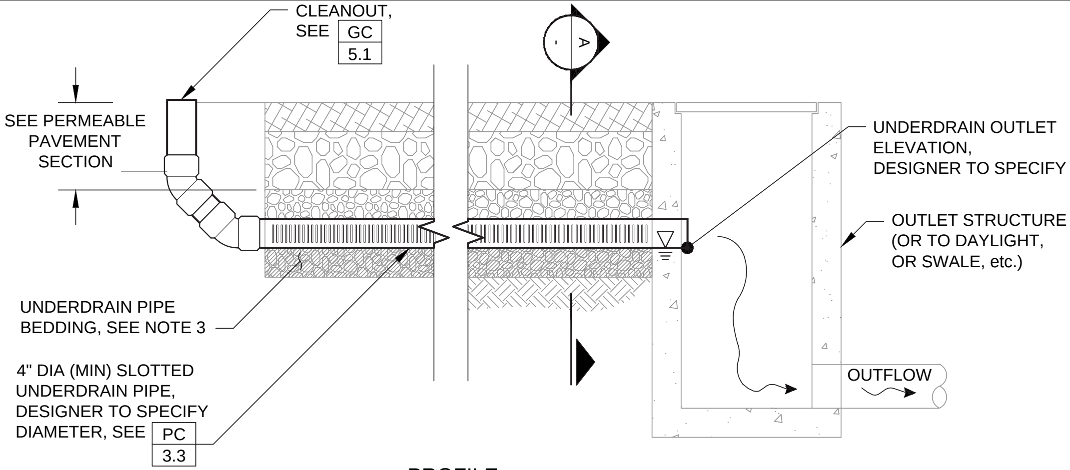
VERSION 2.0

REVISED

PAVEMENT COMPONENTS

SUBSURFACE OVERFLOW

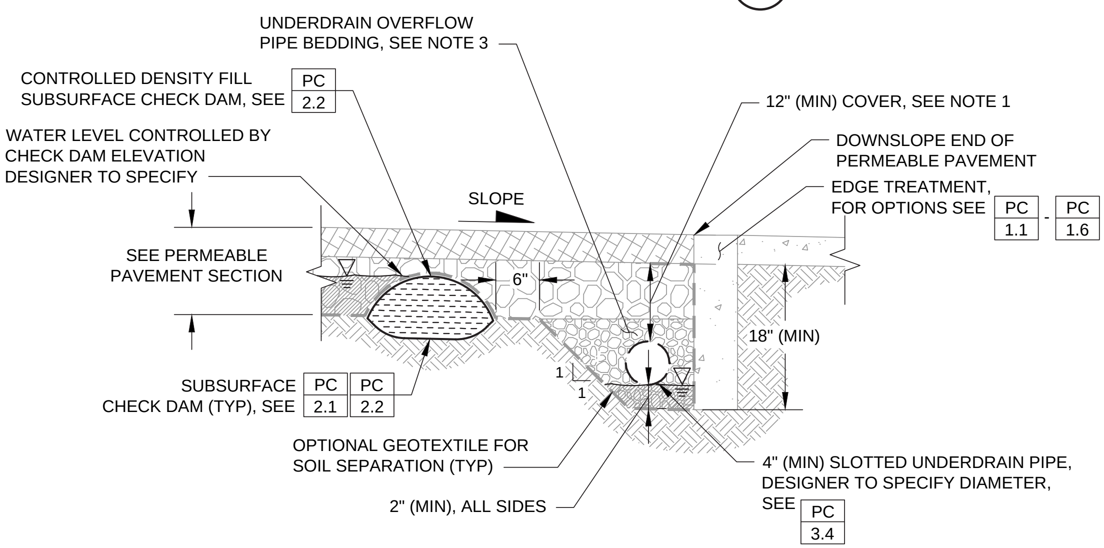
DWG NO. PC 3.2



UNDERDRAIN TO DAYLIGHT 1

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LOCATE UNDERDRAIN PIPE BELOW STRUCTURAL PAVEMENT BASE DEPTH.
3. UNDERDRAIN PIPE BEDDING SHALL BE ASTM NO. 57 CONFORMING TO THE REQUIREMENTS OF GRAVEL BASE MATERIAL FOR PAVEMENTS, UNLESS OTHERWISE SPECIFIED.



CHECK DAM-CONTROLLED WITH UNDERDRAIN A

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

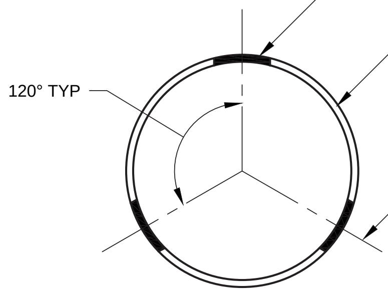
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

PAVEMENT COMPONENTS

SUBSURFACE UNDERDRAIN

DWG NO. PC 3.3



SLOTTED UNDERDRAIN PIPE (2)

CONSTRUCTION NOTES:

1. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE MATERIAL PER ENGINEERS SPECIFICATION. SINGLE WALL AND DUAL WALL CORRUGATED HDPE PIPE (AASHTO M252 AND M294 TYPES C, S, AND D) ARE NOT ACCEPTABLE.
2. ALL PERFORATIONS SHALL BE SLOTTED TYPE, MEASURING 0.032 INCH WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDING A MINIMUM INLET AREA OF 5.0 SQUARE INCH PER LINEAR FOOT OF PIPE.
3. PERFORATIONS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.

EDGE TREATMENTS						SUBSURFACE CHECK DAMS		SUBSURFACE OUTLETS			
NOTES	KEY MAP	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS		
PC 1.1	PC 1.2	PC 1.3	PC 1.4	PC 1.5	PC 1.6	PC 2.1	PC 2.2	PC 3.1	PC 3.2	PC 3.3	PC 3.4

San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	PAVEMENT COMPONENTS UNDERDRAIN PIPE	DWG NO. PC 3.4

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

BIORETENTION PLANTERS CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF BY PROVIDING SURFACE, SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS ALSO TREATED AS IT FILTERS THROUGH THE BIORETENTION SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. PLANTER AREA, PONDING DEPTH, BIORETENTION SOIL DEPTH, AND AGGREGATE STORAGE DEPTH MUST BE SIZED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS.
3. PONDING AND BIORETENTION SOIL DRAWDOWN TIME (I.E., TIME FOR MAXIMUM SURFACE PONDING TO DRAIN THROUGH THE BIORETENTION SOIL AFTER THE END OF A STORM) RECOMMENDATIONS:
   - 3 - 12 HOUR PONDING AND BIORETENTION SOIL DRAWDOWN (TYPICAL)
   - 24 HOUR MAXIMUM PONDING AND BIORETENTION SOIL DRAWDOWN
4. FACILITY DRAWDOWN TIME (i.e., TIME FOR SURFACE PONDING TO DRAIN THROUGH THE ENTIRE SECTION INCLUDING AGGREGATE STORAGE AFTER THE END OF A STORM) REQUIREMENTS:
   - 48 HOUR MAXIMUM FACILITY DRAWDOWN (i.e. ORIFICE CONTROLLED SYSTEM OR EXTENDED STORAGE DEPTH WITHIN INFILTRATION SYSTEM)
5. AN AGGREGATE COURSE IS REQUIRED UNDER THE BIORETENTION SOIL FOR BIORETENTION IN SEPARATE SEWER SYSTEM AREAS TO PROVIDE ADDITIONAL TREATMENT. THIS AGGREGATE COURSE IS OPTIONAL FOR FACILITIES IN COMBINED SEWER SYSTEM AREAS. SEE GUIDANCE ON **BC 4.1**.
6. THE PLANTER WALL SLOPE IS TYPICALLY DESIGNED TO MATCH THE LONGITUDINAL SLOPE OF THE ADJACENT ROADWAY/SIDEWALK. THE FACILITY SUBGRADE, HOWEVER, SHOULD BE FLAT. CHECK DAMS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO **BC 6.1** AND **BC 6.2** FOR GUIDANCE ON CHECK DAM DESIGN.
7. DEPENDING ON THE HEIGHT OF THE PROPOSED PLANTER WALL, ADDITIONAL STRUCTURAL CONSIDERATIONS MAY BE REQUIRED TO ADDRESS WALL LOADING. REFER TO **BC 1.1** THROUGH **BC 1.7** FOR GUIDANCE ON EDGE TREATMENTS.
8. WHEN FACILITY CONSTRUCTION IMPACTS EXISTING SIDEWALK, ALL SAW CUTS MUST ADHERE TO SFPUC REQUIREMENTS. SAW CUTS SHOULD BE ALONG SCORE LINES AND ANY DISTURBED SIDEWALK FLAGS SHOULD BE REPLACED IN THEIR ENTIRETY.
9. PLANTERS IN PUBLIC RIGHT OF WAY SHALL BE DESIGNED WITH EMERGENCY OVERFLOW TO THE STREET IN THE EVENT THE PLANTER OUTLET IS OBSTRUCTED OR CLOGGED.
10. UP TO TWO PLANTERS MAY BE CONNECTED IN SERIES, IN LIEU OF MULTIPLE INLETS, PROVIDED THE CONNECTION IS A TRENCH DRAIN OR EQUAL SURFACE CONVEYANCE AND IS ADEQUATELY SIZED TO CONVEY FLOWS.
11. PLANTER VEGETATION MUST BE SPECIFIED BY DESIGN PROFESSIONAL PER SFPUC VEGETATION PALLET
12. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. REFER TO **GC 2.1** - **GC 2.12** FOR UTILITY CROSSING DETAILS AND **GC 1.4** - **GC 4.4** FOR UTILITY CROSSING CONFLICT DETAILS.
13. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS.

RELATED COMPONENTS	
EDGE TREATMENTS:	BC 1.1 - BC 1.7
INLETS:	BC 2.1 - BC 2.4
OUTLETS:	BC 3.1 - BC 3.4
AGGREGATE STORAGE:	BC 4.1
UNDERDRAINS:	BC 5.1 - BC 5.2
CHECK DAMS:	BC 6.1 - BC 6.2
LINERS:	GC 1.1 GC 1.2
UTILITY CROSSINGS:	GC 2.1 - GC 2.12
OBSERVATION PORTS:	GC 3.1 GC 3.3
UTILITY CONFLICTS:	GC 4.1 - GC 4.4
CLEANOUTS:	GC 5.2

RELATED SPECIFICATIONS	CSI NO.
BIORETENTION: - BIORETENTION SOIL MIX - AGGREGATE STORAGE - MULCH - STREAMBED COBBLES	33 47 27

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

BIORETENTION PLANTER

DESIGNER NOTES (1 OF 2)

DWG NO. BP 1.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

LAYOUT REQUIREMENTS:

1. REFER TO THE SAN FRANCISCO STANDARD ACCESSIBILITY REQUIREMENTS IN THE SAN FRANCISCO PUBLIC WORKS SIDEWALK LANDSCAPING REFERENCE DRAWINGS AND SPECIFICATIONS FOR COURTESY STRIP, THROUGHWAY, PARKING SPACE AND ACCESSIBLE PATH REQUIREMENTS.
2. LOCATE CURB CUTS AND GUTTER MODIFICATIONS TO AVOID CONFLICTS WITH ACCESSIBILITY REQUIREMENTS (E.G., LOCATE OUTSIDE OF CROSSWALKS).

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PLANTER WIDTH AND LENGTH
- ☐ DEPTH OF PONDING
- ☐ DEPTH OF FREEBOARD
- ☐ DEPTH OF BIORETENTION SOIL
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE, IF ANY
- ☐ PLANTER SURFACE ELEVATION (TOP OF BIORETENTION SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY
- ☐ CONTROL POINTS AT EVERY PLANTER WALL CORNER AND POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CHECK DAM, PLANTER WALL CORNER, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF PLANTER COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS)

SOIL TYPE GUIDANCE:

HYDROLOGIC SOIL GROUP	SOIL TYPE	CORRESPONDING UNIFIED SOIL CLASSIFICATION	DESCRIPTION
A	SAND, LOAMY SAND, OR SANDY LOAM	GW - WELL-GRADED GRAVELS, SANDY GRAVELS GP - GAP-GRADED OR UNIFORM GRAVELS, SANDY GRAVELS GM - SILTY GRAVELS, SILTY SANDY GRAVELS SW - WELL-GRADED, GRAVELLY SANDS SP - GAP-GRADED OR UNIFORM SANDS, GRAVELLY SANDS	LOW RUNOFF POTENTIAL. SOILS HAVING HIGH INFILTRATION RATES EVEN WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF DEEP, WELL TO EXCESSIVELY DRAINED SANDS OR GRAVELS.
B	SILT LOAM OR LOAM	SM - SILTY SANDS, SILTY GRAVELLY SANDS MH - MICACEOUS SILTS, DIATOMACEOUS SILTS, VOLCANIC ASH	SOILS HAVING MODERATE INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF MODERATELY DEEP TO DEEP, MODERATELY WELL TO WELL-DRAINED SOILS WITH MODERATELY FINE TO MODERATELY COARSE TEXTURES.
C	SANDY CLAY LOAM	ML - SILTS, VERY FINE SANDS, SILTY AND CLAYEY FINE SANDS	SOILS HAVING SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF SOILS WITH A LAYER THAT IMPEDES DOWNWARD MOVEMENT OF WATER, OR SOILS WITH MODERATELY FINE TO FINE TEXTURES.
D	CLAY LOAM, SANDY CLAY, SILTY CLAY, OR CLAY	GC - CLAYEY GRAVELS, CLAYEY SANDY GRAVELS SC - CLAYEY SANDS, CLAYEY GRAVELLY SANDS CL - LOW PLASTICITY CLAYS, SANDY OR SILTY CLAYS OL - ORGANIC SILTS AND CLAYS OF LOW PLASTICITY CH - HIGHLY PLASTIC LAYS AND SANDY CLAYS OH - ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY	HIGH RUNOFF POTENTIAL. SOILS HAVING VERY SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF CLAY SOILS WITH A HIGH SWELLING POTENTIAL, SOILS WITH A PERMANENT HIGH WATER TABLE, AND SHALLOW SOILS OVER NEARLY IMPERVIOUS MATERIAL.

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

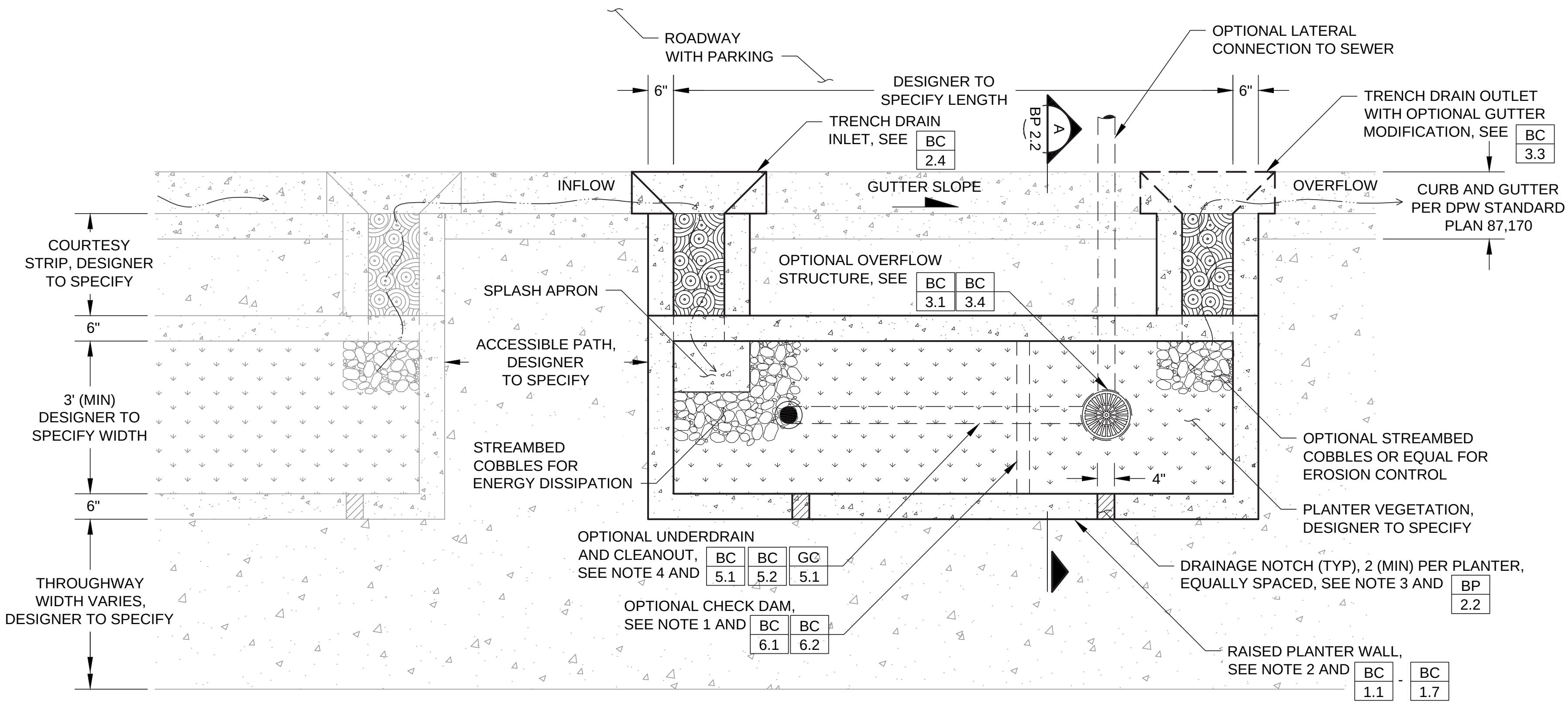
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER
DESIGNER NOTES (2 OF 2)

DWG NO. BP 1.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

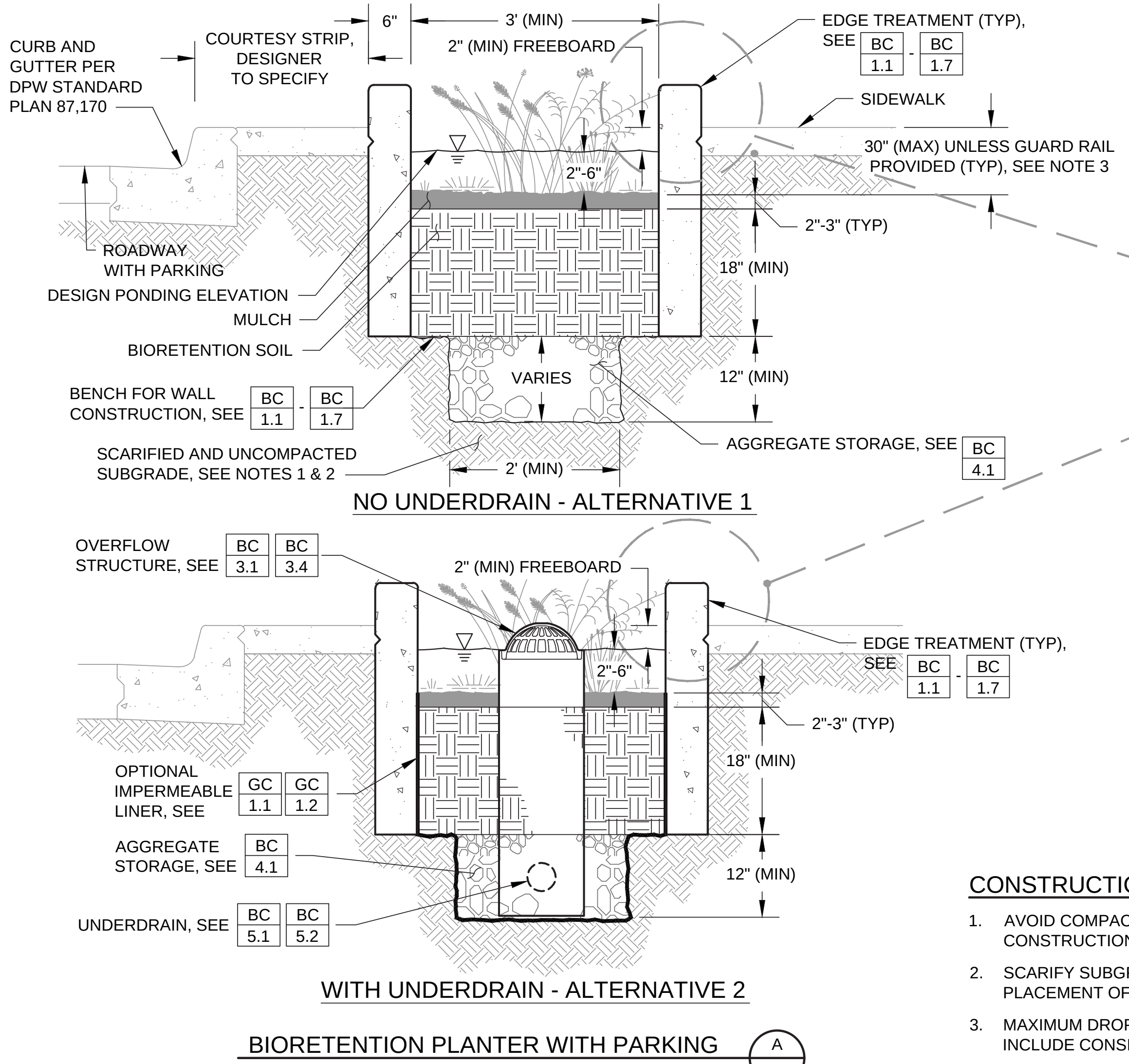
BIORETENTION PLANTER

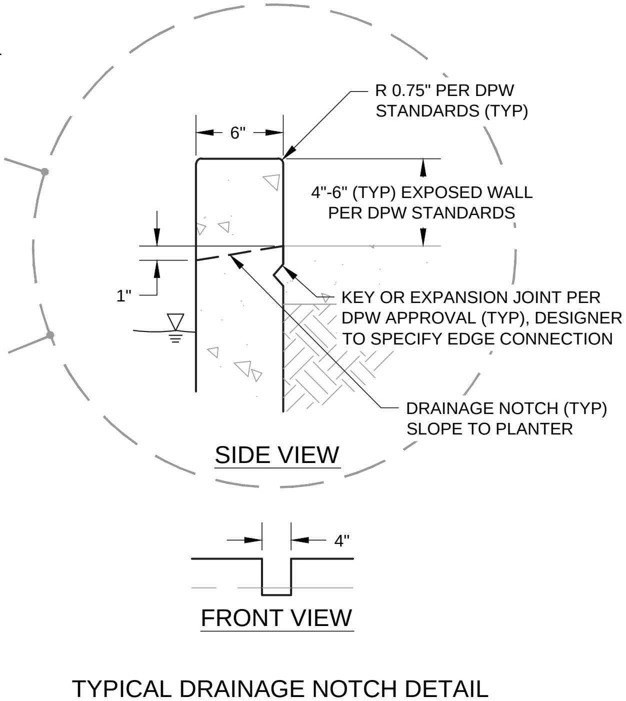
ROADSIDE PLANTER WITH PARKING

PLAN

DWG NO. BP 2.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE





CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER DURING CONSTRUCTION.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIAL.
3. MAXIMUM DROP FROM TOP OF CURB TO TOP OF BIORETENTION SOIL SHALL INCLUDE CONSIDERATIONS FOR BIORETENTION SOIL SETTLEMENT.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

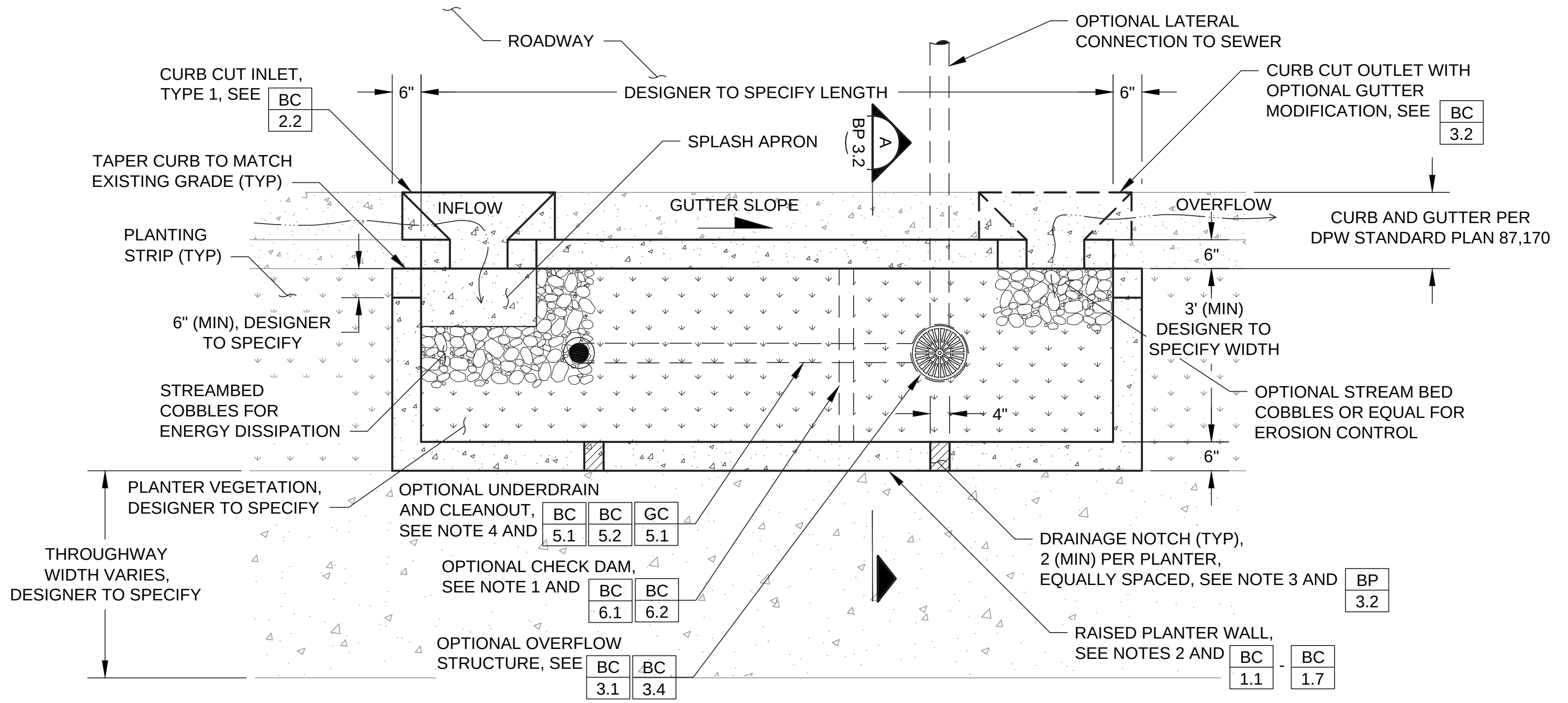
BIORETENTION PLANTER

ROADSIDE PLANTER WITH PARKING

SECTIONS

DWG NO. BP 2.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

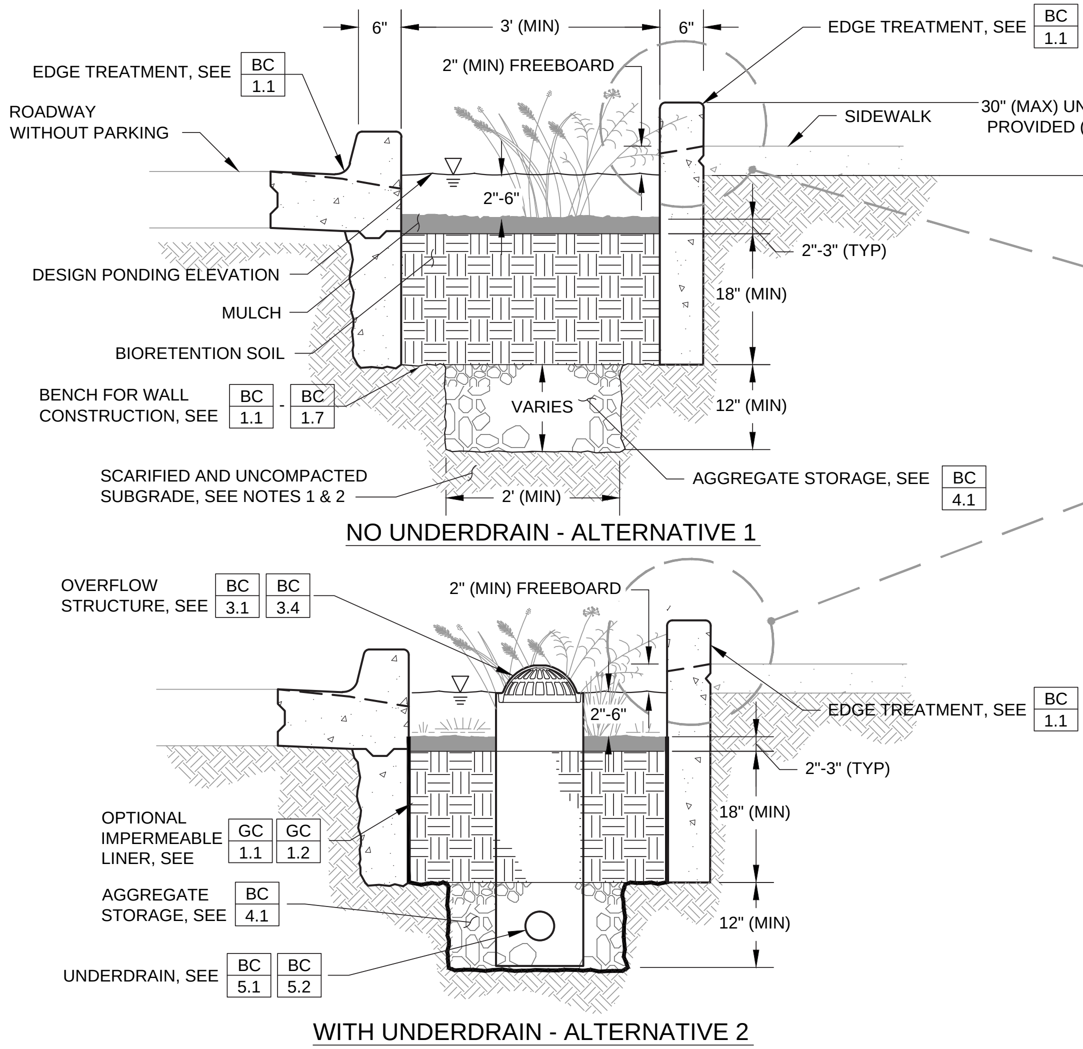


CONSTRUCTION NOTES:

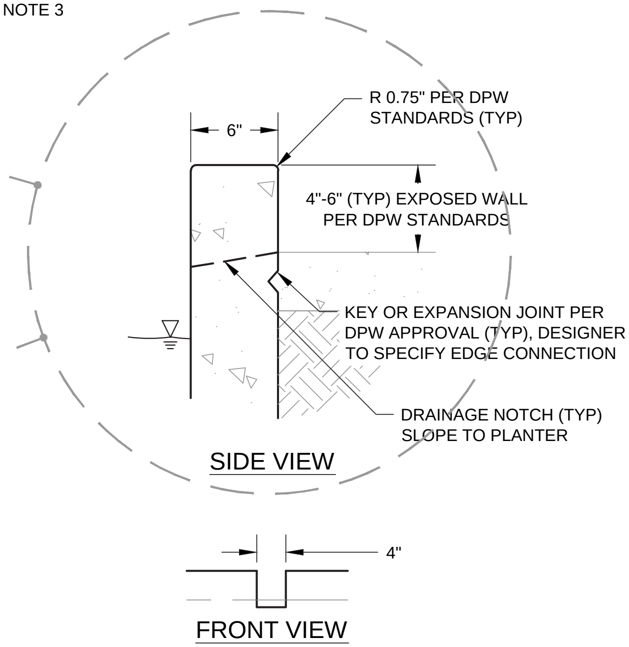
1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	BIORETENTION PLANTER ROADSIDE PLANTER WITHOUT PARKING PLAN	DWG NO. BP 3.1



BIORETENTION PLANTER WITHOUT PARKING (A)



TYPICAL DRAINAGE NOTCH DETAIL

CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER DURING CONSTRUCTION.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIAL.
3. MAXIMUM DROP FROM TOP OF CURB TO TOP OF BIORETENTION SOIL SHALL INCLUDE CONSIDERATIONS FOR BIORETENTION SOIL SETTLEMENT.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

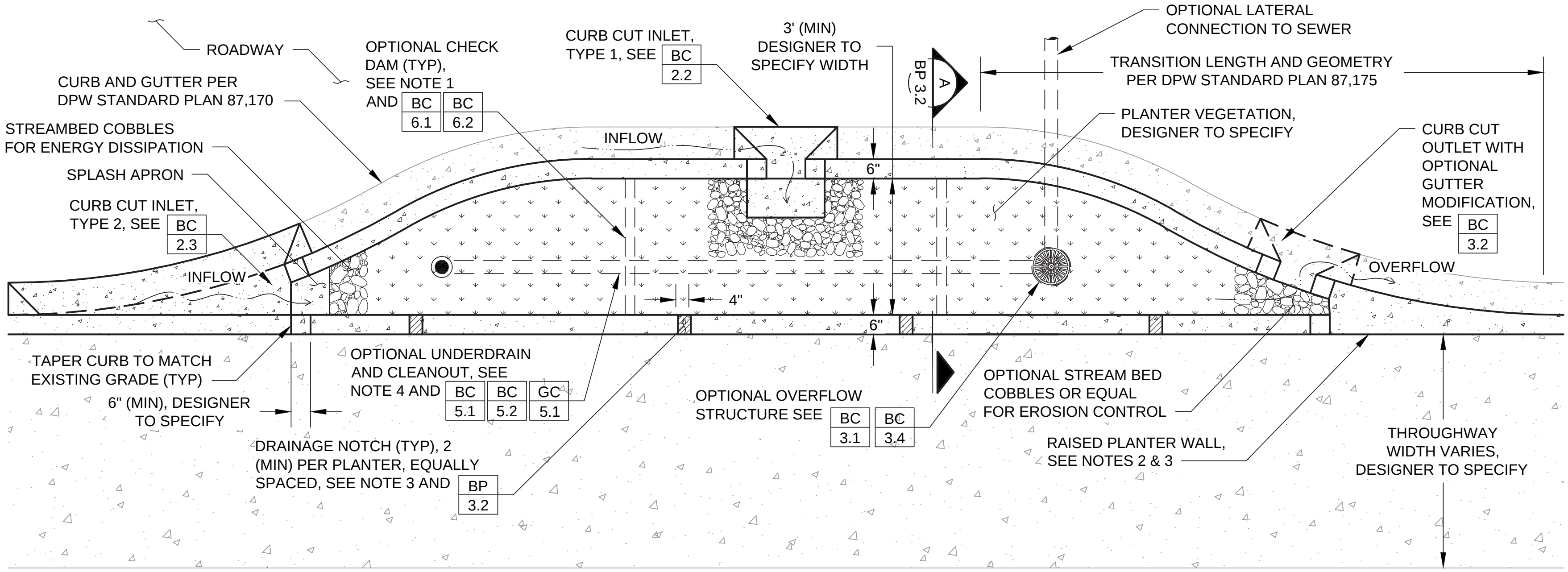
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER

ROADSIDE PLANTER WITHOUT PARKING SECTIONS

DWG NO. BP 3.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

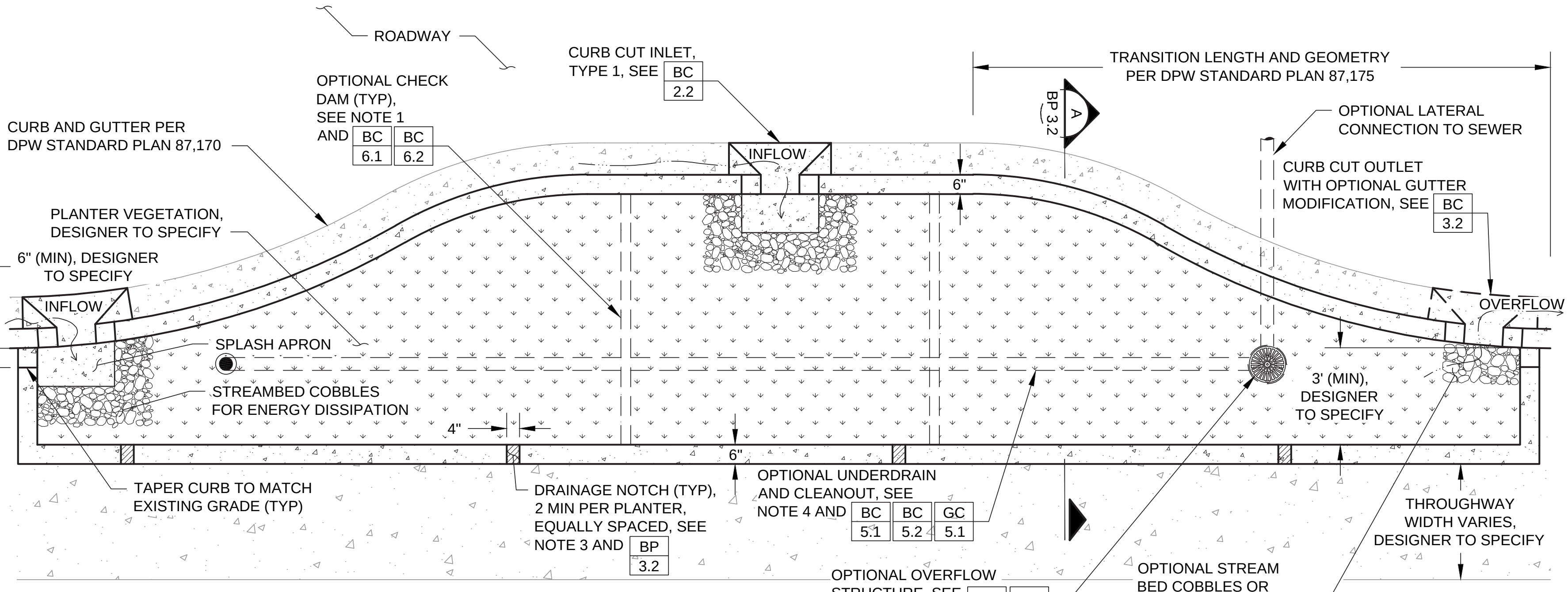
REVISED

BIORETENTION PLANTER

ROADSIDE BULBOUT PLANTER ALTERNATIVE 1

DWG NO. BP 4.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

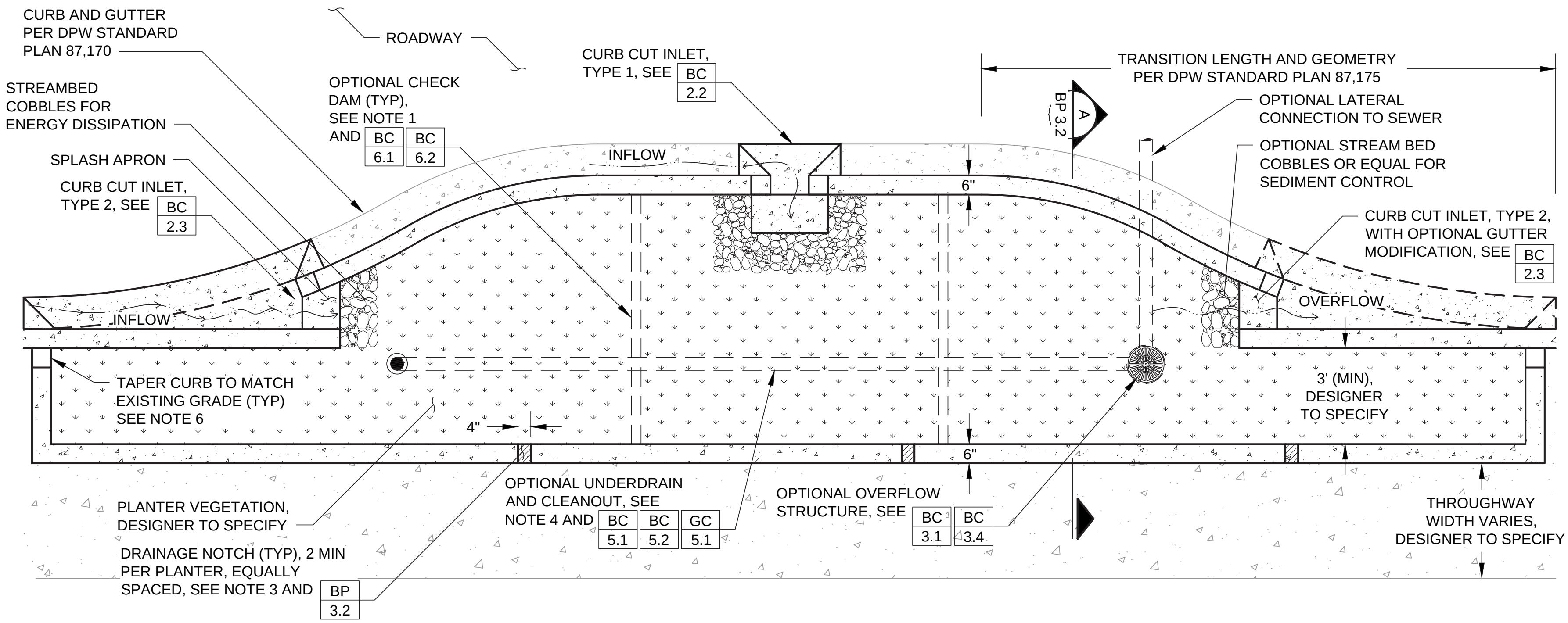
REVISED

BIORETENTION PLANTER

ROADSIDE BULBOUT PLANTER ALTERNATIVE 2

DWG NO. BP 4.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
6. IF STREET PARKING IS ALLOWED IMMEDIATELY ADJACENT TO THE CURB CUT INLET/OUTLET, THE PLANTER WALL TAPER SHOULD BE LOCATED 18" BEHIND THE FACE OF CURB. COORDINATE WITH SAN FRANCISCO PUBLIC WORKS

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

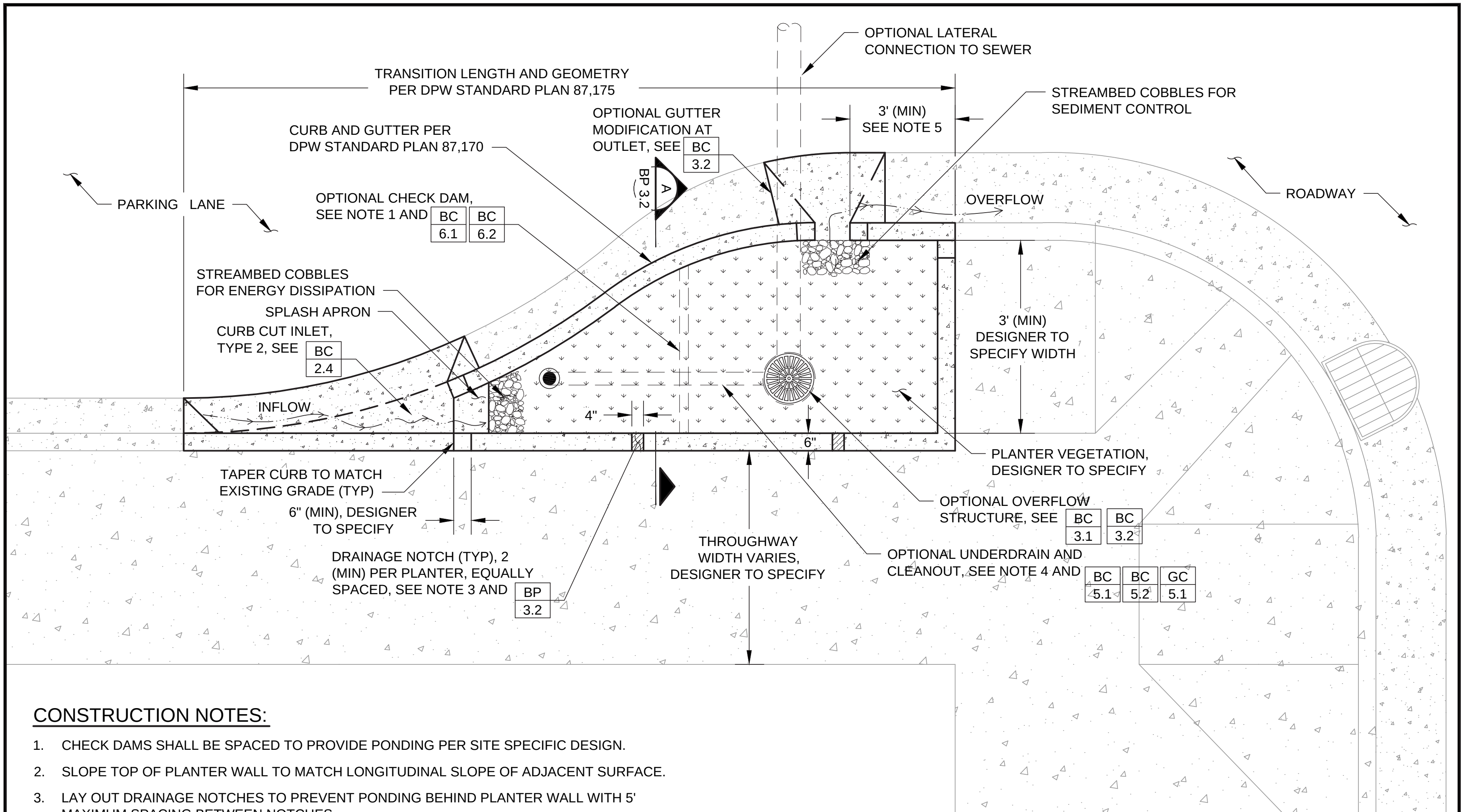
VERSION 2.0

REVISED

BIORETENTION PLANTER

ROADSIDE BULBOUT PLANTER
ALTERNATIVE 3

DWG NO. BP 4.3



NOT FOR CONSTRUCTION - REFER TO USER GUIDE

CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

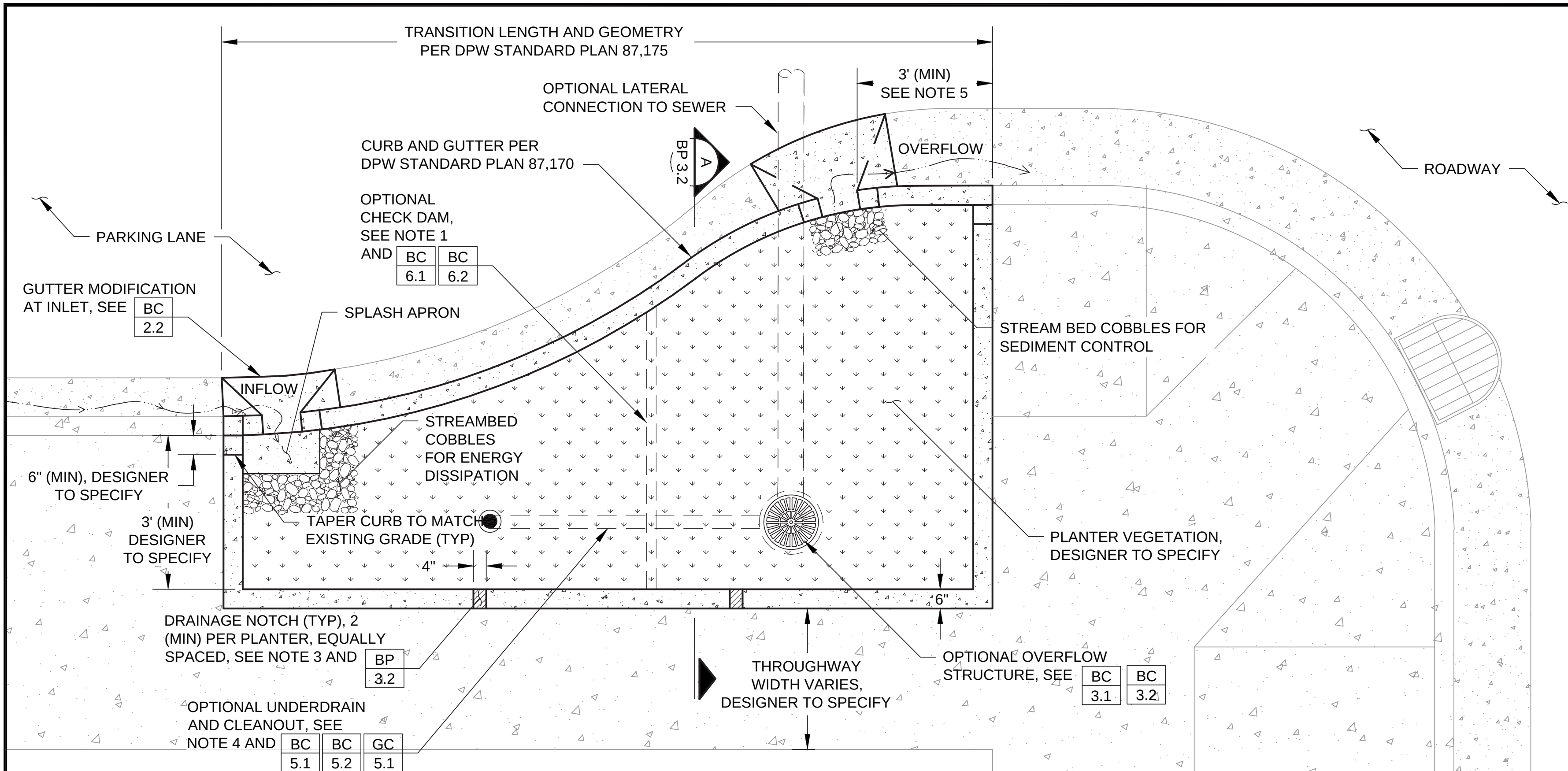
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER

ROADSIDE BULBOUT PLANTER ALTERNATIVE 4

DWG NO. BP 4.4



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN SECTIONS		PLAN SECTIONS		ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

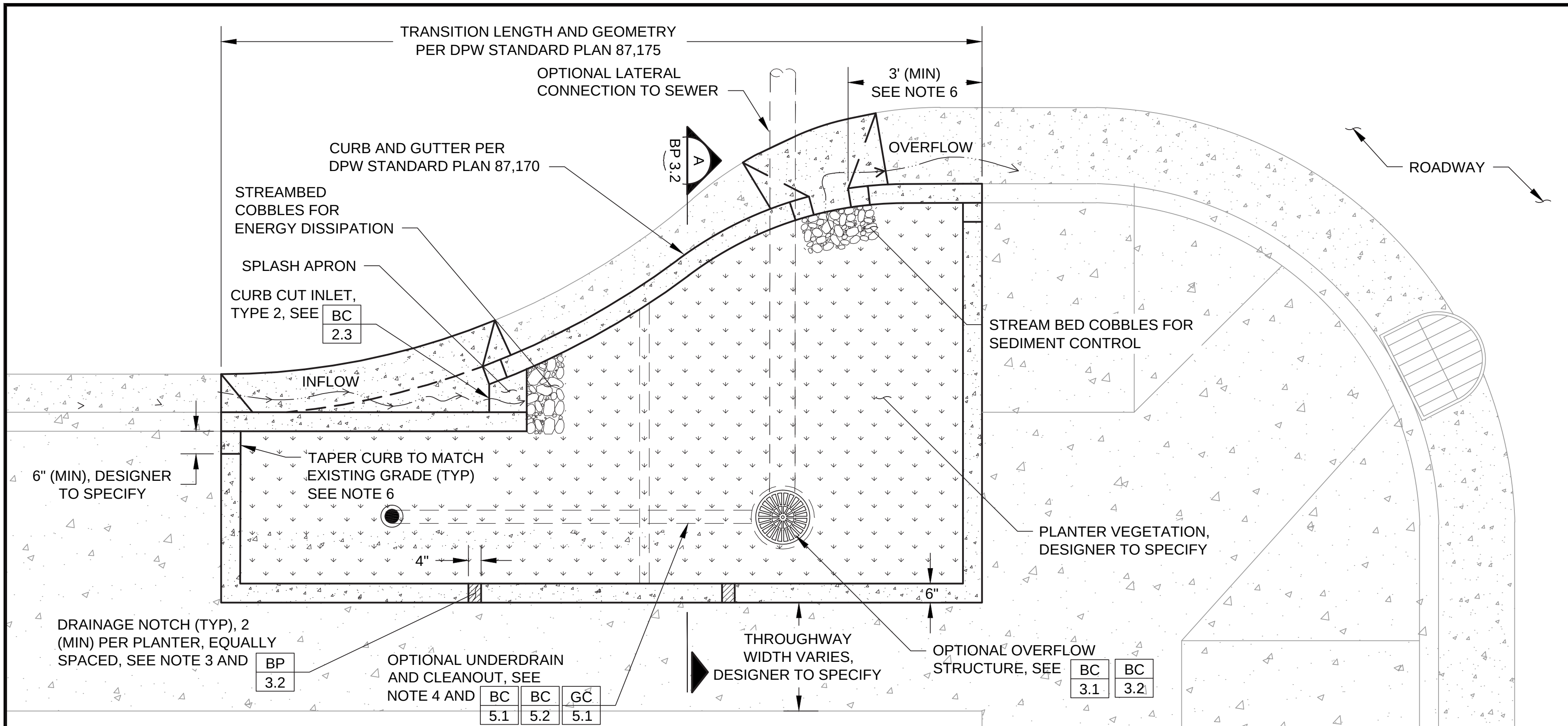
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER

ROADSIDE BULBOUT PLANTER ALTERNATIVE 5

DWG NO. BP 4.5

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
6. IF STREET PARKING IS ALLOWED IMMEDIATELY ADJACENT TO THE CURB CUT INLET/OUTLET, THE PLANTER WALL TAPER SHOULD BE LOCATED 18" BEHIND THE FACE OF CURB. COORDINATE WITH SAN FRANCISCO PUBLIC WORKS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS					
		PLAN SECTIONS		PLAN SECTIONS		ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER
ROADSIDE BULBOUT PLANTER ALTERNATIVE 6

DWG NO. BP 4.6

PURPOSE:

PARCEL BIORETENTION PLANTERS CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF BY PROVIDING SURFACE, SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS TREATED AS IT FILTERS THROUGH THE BIORETENTION SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS BUILDING- AND SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST COMPLY WITH ALL APPLICABLE SITE AND BUILDING CODE REQUIREMENTS FOR ON-SITE ACCESSIBILITY AND SAFETY INCLUDING, BUT NOT LIMITED TO, CURBS, PEDESTRIAN SURFACING, AND GUARDRAILS/FALL HEIGHTS.
3. PLANTER AREA, PONDING DEPTH, BIORETENTION SOIL DEPTH, AND AGGREGATE STORAGE DEPTH MUST BE SIZED TO MEET PROJECT-SPECIFIC PERFORMANCE GOALS.
4. PONDING AND BIORETENTIONSOIL DRAWDOWN TIME (I.E., TIME FOR MAXIMUM SURFACE PONDING TO DRAIN THROUGH THE BIORETENTION SOIL AFTER THE END OF A STORM) RECOMMENDATIONS:
   - 3 - 12 HOUR PONDING AND BIORETENTION SOIL DRAWDOWN (TYPICAL)
   - 24 HOUR MAXIMUM PONDING AND BIORETENTION SOIL DRAWDOWN
5. FACILITY DRAWDOWN TIME (I.E., TIME FOR SURFACE PONDING TO DRAIN THROUGH THE ENTIRE SECTION INCLUDING AGGREGATE STORAGE AFTER THE END OF A STORM) REQUIREMENTS:
   - 48 HOUR MAXIMUM FACILITY DRAWDOWN (i.e.ORFICE CONTROLLED SYSTEM OR EXTENDED STORAGE DEPTH WITHIN INFILTRATION SYSTEM)
6. AN AGGREGATE COURSE IS REQUIRED UNDER THE BIORETENTION SOIL FOR BIORETENTION IN SEPERATE SEWER SYSTEM AREAS TO PROVIDE ADDITIONAL TREATMENT. THIS AGGREGATE COURSE OPTIONAL FOR FACILITIES IN COMBINED SEWER SYSTEM AREAS. SEE GUIDANCE ON **BC 4**.1.
7. CHECK DAMS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO **BC 6.1** AND **BC 6.2** FOR GUIDANCE ON CHECK DAM DESIGN.
8. PLANTER OVERFLOW STRUCTURES SHALL BE DESIGNED TO CONVEY THE ANTICIPATED DESIGN FLOWS PER SAN FRANCISCO DBI REQUIREMENTS.
9. PLANTERS SHALL BE DESIGNED TO OVERFLOW TO THE STREET IN THE EVENT THE PLANTER OUTLET IS OBSTRUCTED OR CLOGGED.
10. MATERIALS FOR PLANTERS MAY VARY TO WORK WITH SITE AND ARCHITECTURAL PALETTE.
11. FACILITIES ADJACENT TO A BUILDING (WITHIN 10 FEET) SHOULD BE LINED TO AVOID NEGATIVE IMPACTS OF WATER AT FOUNDATION. LINER CAN BE OMITTED WITH LETTER FROM LICENSED DESIGN PROFESSIONAL(S) STATING THAT BUILDING WATERPROOFING, STRUCTURAL INTEGRITY, AND STORMWATER FUNCTION IS NOT IMPACTED.
12. FACILITIES MAY BE EXTENDED ABOVE GRADE FOR SEATWALL OR RAISED PLANTER CONFIGURATIONS, IF APPROPRIATE CONVEYANCE MEASURES ARE PROVIDED TO MEET DESIGN REQUIREMENTS.
13. CONVEYANCE CONNECTIONS MAY BE CONFIGURED TO ACCEPT RUNOFF VIA OVERHEAD CONVEYANCE (DOWNSPOUTS, OVERHEAD RUNNELS), SURFACE FLOW (CHANNELS), OR SUBSURFACE CONVEYANCE (PIPES, TRENCH DRAINS). REFER TO APPLICABLE SAN FRANCISCO DBI CODES FOR CONVEYANCE CONNECTION REQUIREMENTS.
14. CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, PIPE) SHALL BE SIZED TO ACCOMMODATE DRAINAGE FROM ROOF AREA WITH ADEQUATE FREEBOARD TO AVOID OVERFLOWING. REFER TO APPLICABLE SAN FRANCISCO DBI CODES FOR CONVEYANCE CONNECTION REQUIREMENTS.
15. UNDERDRAINS REQUIRED ON STRUCTURE TO DRAIN PLANTER AND AVOID ACCUMULATION OF WATER ON STRUCTURE WATERPROOFING SYSTEM
16. OVERFLOW STRUCTURE (MATERIAL AND WORKMANSHIP) SHALL CONFORM TO APPLICABLE SAN FRANCISCO DBI AND PUBLIC WORKS CODES AND REQUIREMENTS. SIZE AND MODEL OF ATRIUM GRATE AT OVERFLOW TO BE DETERMINED BY ENGINEER TO ENSURE CONVEYANCE OF PEAK FLOW.
17. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. REFER TO **GC 2.1** - **GC 2.12** FOR UTILITY CROSSING DETAILS AND **GC 1.4** - **GC 4.4** FOR UTILITY CROSSING CONFLICT DETAILS.
18. REFER TO SAN FRANCISCO DBI CODES FOR CURB AND/OR RAILING REQUIREMENTS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS						
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

BIORETENTION PLANTER

PARCEL PLANTER

DESIGNER NOTES (1 OF 2)

DWG NO. BP 5.1

LAYOUT REQUIREMENTS:

THE DESIGNER MUST COMPLY WITH ALL STORMWATER, LAND USE, AND BUILDING CODE REQUIREMENTS:

1. ADHERE TO ALL CODES FOR ACCESSIBILITY REQUIRED FOR PARCEL LEVEL DEVELOPMENT
2. PARCEL PLANTERS SHOULD NOT INTERFERE WITH OTHER LAND USE REQUIREMENTS SUCH AS BUFFERING AND SCREENING, SETBACKS, SIGHT DISTANCE, AND MINIMUM SITE COVERAGE.
3. DESIGNER MUST COMPLY WITH ALL CURRENT LOCAL CODES, INCLUDING BUT NOT LIMITED TO:
   - SAN FRANCISCO STORMWATER MANAGEMENT ORDINANCE
   - SAN FRANCISCO PLANNING CODE
   - CALIFORNIA BUILDING CODE
   - SAN FRANCISCO BUILDING CODE AMENDMENTS
   - ADA STANDARDS FOR ACCESSIBLE DESIGN

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PLANTER WIDTH AND LENGTH
- ☐ DEPTH OF PONDING
- ☐ DEPTH OF FREEBOARD
- ☐ DEPTH OF BIORETENTION SOIL
- ☐ DEPTH AND TYPE OF GRAVEL STORAGE, IF ANY
- ☐ PLANTER SURFACE ELEVATION (TOP OF BIORETENTION SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY
- ☐ CONTROL POINTS AT EVERY PLANTER WALL CORNER OR POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CLEAN OUT, PLANTER WALL CORNER, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF PLANTER COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS).
- ☐ OVERFLOW STRUCTURE AND ATRIUM GRATE SIZE AND MODEL NUMBER

RELATED COMPONENTS	
EDGE TREATMENTS:	BC 1.1 - BC 1.7
INLETS:	BC 2.1 - BC 2.4
OUTLETS:	BC 3.1 - BC 3.4
AGGREGATE STORAGE:	BC 4.2
UNDERDRAINS:	BC 5.1 - BC 5.2
CHECK DAMS:	BC 6.1 - BC 6.2
LINERS:	GC 1.1 GC 1.2
UTILITY CROSSINGS:	GC 2.1 - GC 2.12
OBSERVATION PORTS:	GC 3.1 GC 3.3
UTILITY CONFLICTS:	GC 4.1 - GC 4.4
CLEANOUTS:	GC 5.2

RELATED SPECIFICATIONS	CSI NO.
BIORETENTION: - BIORETENTION SOIL MIX - AGGREGATE STORAGE - MULCH - STREAMBED COBBLES	33 47 27

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

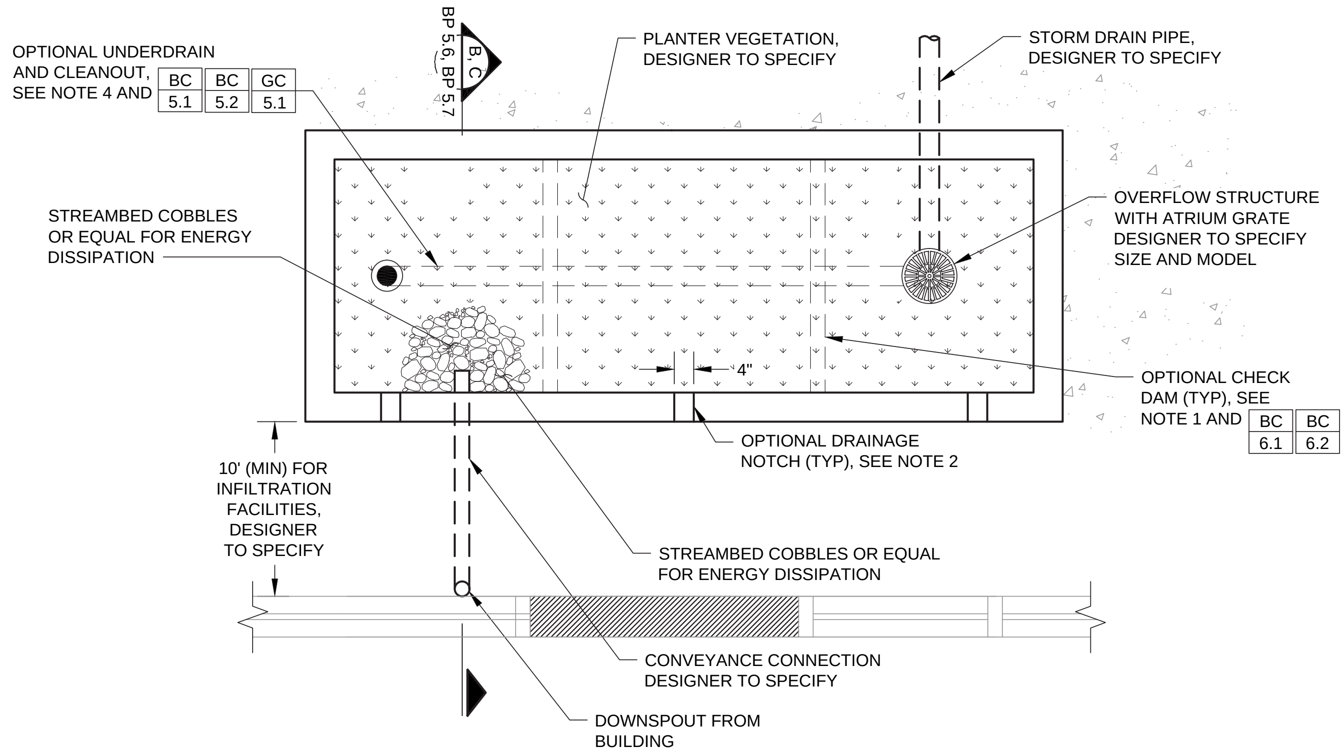
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER
PARCEL PLANTER
DESIGNER NOTES (2 OF 2)

DWG NO. BP 5.2



PLAN - ALTERNATIVE 1 (1)

CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES .
3. COORDINATE WATERPROOFING AT BUILDINGS WITH ARCHITECT AND ENGINEER.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS						
		PLAN	SECTIONS	PLAN	SECTIONS	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

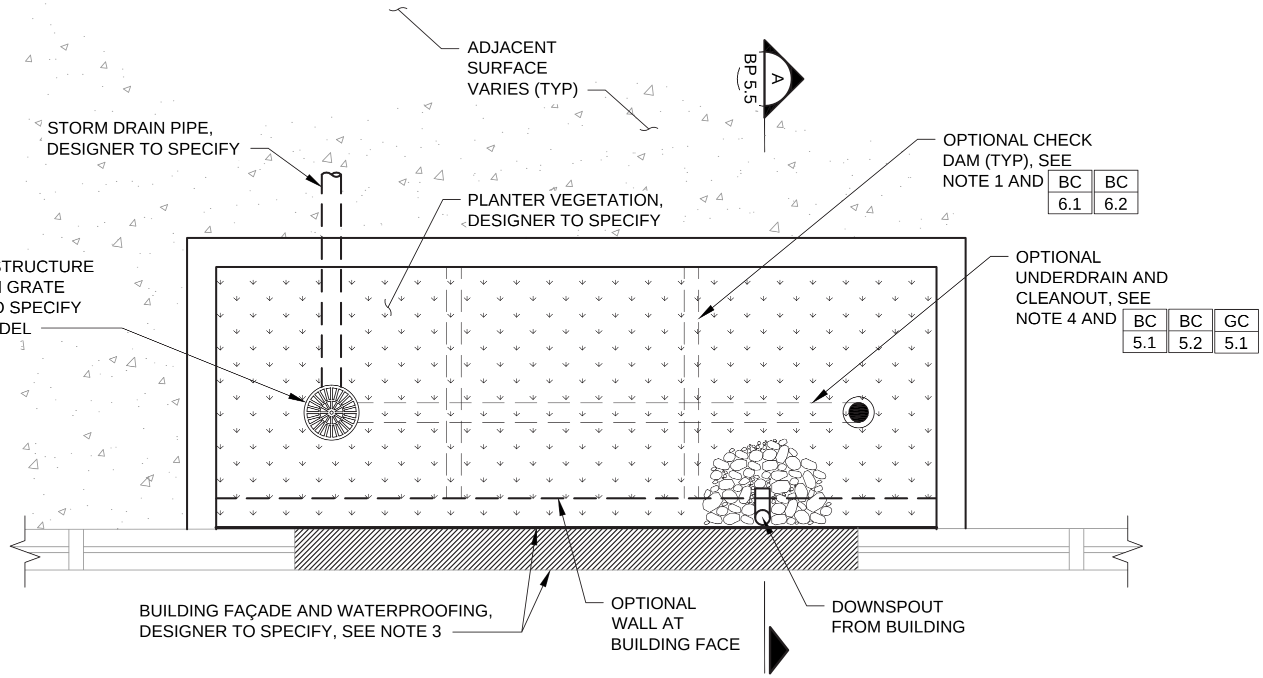
DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

BIORETENTION PLANTER

PARCEL PLANTER PLAN ALTERNATIVE 1

DWG NO. BP 5.3

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



PLAN - ALTERNATIVE 2 (1)

CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
2. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES .
3. COORDINATE WATERPROOFING AT BUILDINGS WITH ARCHITECT AND ENGINEER.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS						
		PLAN SECTIONS		PLAN SECTIONS		ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

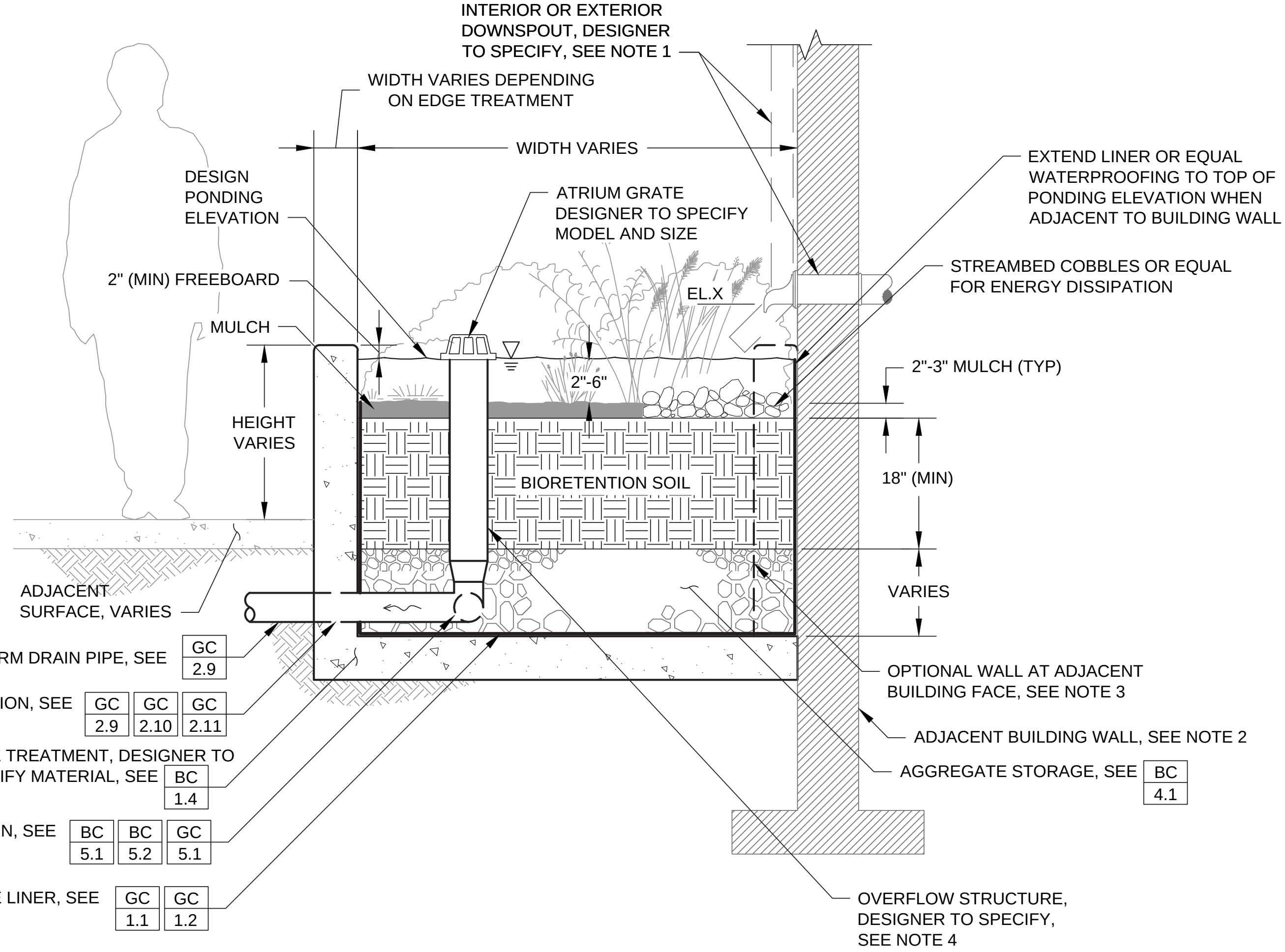
BIORETENTION PLANTER

PARCEL PLANTER PLAN ALTERNATIVE 2

DWG NO. BP 5.4

CONSTRUCTION NOTES:

1. INSTALL DOWNSPOUTS OR OTHER CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, OVERHEAD RUNNEL) FROM BUILDING TO DRAIN ABOVE DESIGN PONDING ELEVATION. REFER TO APPLICABLE SAN FRANCISCO DBI CODES FOR CONVEYANCE CONNECTION REQUIREMENTS.
2. BUILDING WATERPROOFING BY ARCHITECT; COORDINATE PLANTER CONSTRUCTION WITH BUILDING FAÇADE / WATERPROOFING.
3. PROVIDE WALL AT BUILDING FACE IN CASES WHERE GAP IS REQUIRED BETWEEN WALL AND PLANTER OR WHERE BUILDING FAÇADE IS INCOMPATIBLE WITH PLANTER CONFIGURATION.
4. OVERFLOW STRUCTURE (MATERIAL AND WORKMANSHIP) SHALL CONFORM TO APPLICABLE SAN FRANCISCO DBI AND PUBLIC WORKS CODES AND REQUIREMENTS.



SECTION - RAISED BIORETENTION PLANTER (A)

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

BIORETENTION PLANTER

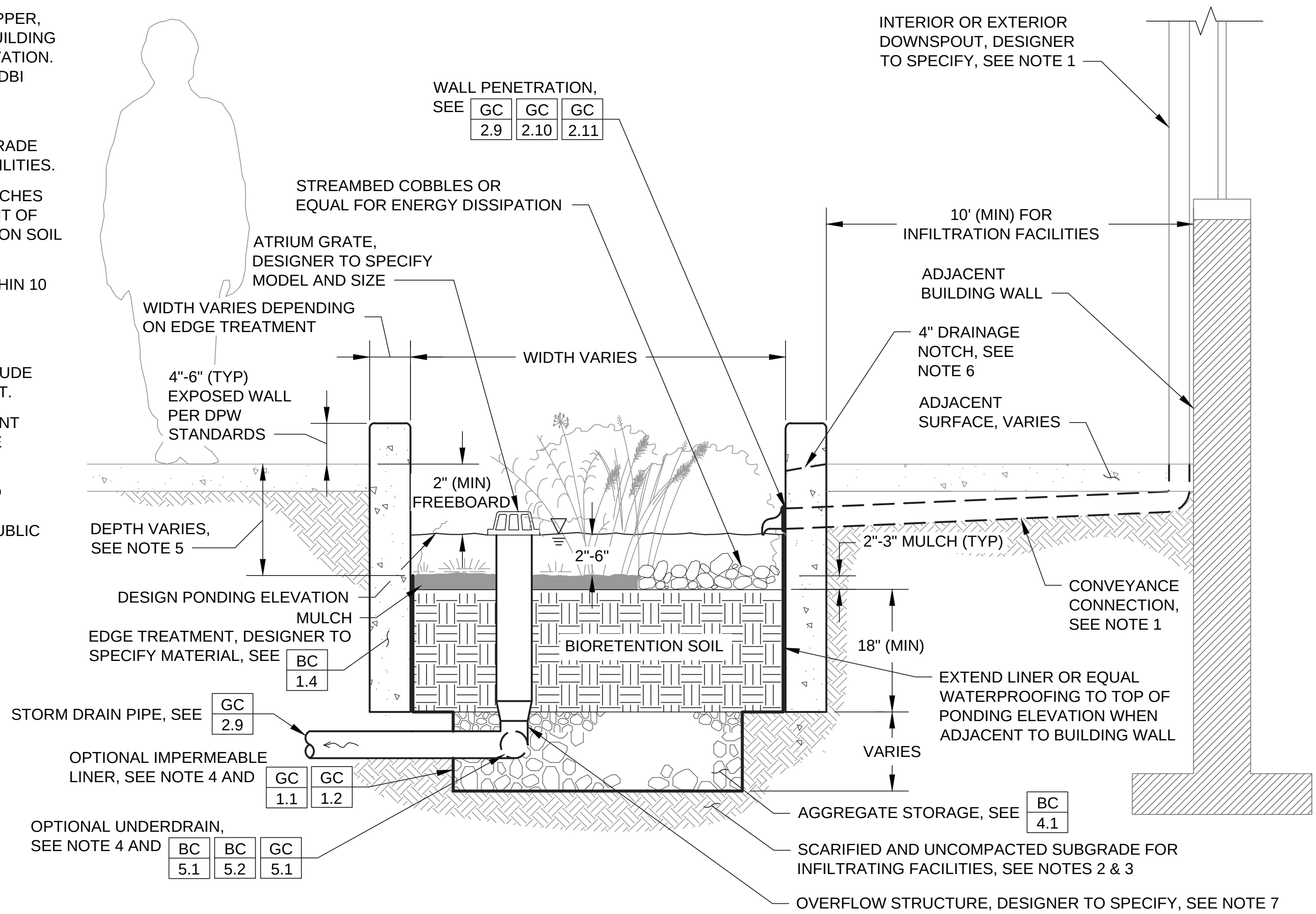
PARCEL PLANTER

RAISED PLANTER SECTION

DWG NO. BP 5.5

CONSTRUCTION NOTES:

1. INSTALL DOWNSPOUTS AND OTHER CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, OVERHEAD RUNNEL) FROM BUILDING TO DRAIN ABOVE DESIGN PONDING ELEVATION. REFER TO APPLICABLE SAN FRANCISCO DBI CODES FOR CONVEYANCE CONNECTION REQUIREMENTS.
2. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER FOR INFILTRATION FACILITIES.
3. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIALS.
4. UNDERDRAIN AND LINER REQUIRED WITHIN 10 FEET OF BUILDING ENVELOPE UNLESS APPROVED PER DESIGNER.
5. MAXIMUM DROP FROM TOP OF WALKING SURFACE TO TOP OF MULCH SHALL INCLUDE CONSIDERATIONS FOR SOIL SETTLEMENT.
6. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL. SLOPE NOTCHES TO DRAIN TO PLANTER.
7. OVERFLOW STRUCTURE (MATERIAL AND WORKMANSHIP) SHALL CONFORM TO APPLICABLE SAN FRANCISCO DBI AND PUBLIC WORKS CODES AND REQUIREMENTS.



SECTION - SURFACE BIORETENTION PLANTER (B)

NOTES		W/PARKING		W/O PARKING		BULBOUT						PARCEL APPLICATIONS						
		PLAN SECTIONS		PLAN SECTIONS		ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

BIORETENTION PLANTER

PARCEL PLANTER

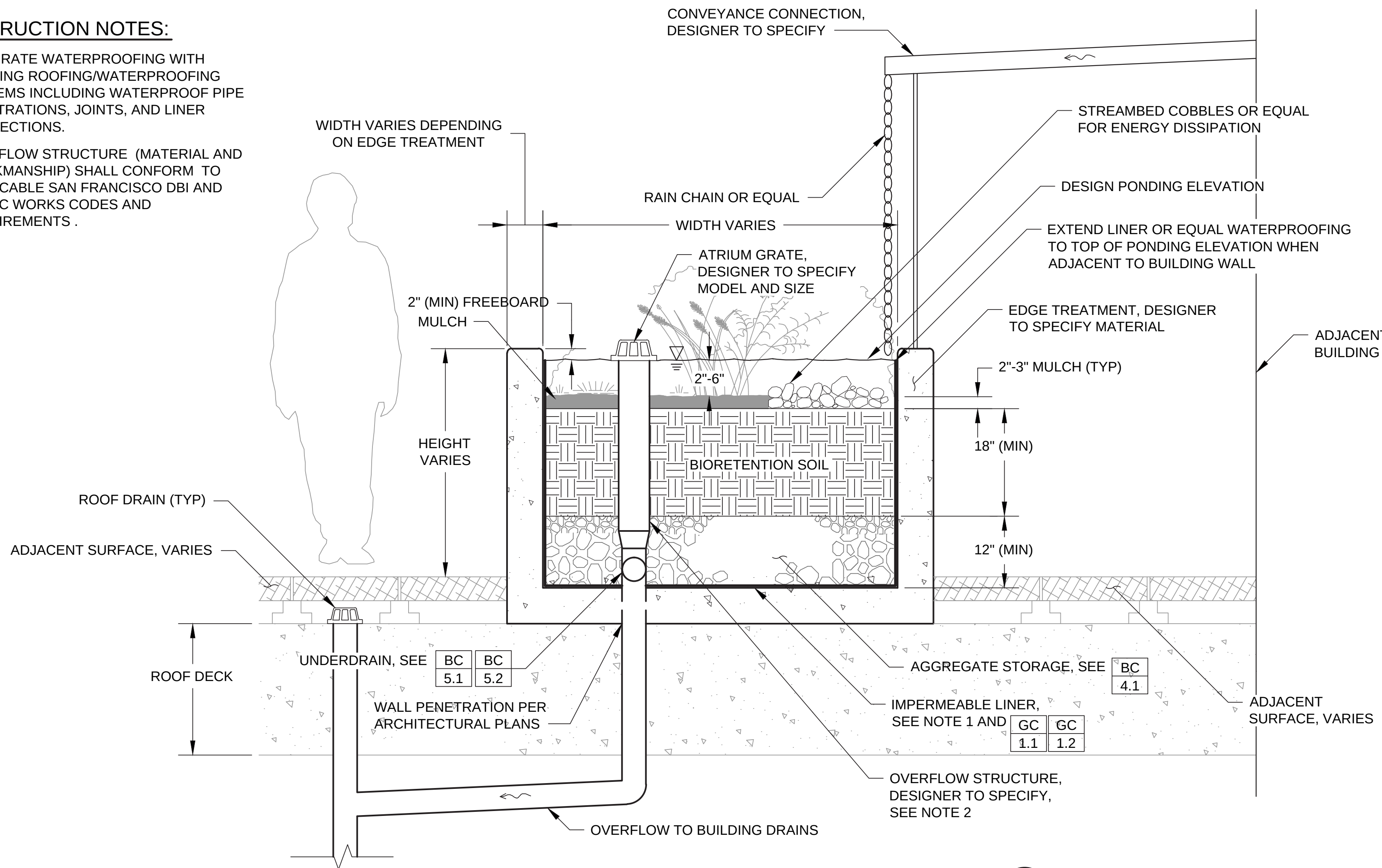
AT-GRADE PLANTER SECTION

DWG NO. **BP 5.6**

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

CONSTRUCTION NOTES:

1. INTEGRATE WATERPROOFING WITH BUILDING ROOFING/WATERPROOFING SYSTEMS INCLUDING WATERPROOF PIPE PENETRATIONS, JOINTS, AND LINER CONNECTIONS.
2. OVERFLOW STRUCTURE (MATERIAL AND WORKMANSHIP) SHALL CONFORM TO APPLICABLE SAN FRANCISCO DBI AND PUBLIC WORKS CODES AND REQUIREMENTS .



SECTION - BIORETENTION PLANTER ON STRUCTURE (C)

NOTES		W/PARKING PLAN SECTIONS		W/O PARKING PLAN SECTIONS		BULBOUT ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	PARCEL APPLICATIONS NOTES		PLAN		SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 4.3	BP 4.4	BP 4.5	BP 4.6	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6	BP 5.7

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION PLANTER
PARCEL PLANTER
PLANTER ON STRUCTURE SECTION

DWG NO. BP 5.7

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

BIORETENTION BASINS CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF BY PROVIDING SURFACE, SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS ALSO TREATED AS IT FILTERS THROUGH THE BIORETENTION SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. FACILITY AREA, PONDING DEPTH, BIORETENTION SOIL DEPTH, AND AGGREGATE STORAGE DEPTH MUST BE SIZED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS.
3. PONDING AND BIORETENTIONSOIL DRAWDOWN TIME (I.E., TIME FOR MAXIMUM SURFACE PONDING TO DRAIN THROUGH THE BIORETENTION SOIL AFTER THE END OF A STORM) RECOMMENDATIONS:
   - 3 - 12 HOUR PONDING AND BIORETENTION SOIL DRAWDOWN (TYPICAL)
   - 24 HOUR MAXIMUM PONDING AND BIORETENTION SOIL DRAWDOWN
4. FACILITY DRAWDOWN TIME (I.E., TIME FOR SURFACE PONDING TO DRAIN THROUGH THE ENTIRE SECTION INCLUDING AGGREGATE STORAGE AFTER THE END OF A STORM) REQUIREMENTS:
   - 48 HOUR MAXIMUM FACILITY DRAWDOWN (i.e.ORFICE CONTROLLED SYSTEM OR EXTENDED STORAGE DEPTH WITHIN INFILTRATION SYSTEM).
5. AN AGGREGATE COURSE IS REQUIRED UNDER THE BIORETENTION SOIL FOR BIORETENTION IN SEPARATE SEWER SYSTEM AREAS TO PROVIDE ADDITIONAL TREATMENT. THIS AGGREGATE COURSE IS OPTIONAL FOR FACILITIES IN COMBINED SEWER SYSTEM AREAS. SEE GUIDANCE ON **BC 4.1**.
6. CHECK DAMS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO **BC 6.1** AND **BC 6.2** FOR GUIDANCE ON CHECK DAM DESIGN.
7. THE FOLLOWING GUIDELINES APPLY TO RIGHT-OF-WAY APPLICATIONS:
   - BULBOUT CURB TRANSITIONS SHALL CONFORM TO DPW STANDARD PLAN 87,175.
   - WHEN FACILITY CONSTRUCTION IMPACTS EXISTING SIDEWALK, ALL SAW CUTS MUST ADHERE TO SFPUC REQUIREMENTS. SAW CUTS SHOULD BE ALONG SCORE LINES AND ANY DISTURBED SIDEWALK FLAGS SHOULD BE REPLACED IN THEIR ENTIRETY.
   - DESIGNER TO SPECIFY TRANSITION OF PLANTER TO TOP OF CURB ELEVATION BETWEEN CURB CUTS OR CONTINUOUS 6 INCH REVEAL AT CURB EDGE.
8. UP TO TWO PLANTERS MAY BE CONNECTED IN SERIES, IN LIEU OF MULTIPLE INLETS, PROVIDED THE CONNECTION IS A TRENCH DRAIN OR EQUAL SURFACE CONVEYANCE AND IS ADEQUATELY SIZED TO CONVEY FLOWS.
9. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDERS REQUIREMENTS. SEE UTILITY CROSSINGS (**GC 2.1 - GC 2.12**) AND UTILITY CONFLICTS (**GC 4.1 - GC 4.4**).

RELATED SPECIFICATIONS	CSI NO.
BIORETENTION: - BIORETENTION SOIL MIX - AGGREGATE STORAGE - MULCH - STREAMBED COBBLES	33 47 27

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ FACILITY WIDTH, LENGTH, SLOPES (INCLUDING SIDE, CROSS, AND LONGITUDINAL), AND SHAPE
- ☐ DEPTH OF BIORETENTION SOIL
- ☐ DEPTH AND TYPE OF GRAVEL STORAGE, IF ANY
- ☐ PLANTER SURFACE ELEVATION (TOP OF BIORETENTION SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY
- ☐ CONTROL POINTS AT EVERY CORNER OF FACILITY AND POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CHECK DAM, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF FACILITY COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS)

LAYOUT REQUIREMENTS:

1. FOR RIGHT-OF-WAY APPLICATIONS, REFER TO THE SAN FRANCISCO STANDARD ACCESSIBILITY REQUIREMENTS IN THE SAN FRANCISCO DPW SIDEWALK LANDSCAPING REFERENCE DRAWINGS AND SPECIFICATIONS FOR CONSTRUCTION FOR COURTESY STRIP, THROUGHWAY, PARKING SPACE AND ACCESSIBLE PATH REQUIREMENTS.
2. LOCATE CURB CUTS AND GUTTER MODIFICATIONS TO AVOID CONFLICTS WITH ACCESSIBILITY REQUIREMENTS (E.G., LOCATE OUTSIDE OF CROSSWALKS).

RELATED COMPONENTS	
EDGE TREATMENTS:	BC 1.1 - BC 1.7
INLETS:	BC 2.1 - BC 2.4
OUTLETS:	BC 3.1 - BC 3.4
AGGREGATE STORAGE:	BC 4.1
UNDERDRAINS:	BC 5.1 - BC 5.2
CHECK DAMS:	BC 6.1 - BC 6.2
LINERS:	GC 1.1, GC 1.2
UTILITY CROSSINGS:	GC 2.1 - GC 2.12
OBSERVATION PORTS:	GC 3.1, GC 3.3
UTILITY CONFLICTS:	GC 4.1 - GC 4.4
CLEANOUTS:	GC 5.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: BB 1.1
SECTIONS: BB 2.1, BB 2.2

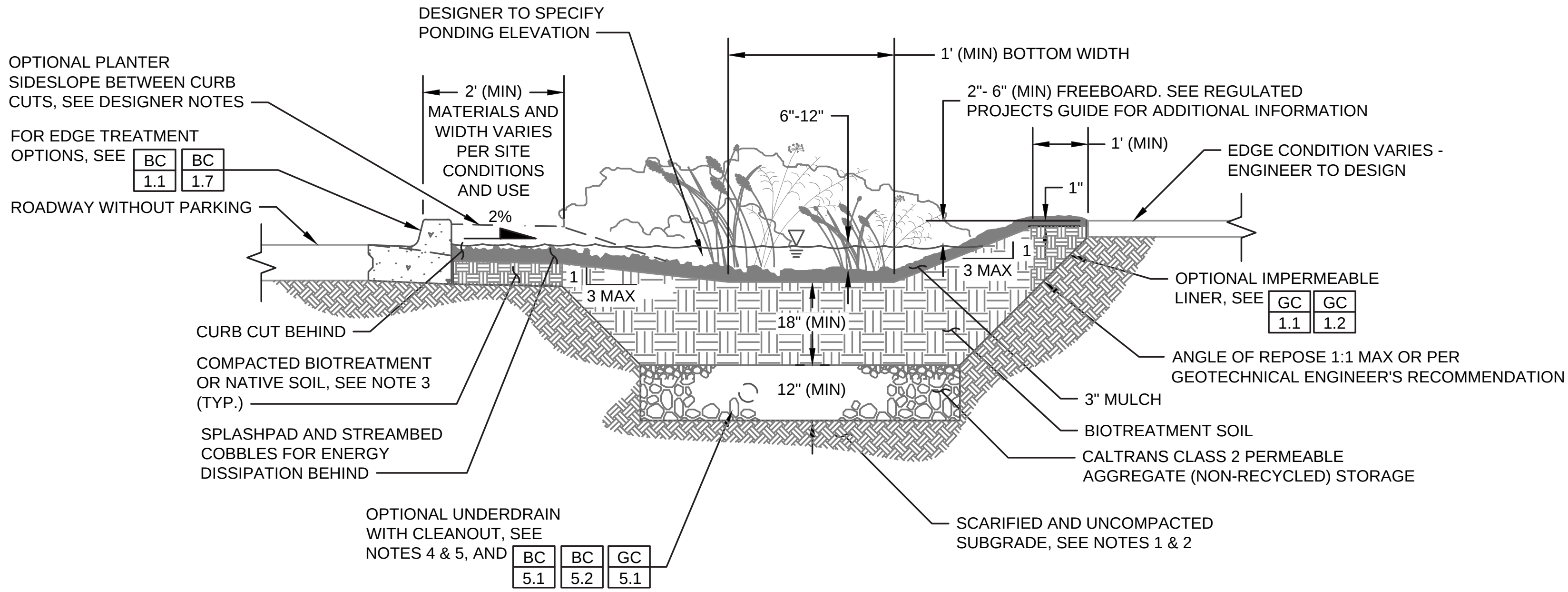
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

BIORETENTION BASIN
DESIGNER NOTES

DWG NO. BB 1.1



CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW BASIN.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIOTREATMENT SOIL MATERIALS.
3. COMPACT SOIL IMMEDIATELY BEHIND CURB TO 90% OF MAXIMUM DENSITY PER STANDARD PROCTOR TEST (ASTM D698).
4. UNDERDRAIN REQUIRED FOR ALL FACILITIES WITH IMPERMEABLE LINER.
5. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
6. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT JURISDICTION PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
7. GEOTECHNICAL OR HYDRAULOGIST ENGINEER TO DETERMINE IF LINER SHALL BE USED.
8. ANGLE OF REPOSE MAY VARY BASED ON GEOTECHNICAL ENGINEER RECOMMENDATIONS.

NOTES BB 1.1 | SECTIONS BB 2.1 BB 2.2

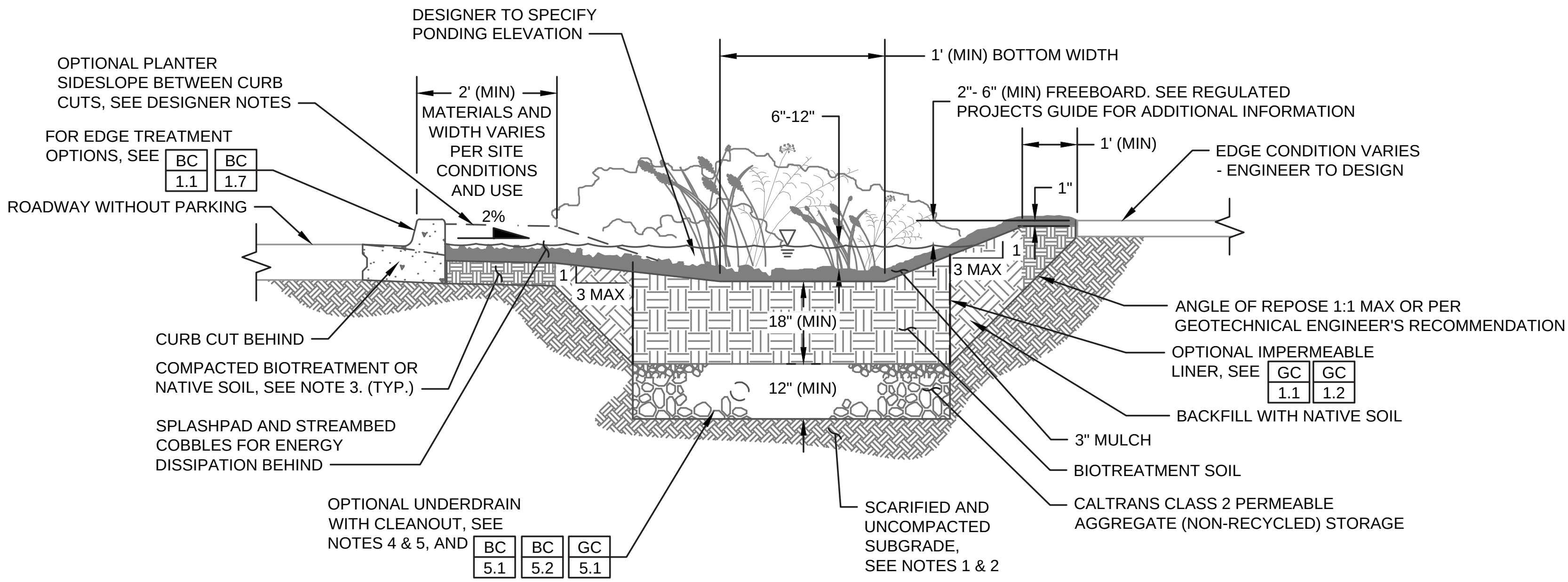
DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BB 2.1)

DATE JANUARY 2019
VERSION 2.0
REVISED OCTOBER, 2019

BIORETENTION BASIN
ROADSIDE SECTION TYPE 1

DWG NO. BB 2.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW BASIN.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIOTREATMENT SOIL MATERIALS.
3. COMPACT SOIL IMMEDIATELY BEHIND CURB TO 90% OF MAXIMUM DENSITY PER STANDARD PROCTOR TEST (ASTM D698).
4. UNDERDRAIN REQUIRED FOR ALL FACILITIES WITH IMPERMEABLE LINER.
5. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
6. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT JURISDICTION PROTECTION STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
7. GEOTECHNICAL OR HYDRAULOGIST ENGINEER TO DETERMINE IF LINER SHALL BE USED.
8. ANGLE OF REPOSE MAY VARY BASED ON GEOTECHNICAL ENGINEER RECOMMENDATIONS.

NOTES	SECTIONS		
BB 1.1	BB 2.1	BB 2.1.1	BB 2.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

DETAIL ADAPTED FROM: SAN FRANCISCO PUBLIC UTILITIES COMMISSION (BB 2.1)	DATE JANUARY 2019 VERSION 2.0 REVISED OCTOBER, 2019	**BIORETENTION BASIN** **ROADSIDE SECTION TYPE 2**	DWG NO. **BB 2.1.1**

PURPOSE:

EDGE TREATMENTS ARE USED TO DEFINE THE BOUNDARIES OF A BIORETENTION FACILITY AND ARE INTENDED PRIMARILY TO STABILIZE THE EDGE OF ADJACENT PAVEMENT AND MINIMIZE LATERAL MOVEMENT OF WATER, AS APPLICABLE. IN CASES WHERE ADEQUATE SPACE IS AVAILABLE, THE FACILITY SIDESLOPE CAN BE LAID BACK SUCH THAT THE SURROUNDING NATIVE SOIL IS STABLE AND CAN FUNCTION AS THE FACILITY EDGE TREATMENT. HOWEVER, WHEN SPACE IS LIMITED, EDGE TREATMENTS SUCH AS VERTICAL WALLS MAY BE USED TO MAINTAIN THE STRUCTURAL INTEGRITY OF THE SURROUNDING SURFACES. THESE EDGE TREATMENTS RETAIN STORMWATER WITHIN THE FACILITY (AND OUT OF THE SURROUNDING PAVEMENT SECTIONS, AS APPLICABLE) UNTIL WATER INFILTRATES, IS COLLECTED BY THE UNDERDRAIN, OR OVERFLOWS VIA THE DESIGNATED OUTLETS.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. MINIMUM EDGE TREATMENT EMBEDMENT DEPTHS ARE SPECIFIED TO PREVENT LATERAL SEEPAGE UNDER THE EDGE TREATMENT AND INTO ADJACENT PAVEMENT SECTIONS, AS APPLICABLE.
3. DESIGNER MAY ELIMINATE CONSTRUCTION BENCH TO INCREASE EFFECTIVE FACILITY AREA (I.E. INFILTRATION AND STORAGE FOOTPRINT) PROVIDED PLANTER WALL EXTENDS TO BOTTOM OF AGGREGATE STORAGE.
4. DESIGNER MAY SPECIFY ALTERNATIVE MATERIAL TYPE FOR EDGE TREATMENTS PROVIDED MATERIAL MEETS STRUCTURAL REQUIREMENTS FOR LOADING CONDITIONS, SERVES AS A WATER BARRIER BETWEEN THE FACILITY AND ADJACENT PAVEMENT SECTIONS (AS APPLICABLE), AND COMPLIES WITH SAN FRANCISCO DPW STANDARD ACCESSIBILITY REQUIREMENTS.
5. FOOTING OR LATERAL BRACING SHALL BE PROVIDED FOR ALL PLANTER WALLS UNLESS THE DESIGNER DEMONSTRATES THAT THE PROPOSED WALL DESIGN MEETS LOADING REQUIREMENTS.
6. FOOTINGS AND LATERAL BRACING SHALL BE DESIGNED TO WITHSTAND ANTICIPATED LOADING ASSUMING NO REACTIVE FORCES FROM THE UNCOMPACTED BIORETENTION SOIL WITHIN THE FACILITY.
7. LATERAL BRACING SHALL MEET HYDROLOGIC AND HYDRAULIC DESIGN REQUIREMENTS FOR CHECK DAMS WHEN USED AS CHECK DAMS. SEE **BC 6.1**.
8. PLANTER WALLS EXTENDING MORE THAN 36 INCHES BELOW ADJACENT LOAD-BEARING SURFACE, OR WHEN LOCATED ADJACENT TO PAVERS, MUST HAVE FOOTING OR LATERAL BRACING. SEE **BC 1.5**

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ EDGE TREATMENT TYPE AND MATERIAL
- ☐ EDGE TREATMENT WIDTH AND HEIGHT
- ☐ EMBEDMENT DEPTH INTO SUBGRADE SOILS
- ☐ LATERAL BRACING/FOOTING REQUIREMENTS
- ☐ PIPE MATERIAL AND DIAMETER FOR ALL WALL PENETRATIONS
- ☐ WATER TIGHT CONNECTOR TYPE FOR ALL WALL PENETRATIONS (E.G., GROUTED, COMPRESSION, BOOT) SEE **GC 2.9** AND **GC 2.10**.
- ☐ ELEVATIONS - INLET, OUTLET, OVERFLOW STRUCTURE (RIM & INVERT), CLEANOUT (RIM & INVERT)
- ☐ ELEVATIONS - TOP OF SLOPE AND TOE OF SLOPE

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016

VERSION: 2.0

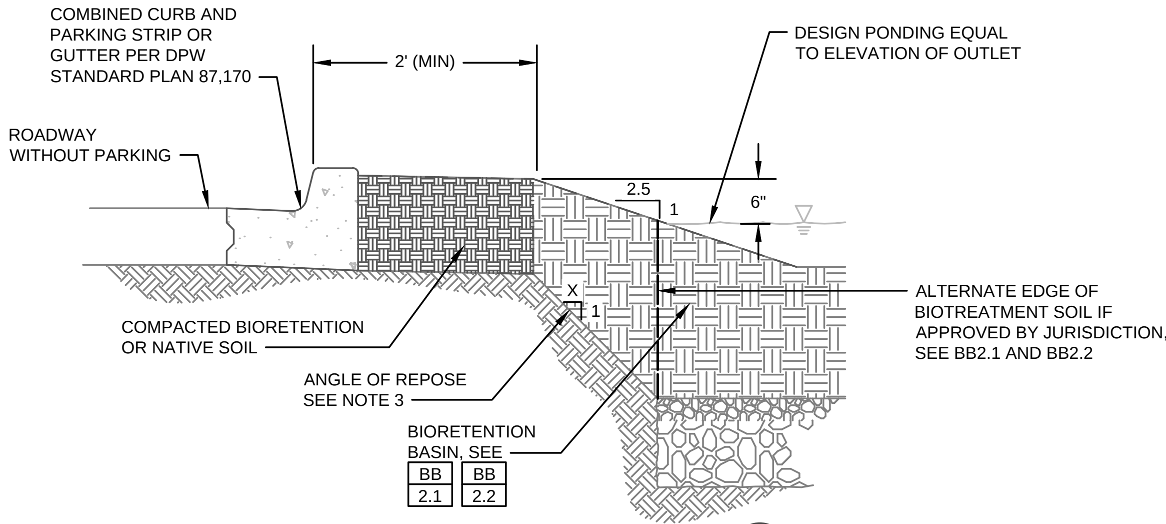
REVISED:

BIORETENTION COMPONENTS

EDGE TREATMENTS

DESIGNER NOTES

DWG NO. BC 1.1



STANDARD CURB EDGE AT BIORETENTION BASIN (1)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. COMPACT BIORETENTION OR NATIVE SOIL TO 90% OF MAXIMUM DENSITY PER STANDARD PROCTOR TEST (ASTM D698).
3. ANGLE OF REPOSE VARIES PER GEOTECHNICAL ENGINEERS RECOMMENDATIONS.

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

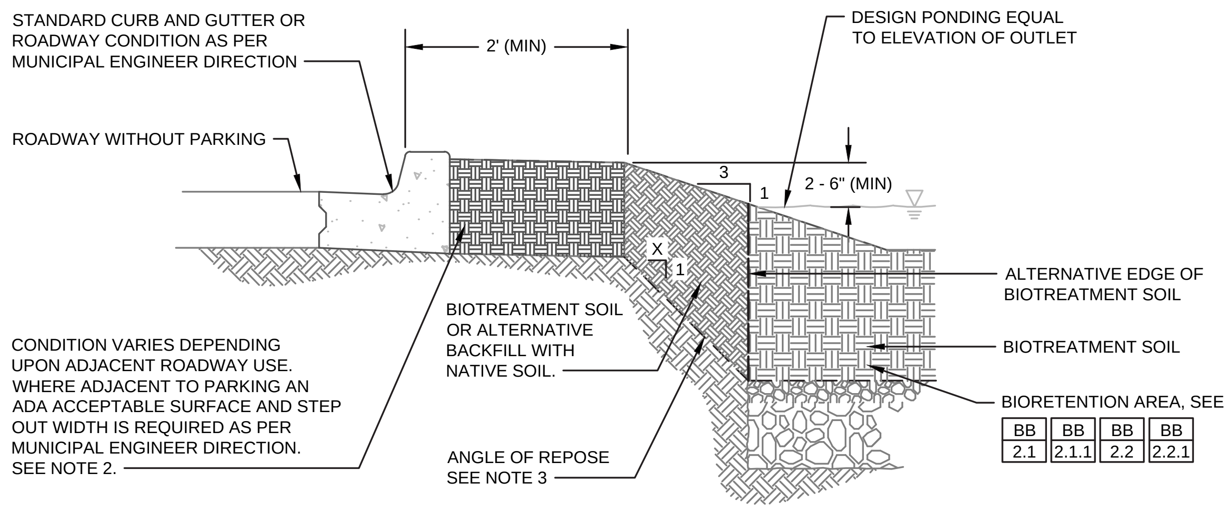
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS
EDGE TREATMENTS
VEHICULAR APPLICATIONS (1 OF 2)

DWG NO. BC 1.2



STANDARD CURB EDGE AT BIORETENTION AREA (1)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER RESPONSIBLE JURISDICTION.
2. COMPACT SOIL IMMEDIATELY BEHIND CURB TO 90% OF MAXIMUM DENSITY PER STANDARD PROCTOR TEST (ASTM D698).
3. ANGLE OF REPOSE VARIES PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.

EDGE TREATMENTS								INLETS						OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS							NOTES	COMPONENTS					NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.2.1	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.2.1	BC 2.3	BC 2.3.1	BC 2.4.1	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

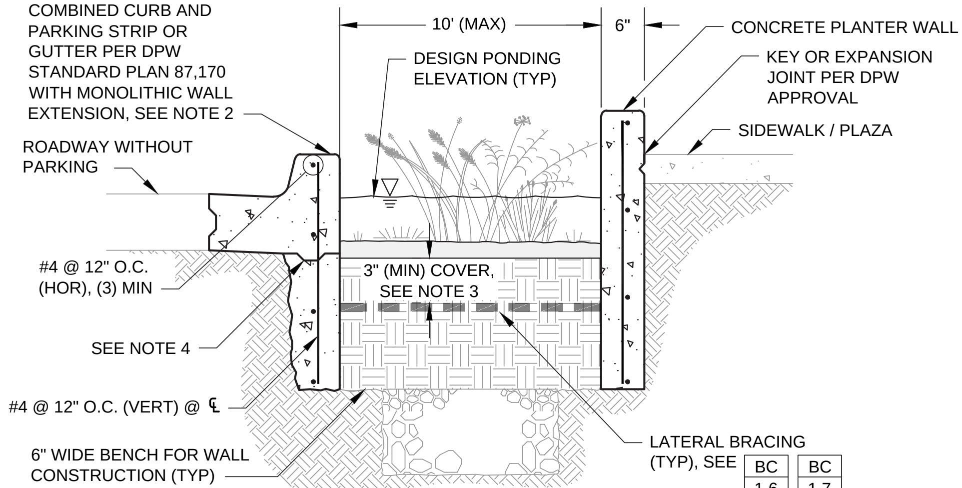
DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BC 1.2)

DATE: JANUARY 2019
VERSION:
REVISED: OCTOBER, 2019

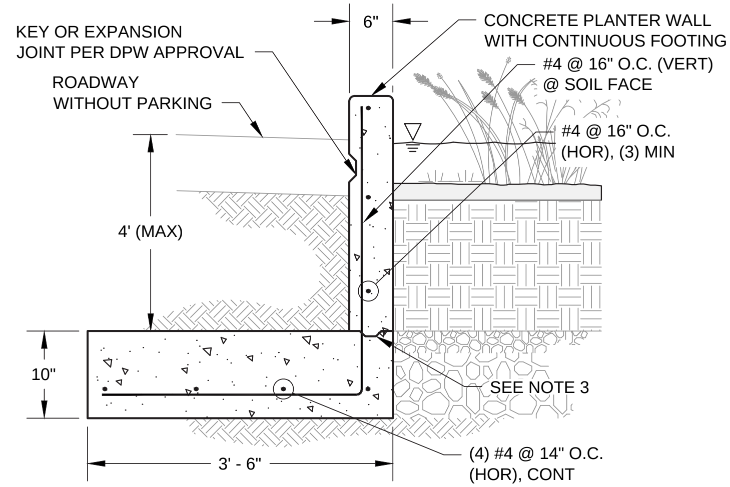
BIORETENTION COMPONENTS
EDGE TREATMENTS
VEHICULAR APPLICATIONS MODIFICATION (1B OF 2)

DWG NO. BC 1.2.1

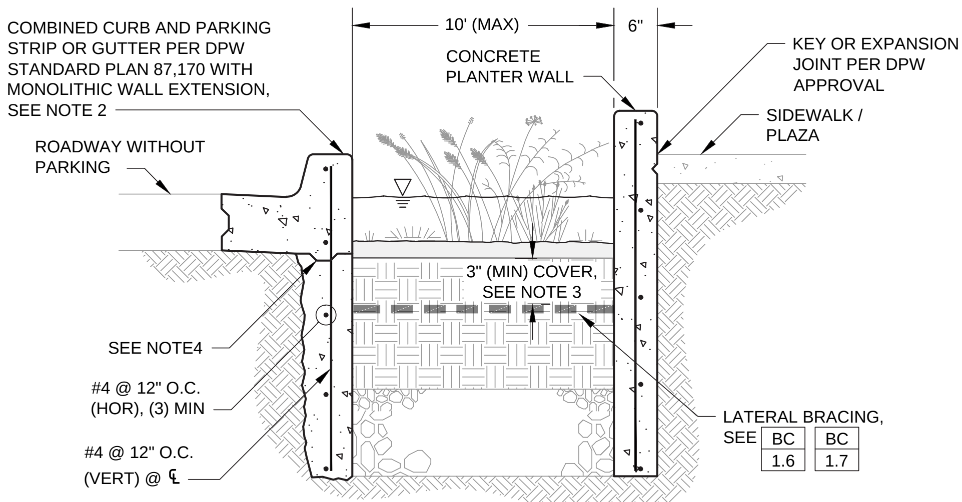
NOT FOR CONSTRUCTION - REFER TO USER GUIDE



SHORT WALL



PLANTER WALL WITH CONTINUOUS FOOTING 2



EXTENDED WALL

PLANTER WALL WITH LATERAL BRACING 1

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. ALL PLANTER WALLS SHALL EXTEND TO BOTTOM OF BIORETENTION SOIL OR DEEPER.
3. CONTRACTOR TO PROVIDE 3 INCH MINIMUM COVER OVER ALL LATERAL BRACING FOR PLANT ESTABLISHMENT.
4. ALL CONSTRUCTION COLD JOINTS SHALL INCORPORATE EPOXY, DOWEL/TIE BAR, KEYWAY, OR WATER STOP.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

Category	Notes	Components
EDGE TREATMENTS	BC 1.1	BC 1.2, BC 1.3, BC 1.4, BC 1.5, BC 1.6, BC 1.7
INLETS	BC 2.1	BC 2.2, BC 2.3, BC 2.4
OUTLETS	BC 3.1	BC 3.2, BC 3.3, BC 3.4
AGGREGATE STORAGE COMPONENTS		BC 4.1
UNDERDRAINS	BC 5.1	BC 5.2
CHECK DAM	BC 6.1	BC 6.2
MONITORING	BC 7.1	BC 7.2, BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

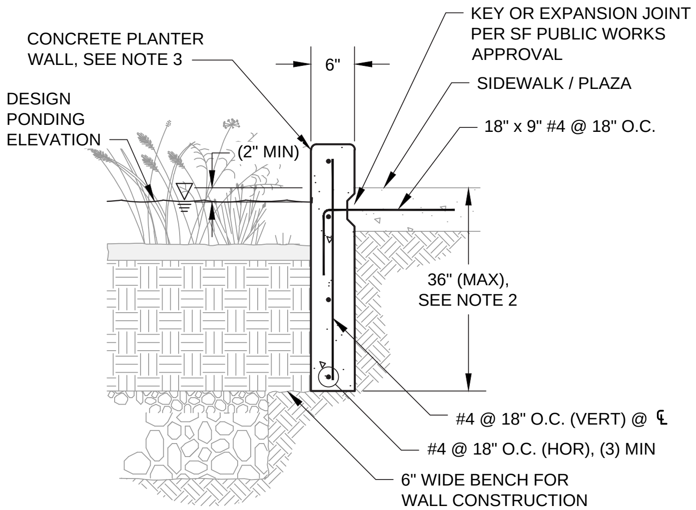
REVISED

BIORETENTION COMPONENTS

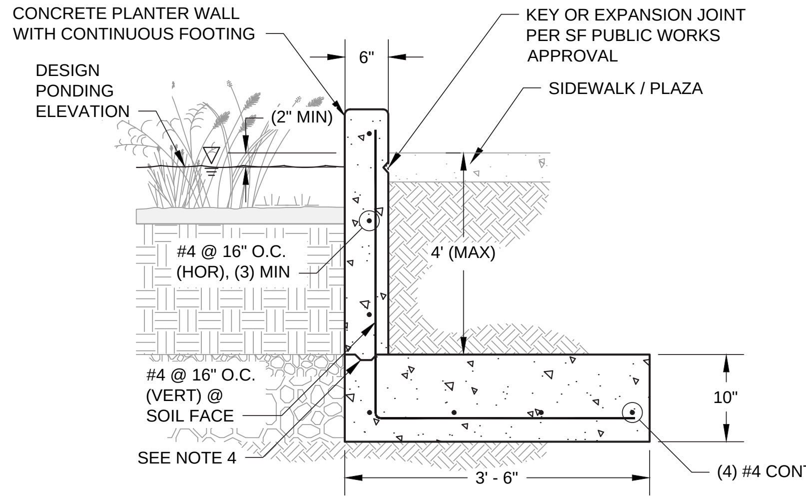
EDGE TREATMENTS

VEHICULAR APPLICATIONS (2 OF 2)

DWG NO. BC 1.3



PLANTER WALL - PARCEL ONLY (1)



PLANTER WALL WITH CONTINUOUS FOOTING (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. PLANTER WALLS EXTENDING MORE THAN 36 INCHES BELOW ADJACENT LOAD-BEARING SURFACE, OR WHEN LOCATED ADJACENT TO PAVERS, MUST HAVE FOOTING OR LATERAL BRACING. COORDINATE WITH ENGINEER.
3. ALL PLANTER WALLS SHALL EXTEND TO BOTTOM OF BIORETENTION SOIL OR DEEPER.
4. ALL CONSTRUCTION COLD JOINTS SHALL INCORPORATE EPOXY, DOWEL/TIE BAR, KEYWAY, OR WATER STOP.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

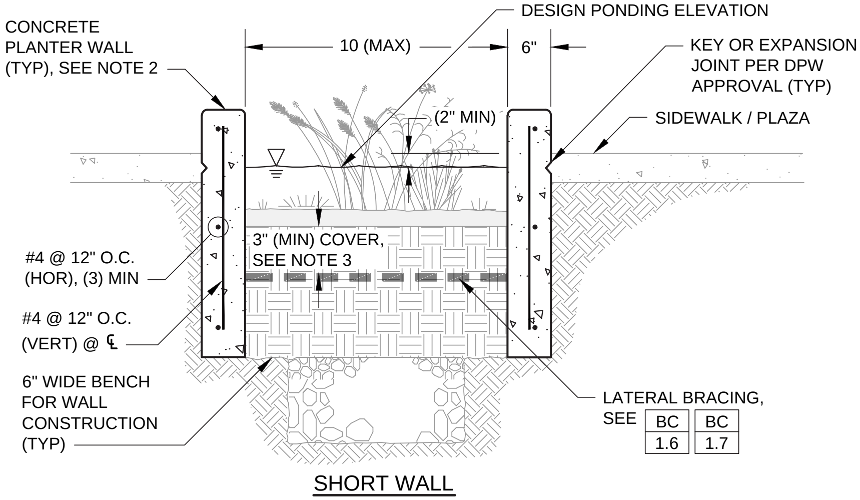
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

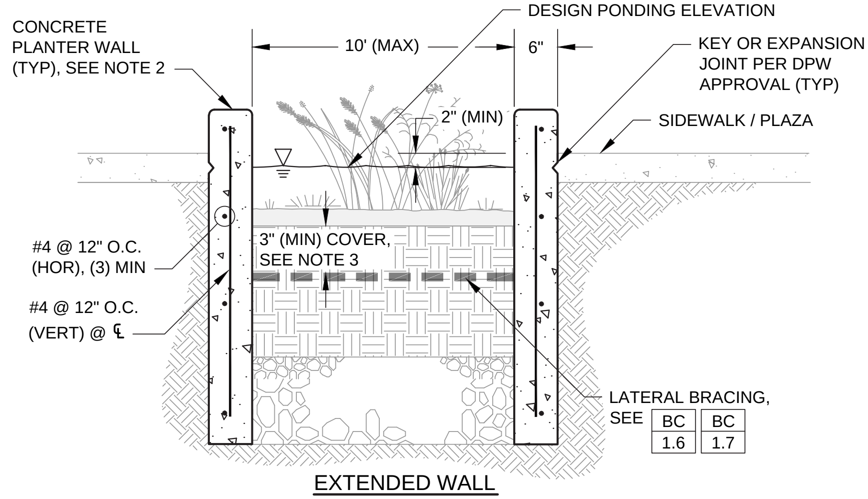
DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

BIORETENTION COMPONENTS

EDGE TREATMENTS
PEDESTRIAN APPLICATIONS (1 OF 2)

DWG NO. BC 1.4





PLANTER WALL WITH LATERAL BRACING -SHORT (1)

PLANTER WALL WITH LATERAL BRACING - EXTENDED (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR EDGE TREATMENTS SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. ALL PLANTER WALLS SHALL EXTEND TO BOTTOM OF BIORETENTION SOIL OR DEEPER.
3. CONTRACTOR TO PROVIDE 3 INCH MINIMUM COVER OVER ALL LATERAL BRACING FOR PLANT ESTABLISHMENT.
4. ALL CONSTRUCTION COLD JOINTS SHALL INCORPORATE EPOXY, DOWEL/TIE BAR, KEYWAY, AND WATER STOP.

Category	Notes	Components
EDGE TREATMENTS	BC 1.1	BC 1.2, BC 1.3, BC 1.4, BC 1.5, BC 1.6, BC 1.7
INLETS	BC 2.1	BC 2.2, BC 2.3, BC 2.4
OUTLETS	BC 3.1	BC 3.2, BC 3.3, BC 3.4
AGGREGATE STORAGE COMPONENTS		BC 4.1
UNDERDRAINS	BC 5.1	BC 5.2
CHECK DAM	BC 6.1	BC 6.2
MONITORING	BC 7.1	BC 7.2, BC 7.3

San Francisco Water Power Sewer

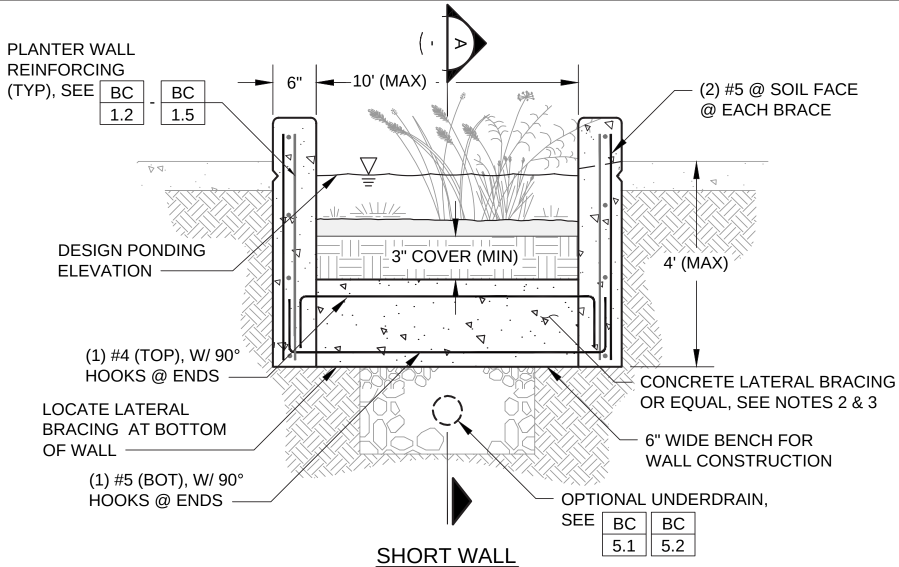
GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

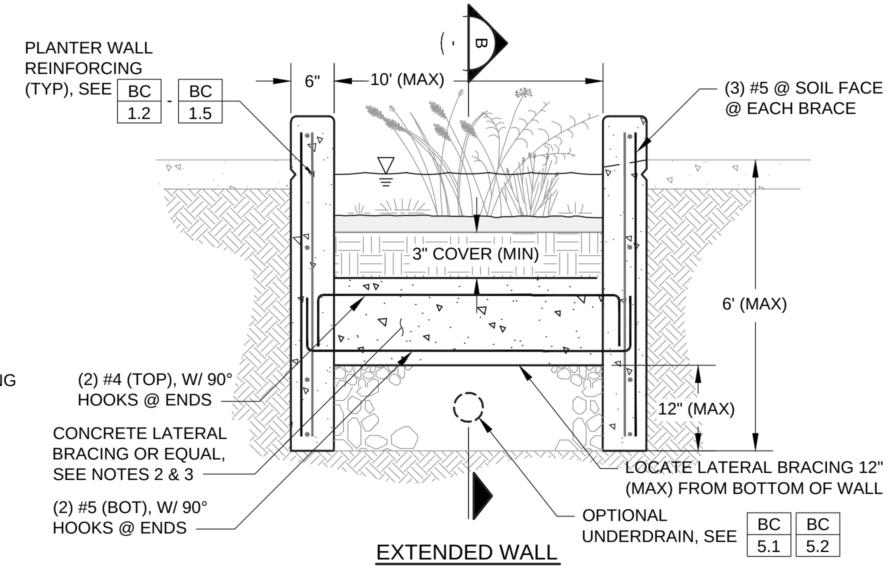
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

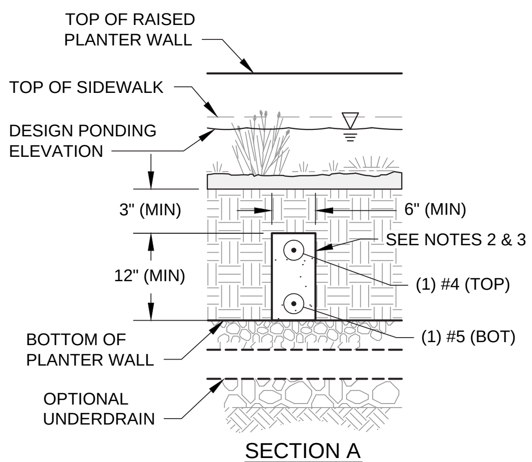
BIORETENTION COMPONENTS
EDGE TREATMENTS
PEDESTRIAN APPLICATIONS (2 OF 2)

DWG NO. BC 1.5

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

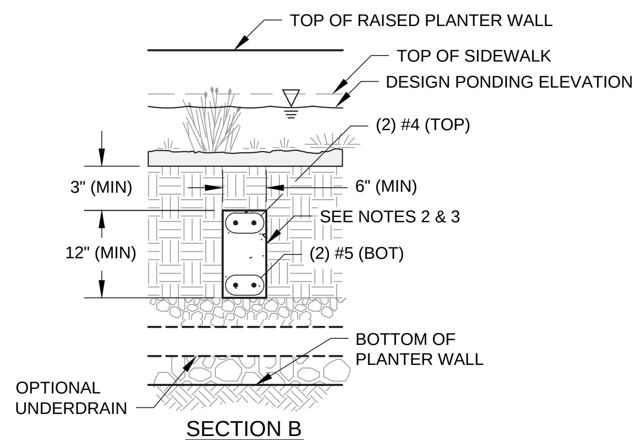






CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR LATERAL BRACING SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. CONCRETE LATERAL BRACING SHALL BE CONTINUOUS (NO JOINTS).
3. LATERAL BRACING SHALL BE PROVIDED EVERY 6 FEET (MAX) FOR WALLS UP TO 4 FEET IN HEIGHT AND EVERY 4 FEET (MAX) FOR WALLS BETWEEN 4 AND 6 FEET IN HEIGHT.



CONCRETE BRACING WALL - SHORT 1

CONCRETE BRACING WALL - EXTENDED 2

EDGE TREATMENTS NOTES	EDGE TREATMENTS COMPONENTS						INLETS NOTES	INLETS COMPONENTS			OUTLETS NOTES	OUTLETS COMPONENTS			AGGREGATE STORAGE COMPONENTS	UNDERDRAINS NOTES	UNDERDRAINS COMPONENTS	CHECK DAM NOTES	CHECK DAM COMPONENTS	MONITORING NOTES	MONITORING COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

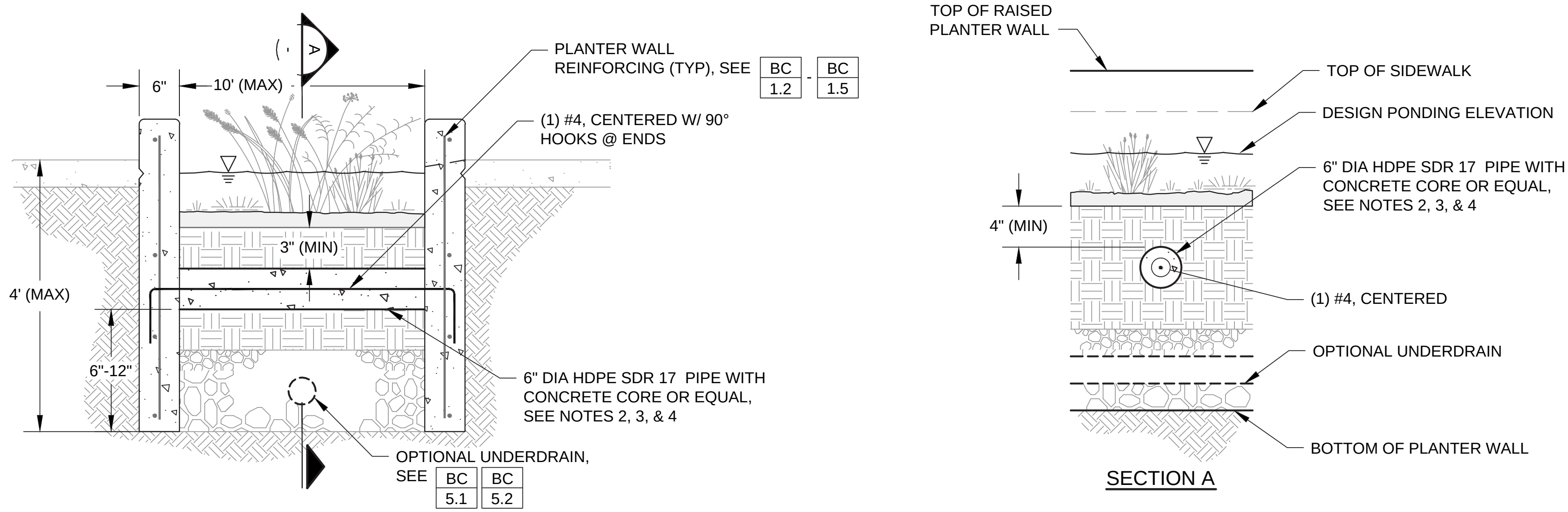
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS
EDGE TREATMENTS
LATERAL BRACING (1 OF 2)

DWG NO. BC 1.6



CONCRETE STRUT 1

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR LATERAL BRACING STRUCTURES SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. LATERAL BRACING SHALL BE PROVIDED EVERY 6 FEET (MAX) FOR WALLS UP TO 4 FEET IN HEIGHT.
3. OTHER MATERIALS MAY BE USED IN LIEU OF HDPE PROVIDED MATERIAL IS NON CORROSIVE, NON-LEACHING, AND SCHEDULE 40.
4. PROVIDE 3 INCH CONTINUOUS SLOT ACROSS TOP OF PIPE TO PLACE REINFORCEMENT AND ENSURE STRUT IS FREE OF VOIDS.

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS

EDGE TREATMENTS
LATERAL BRACING (2 OF 2)

DWG NO. BC 1.7

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

CURB CUTS AND TRENCH DRAINS SERVE AS INLETS TO CONVEY STORMWATER RUNOFF TO A BIORETENTION FACILITY. CURB CUTS ARE TYPICALLY USED IN PLANTER APPLICATIONS WHEN THE FACILITY IS IMMEDIATELY ADJACENT TO THE ROADWAY (I.E. NO COURTESY STRIP), PROVIDING AN OPENING TO INTERCEPT AND CONVEY STORMWATER FROM THE GUTTER TO THE PLANTER. TRENCH DRAIN SYSTEMS ARE MOST COMMONLY USED TO CONVEY STORMWATER FROM A GUTTER THROUGH THE COURTESY STRIP TO A BIORETENTION PLANTER; PROVIDING A CONTINUOUS SURFACE FOR PEDESTRIAN ACCESS WHILE MINIMIZING ELEVATION LOSSES AT THE FACILITY INFLOW LOCATIONS. CURB CUT AND TRENCH DRAIN INLETS INCLUDE MODIFICATIONS TO THE GUTTER TO HELP DIRECT FLOW INTO THE FACILITY.

DESIGNER NOTES & GUIDELINES:

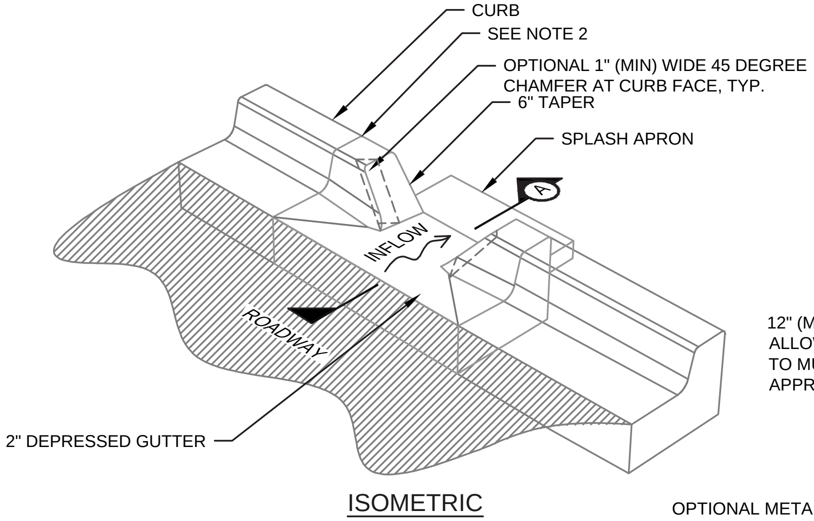
1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST ENSURE THAT CURB CUTS AND TRENCH DRAIN INLETS ARE ADEQUATELY SIZED, SPACED, AND SLOPED TO SATISFY PERMITTING JURISDICTION DPW HYDRAULIC REQUIREMENTS. THE CURB CUT OPENING WIDTH MUST BE SIZED BASED ON THE CATCHMENT AREA, LONGITUDINAL SLOPE ALONG THE CURB, AND THE CROSS SLOPE OF THE GUTTER OR ADJACENT PAVEMENT AT THE INLET. SEE SIZING EQUATIONS AND NOMOGRAPHS FOR CURB OPENING INLETS IN THE U.S. DEPARTMENT OF TRANSPORTATION HYDRAULIC ENGINEERING CIRCULAR NO. 27.
3. TRENCH DRAIN GRATES AND ASSEMBLIES MUST COMPLY WITH PERMITTING JURISDICTION DPW STANDARD
4. USE CURB CUT INLET/OUTLET MODIFICATION WITH METAL PLATE TOP (BC 2.2.1) WHEN ADJACENT TO VEHICLE PARKING AND LOADING AREAS

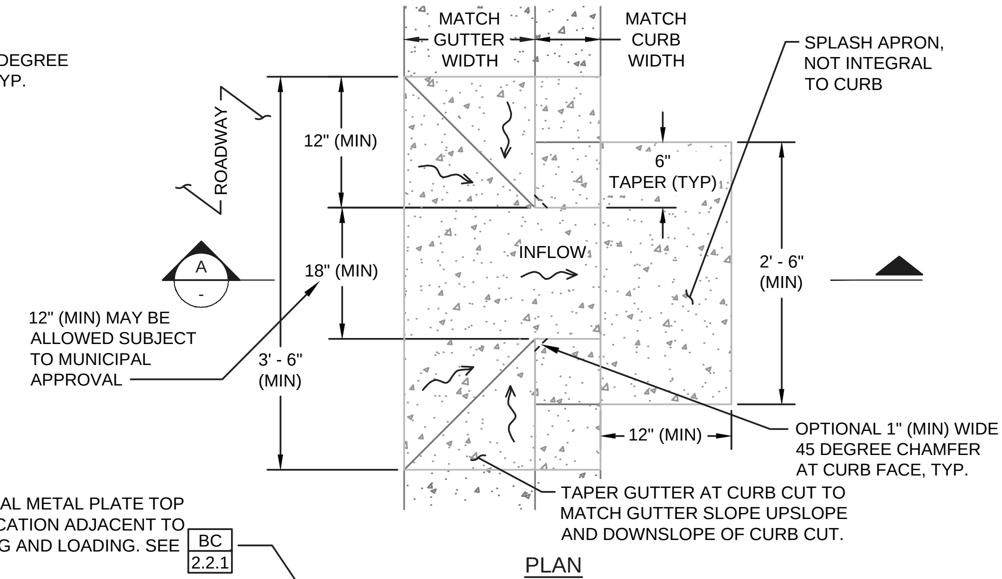
DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

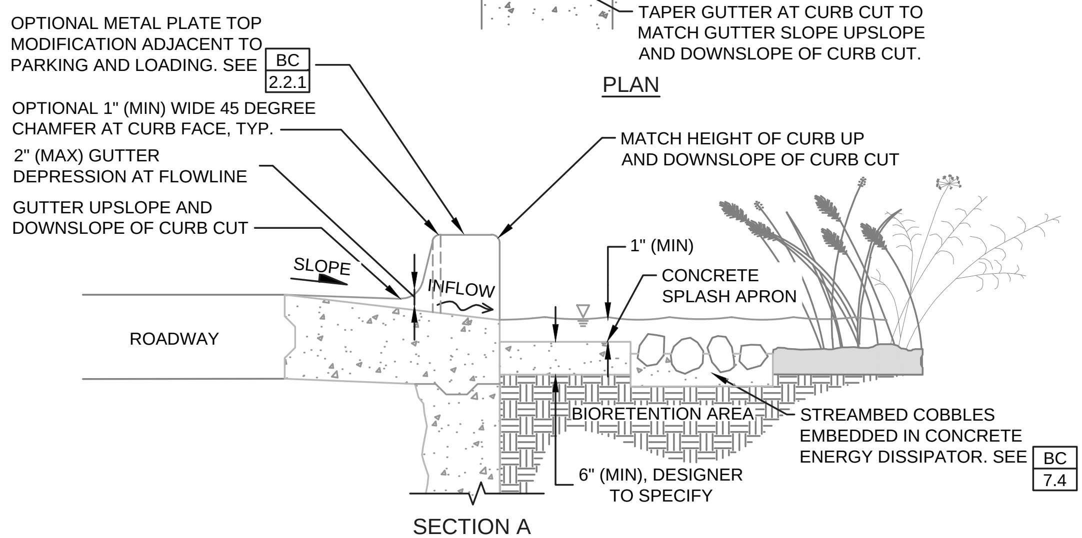
- ☐ CURB CUT DIMENSIONS
- ☐ FRAME AND GRATE TYPE/MATERIAL AND DIMENSIONS
- ☐ CHANNEL DIMENSIONS
- ☐ CONTROL ELEVATIONS FOR OPENINGS AT GUTTER AND PLANTER WALL
- ☐ CURBCUT TYPE WITH OR WITHOUT METAL PLATE TOP MODIFICATION

DATE	JANUARY 2019	BIORETENTION COMPONENTS	DWG NO.
VERSION	2.0	INLETS	BC
REVISED	OCTOBER, 2019	DESIGNER NOTES	2.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE







CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO PERMITTING JURISDICTION STANDARD SPECIFICATIONS AND APPLICABLE CODES PER THE BUILDING DEPARTMENT AND PUBLIC WORKS.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.

INLET - CURB CUT TYPE 1 (1)

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

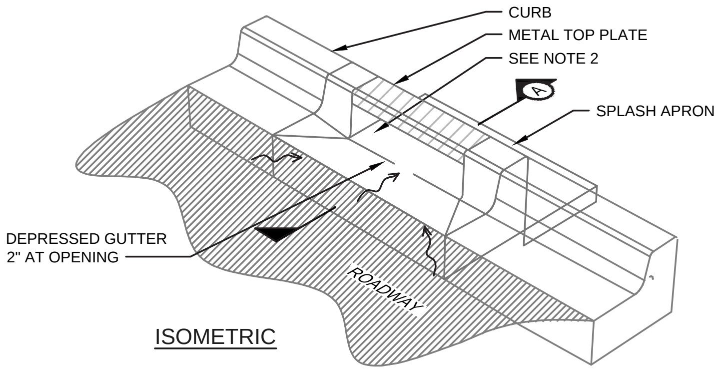
Category	Group	Items
EDGE TREATMENTS	NOTES	BC 1.1
EDGE TREATMENTS	COMPONENTS	BC 1.2, BC 1.2.1, BC 1.3, BC 1.4, BC 1.5, BC 1.6, BC 1.7
INLETS	NOTES	BC 2.1
INLETS	COMPONENTS	BC 2.2, BC 2.2.1, BC 2.3, BC 2.3.1, BC 2.4.1
OUTLETS	NOTES	BC 3.1
OUTLETS	COMPONENTS	BC 3.2, BC 3.3, BC 3.4
AGGREGATE STORAGE	COMPONENTS	BC 4.1
UNDERDRAINS	NOTES	BC 5.1
UNDERDRAINS	COMPONENTS	BC 5.2
CHECK DAM	NOTES	BC 6.1
CHECK DAM	COMPONENTS	BC 6.2
MONITORING	NOTES	BC 7.1
MONITORING	COMPONENTS	BC 7.2, BC 7.3, BC 7.4

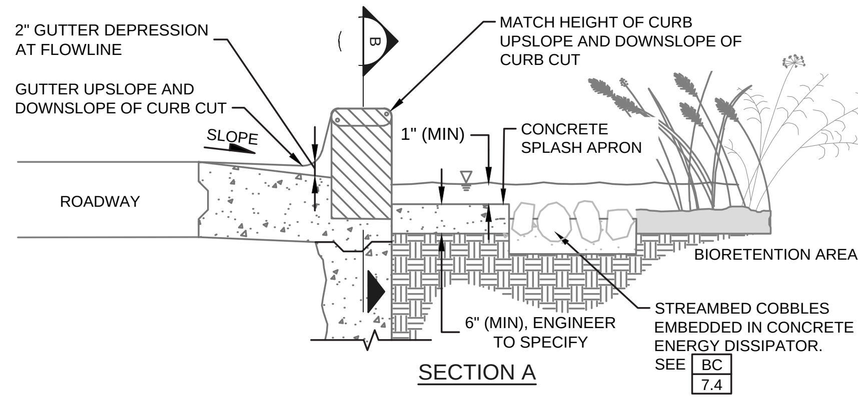
DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

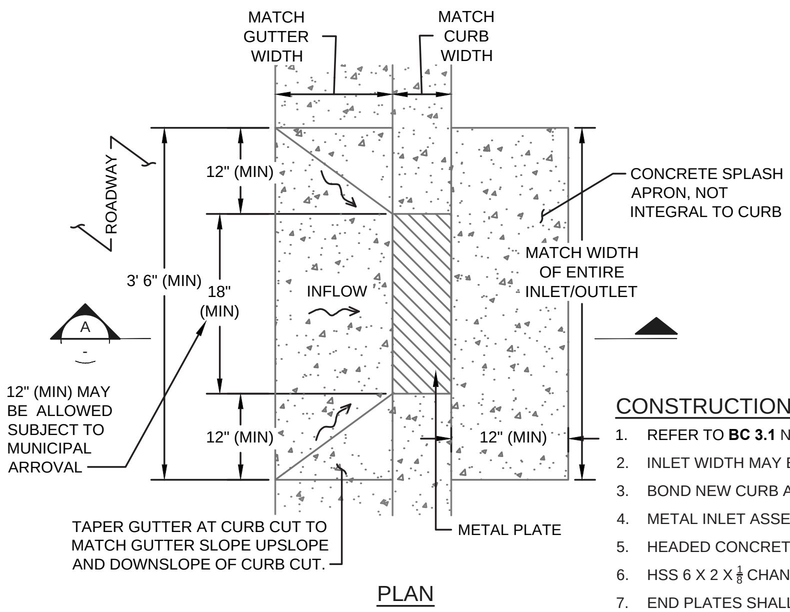
DATE JANUARY 2019
VERSION 2.0
REVISED OCTOBER, 2019

BIORETENTION COMPONENTS
INLETS
CURB CUT WITH GUTTER MODIFICATION

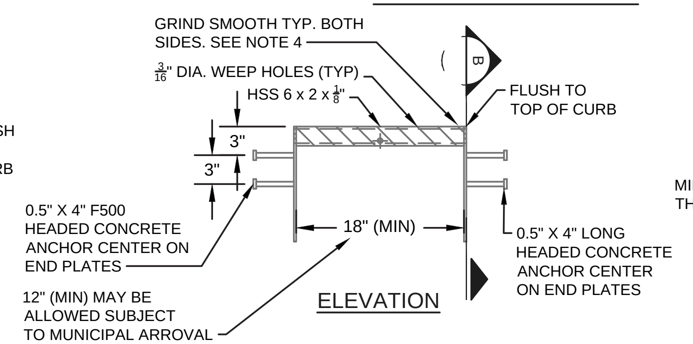
DWG NO. **BC 2.2**

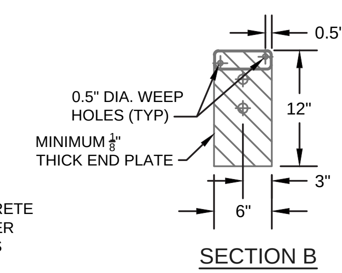






METAL INLET ASSEMBLY





CONSTRUCTION NOTES:

1. REFER TO **BC 3.1** NOTES FOR GUIDELINES AND CHECKLIST.
2. INLET WIDTH MAY BE GREATER ON STEEP GUTTER SLOPES. DESIGNER TO SPECIFY.
3. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
4. METAL INLET ASSEMBLY SHALL BE HOT-DIP GALVANIZED IN ACCORDANCE WITH ASTM A-123.
5. HEADED CONCRETE ANCHORS SHALL MEET THE REQUIREMENTS OF ASTM A-108.
6. HSS 6 X 2 X $\frac{1}{8}$ CHANNEL SHALL MEET THE REQUIREMENTS OF ASTM A-500 GRADE B.
7. END PLATES SHALL MEET THE REQUIREMENTS OF ASTM A-36
8. DESIGN VERTICAL WHEEL LOAD IS 8.5 KIPS ($\frac{1}{2}$ OF TANDEM AZLE WEIGHT SPECIFIED IN FHWA-HOP-06-105) AND SHALL WITHSTAND H-20 LOADING
9. SINGLE BEVEL GROOVE WELD
10. ALTERNATE MATERIAL FOR ASSEMBLY (E.G. CAST IRON, GRAY IRON) MAY BE USED PER DESIGN PLANS IF APPROVED BY JURISDICTION ENGINEER.

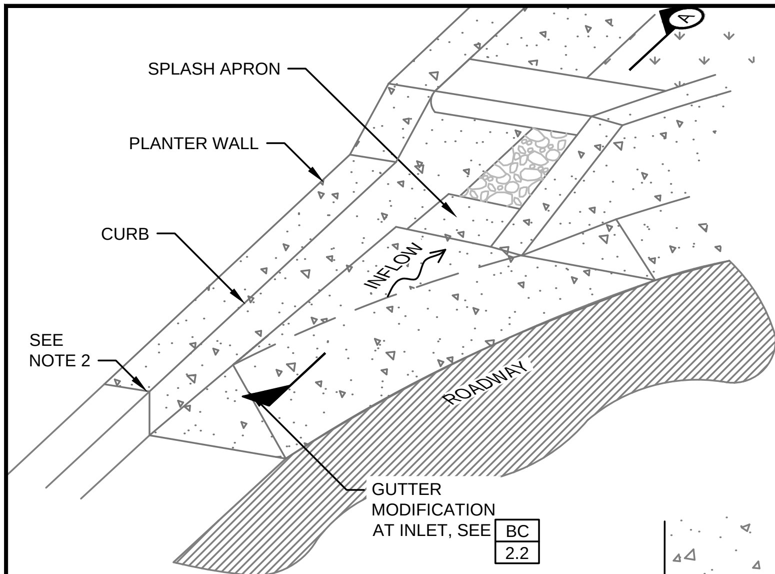
DETAIL ADAPTED FROM DUBLIN, CA (GI-6A), DISTRICT OF COLUMBIA DOT (DWG 621.45), AND PORTLAND, OR (SW-332)

DATE	JANUARY, 2019
VERSION	2.0
REVISED	OCTOBER, 2019

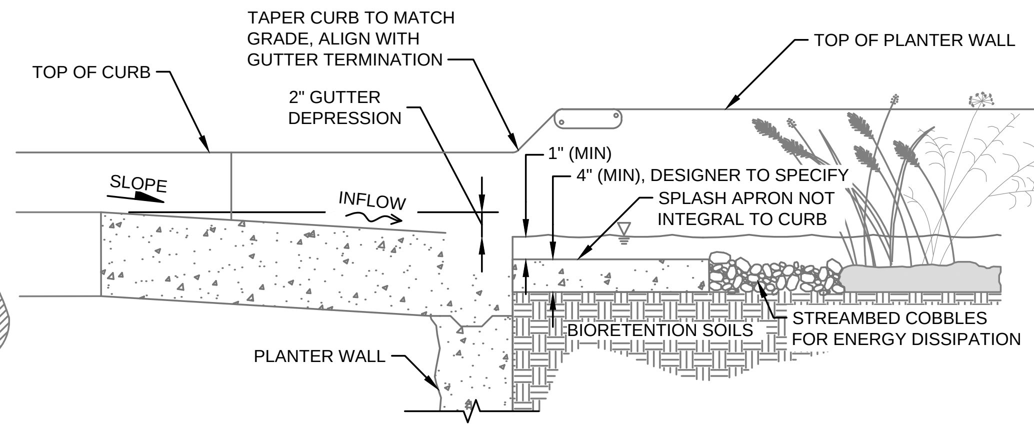
BIORETENTION COMPONENTS
INLETS
CURB CUT WITH METAL PLATE TOP

DWG NO. BC 2.2.1

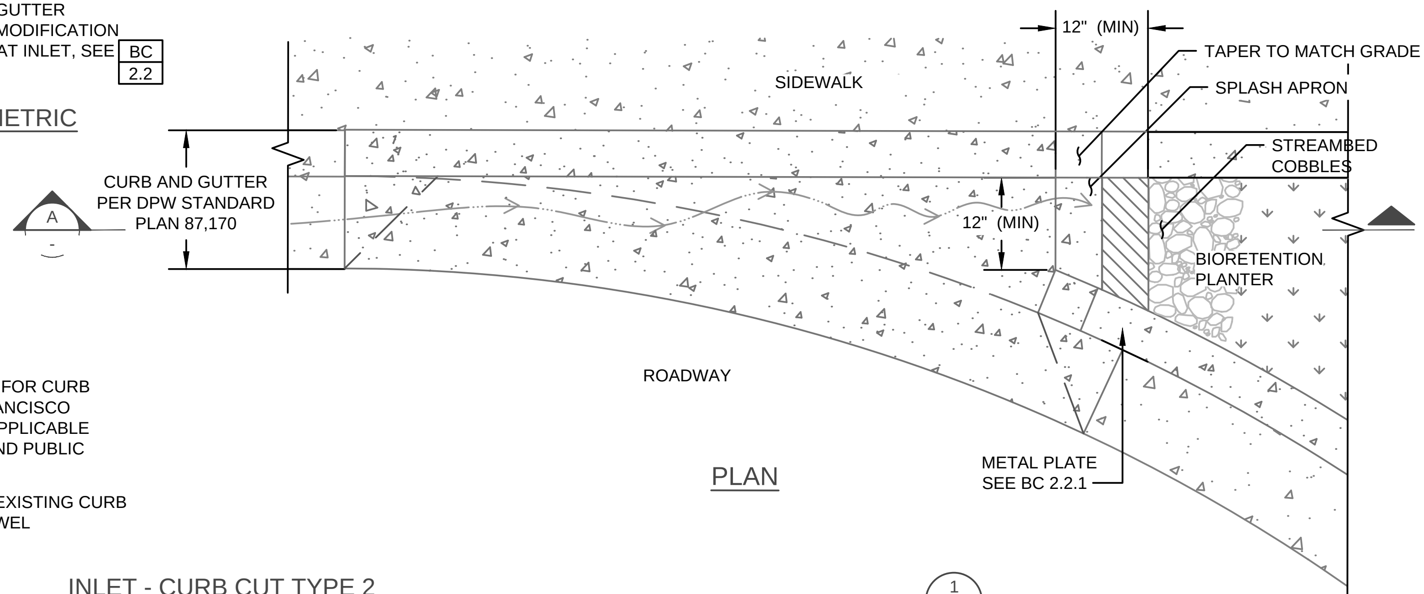
NOT FOR CONSTRUCTION - REFER TO USER GUIDE



ISOMETRIC



SECTION A



PLAN

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.

INLET - CURB CUT TYPE 2 (1)

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

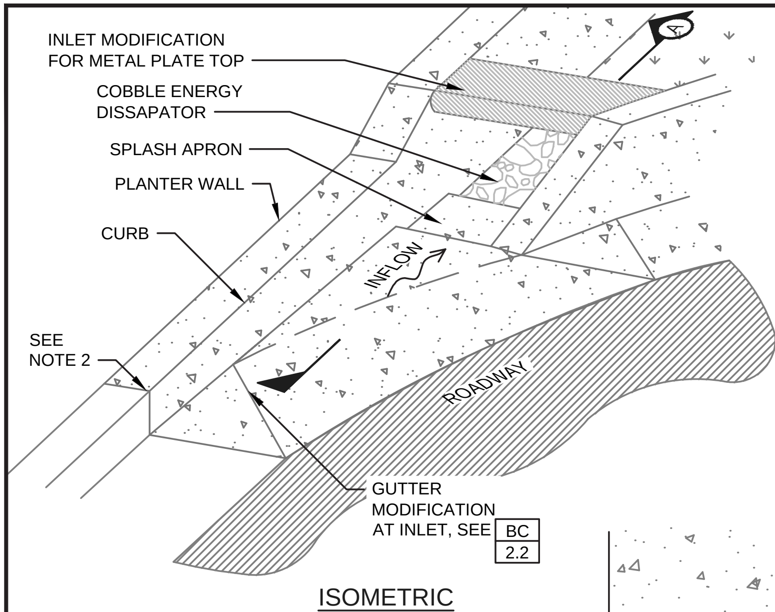
REVISED OCTOBER 2018

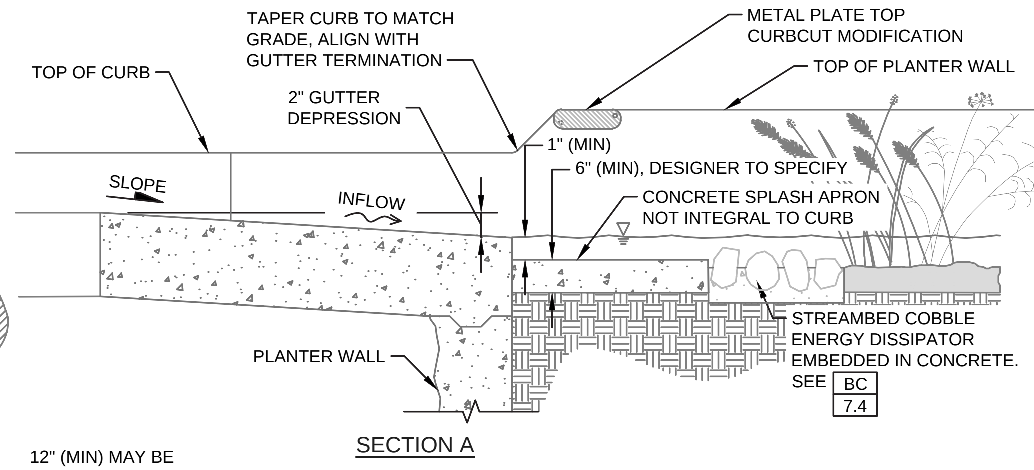
BIORETENTION COMPONENTS

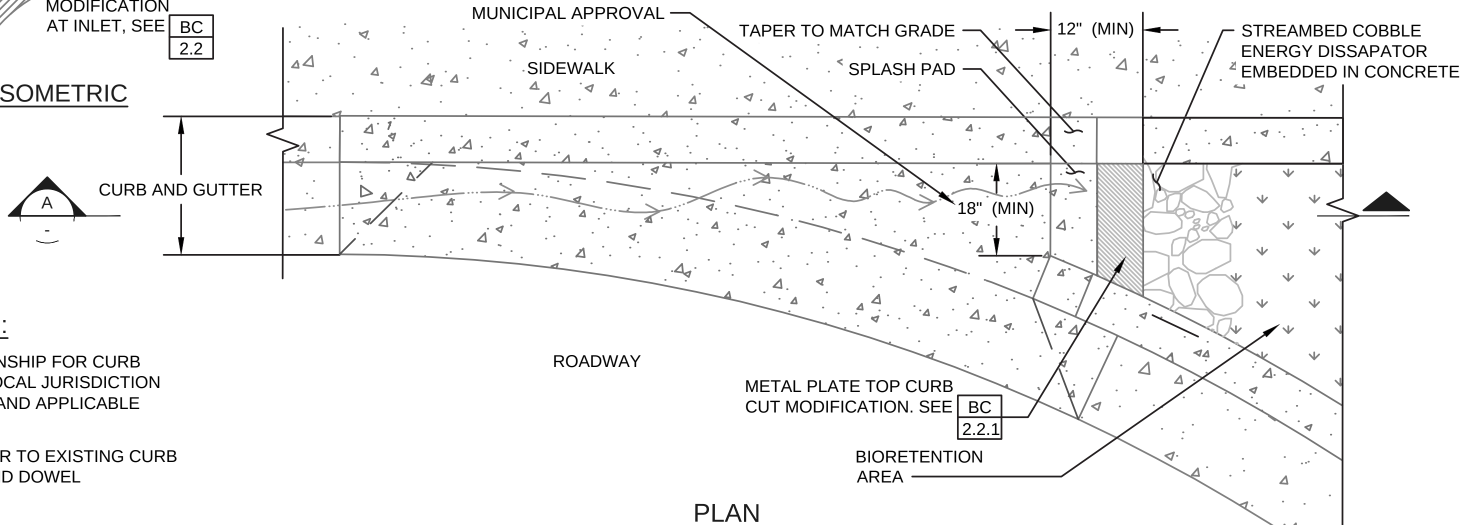
INLETS

CURB CUT AT BULB OUT

DWG NO. BC 2.3







CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO LOCAL JURISDICTION STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.

INLET - CURB CUT TYPE 2 (1)

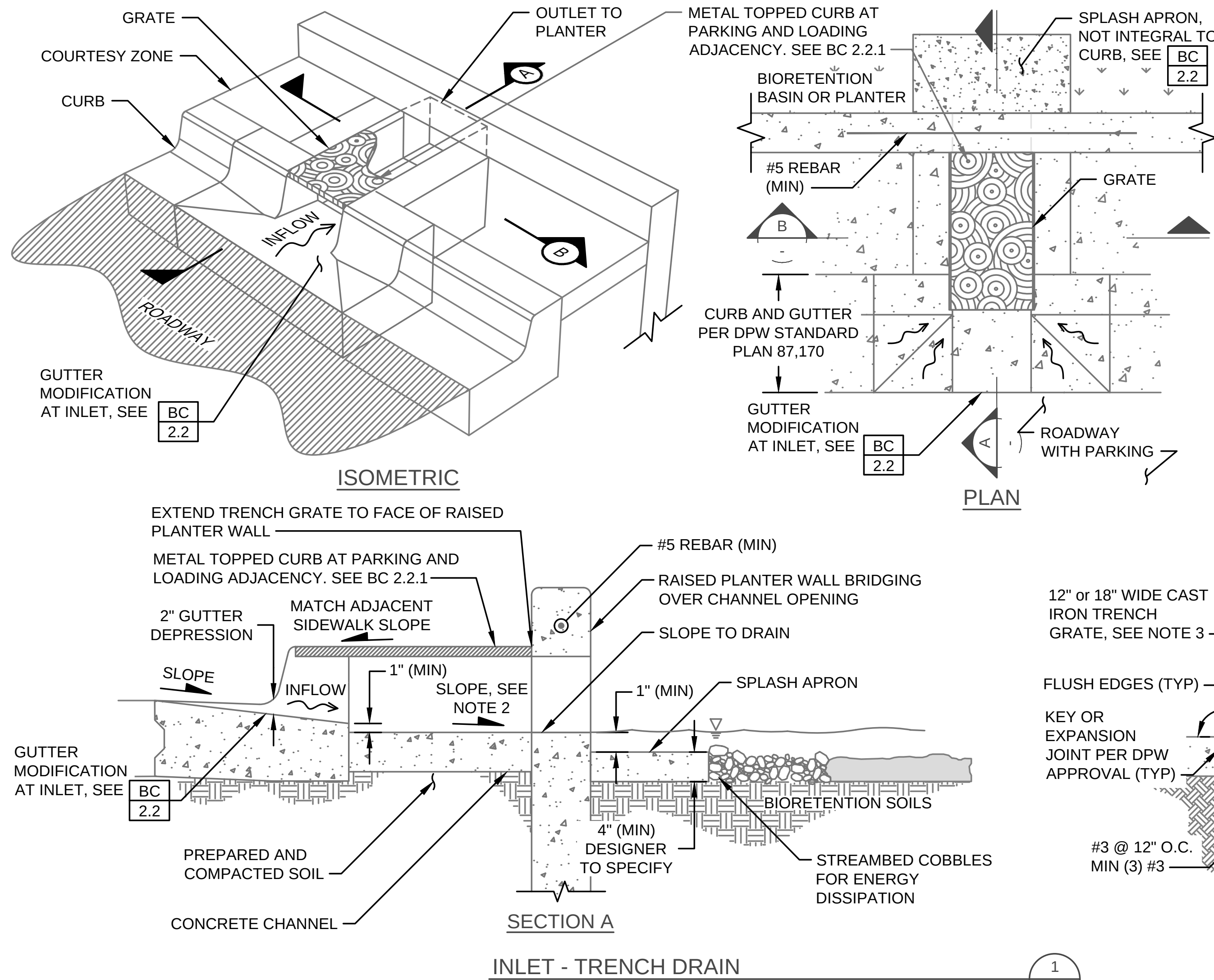
DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BC 2.3)

DATE JANUARY 2019
VERSION
REVISED

BIORETENTION COMPONENTS
INLETS - CURB CUT AT BULB OUT MODIFICATION WITH METAL PLATE TOP

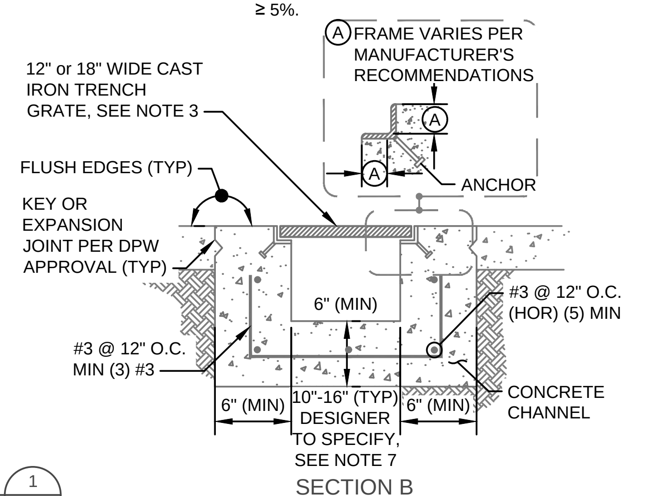
DWG NO. **BC 2.3.1**

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR A MINIMUM OF 2 PERCENT, WHICHEVER IS LARGER.
3. ALL TRENCH GRATES SHALL BE REMOVABLE, RATED PER THE ANTICIPATED LOADING, AND BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM, FLUSH OR RECESSED IN GRATE.
4. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
7. INLET CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE 16" (MIN) ON GUTTER SLOPES ≥ 5%.



INLET - TRENCH DRAIN 1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE COMPONENTS	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS				NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

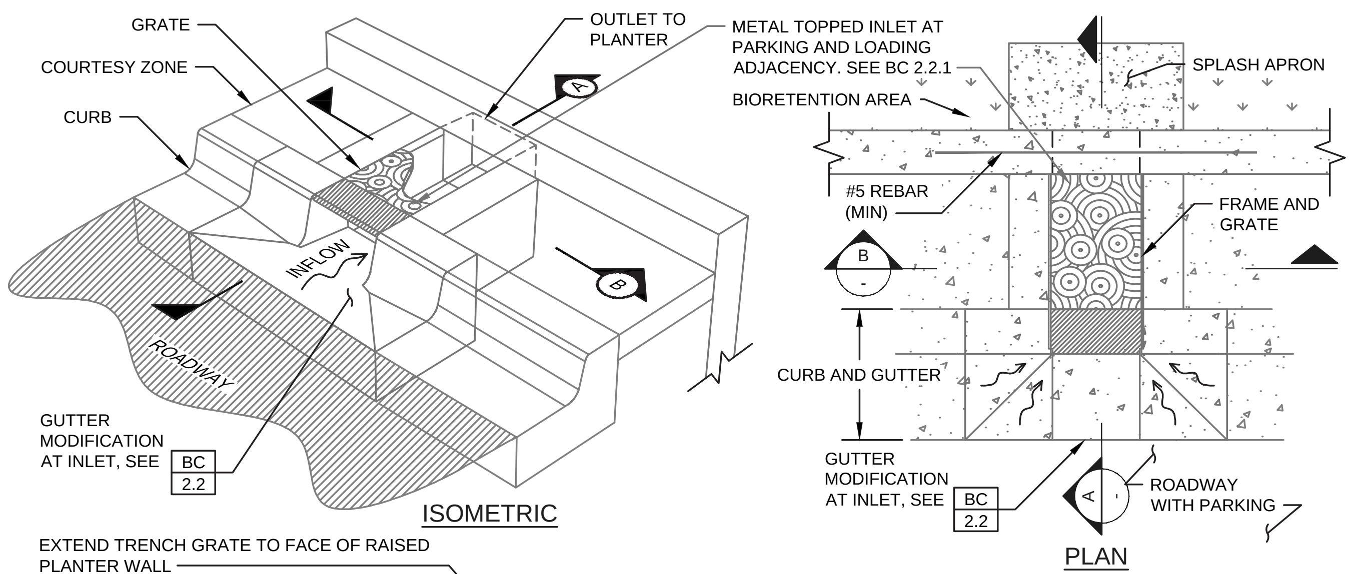
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS

INLETS

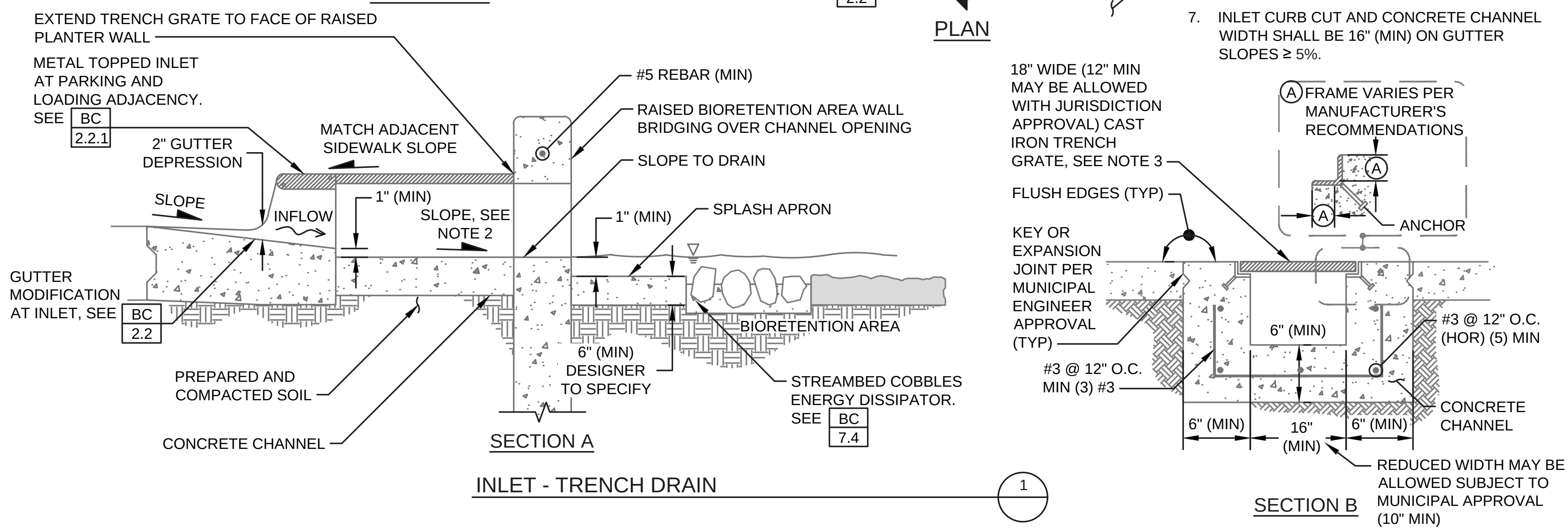
CURB CUT WITH TRENCH DRAINS

DWG NO. BC 2.4



CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO MUNICIPAL'S STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR A MINIMUM OF 2 PERCENT, WHICHEVER IS LARGER.
3. ALL TRENCH GRATES SHALL BE REMOVABLE, RATED PER THE ANTICIPATED LOADING, AND BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM, FLUSH OR RECESSED IN GRATE.
4. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
7. INLET CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE 16" (MIN) ON GUTTER SLOPES ≥ 5%.



INLET - TRENCH DRAIN (1)

EDGE TREATMENTS								INLETS					OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING			
NOTES	COMPONENTS							NOTES	COMPONENTS				NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS		
BC 1.1	BC 1.2	BC 1.2.1	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.2.1	BC 2.3	BC 2.4.1	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3	BC 7.4

DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BC 2.4)

DATE: JANUARY 2019
VERSION: 2.0
REVISED: OCTOBER, 2019

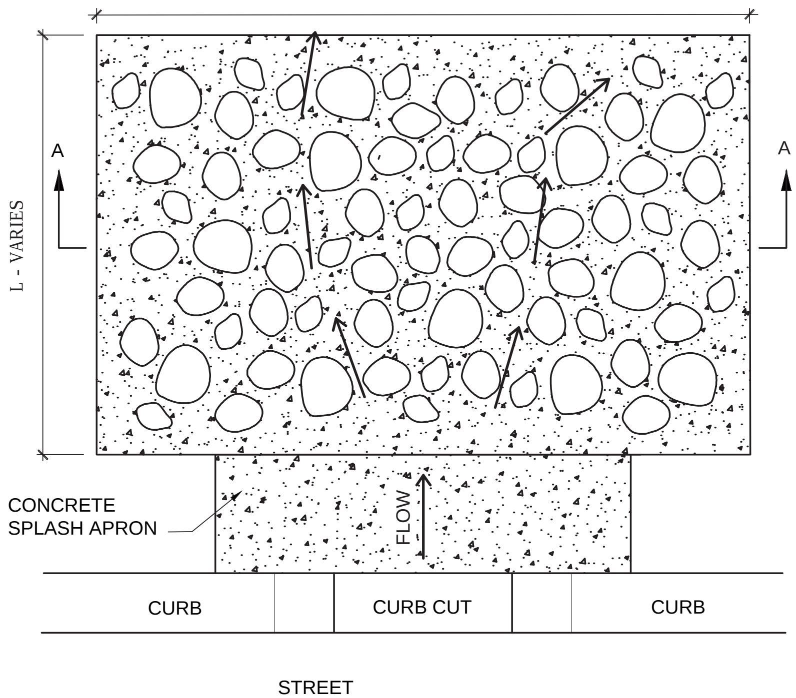
BIORETENTION COMPONENTS
INLETS
CURB CUT WITH TRENCH DRAINS MODIFICATION

DWG NO. BC 2.4.1

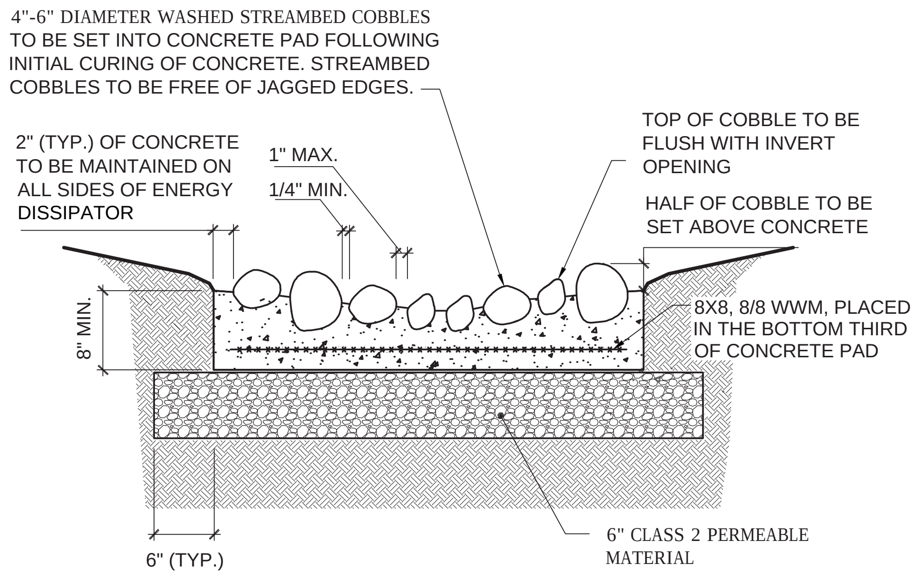
WIDTH (W) x LENGTH (L)
INLET:
W = EXTEND MIN. 12" BEYOND SPLASH APRON
L = EXTEND MIN. 12" BEYOND SPLASH APRON
OUTLET:
W= EXTEND 6" MIN. BEYOND BOTTOM OF CURB CUT
L = 12" MIN.

CONSTRUCTION NOTES:

1. COBBLES SHALL BE ARRANGED IN PATTERN THAT PREVENTS LINEAR FLOW PATHS THROUGH THE ENERGY DISSIPATOR.
2. ENSURE THAT SOIL BENEATH ENERGY DISSIPATOR IS STABLE AND WILL NOT SETTLE OVER TIME.
3. ENSURE CONCAVITY IN BOTH DIRECTIONS OF ENERGY DISSIPATOR.



PLAN



SECTION AA

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

DETAIL ADAPTED FROM: SAN FRANCISCO PUBLIC UTILITIES COMMISSION (BB 2.1)	DATE JANUARY 2019 / VERSION 2.0 / REVISED OCTOBER, 2019	EMBEDDED ROCK ENERGY DISSIPATOR	DWG NO. BC 2.5

PURPOSE:

BIORETENTION OUTLET STRUCTURES CONVEY SURFACE AND/OR SUBSURFACE OUTFLOWS FROM A BIORETENTION FACILITY TO AN APPROVED DISCHARGE LOCATION.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST SIZE CURB CUT, GRATE, AND OTHER OVERFLOW STRUCTURE FEATURES TO SATISFY RESPONSIBLE JURISDICTION HYDRAULIC REQUIREMENTS.
3. AN OUTLET STRUCTURE OR CLEANOUT(S) THAT ALLOWS MAINTENANCE ACCESS TO ALL PIPES IS REQUIRED FOR FACILITIES WITH UNDERDRAINS.
4. IF SITE CONSTRAINTS NECESSITATE STORM DRAIN PIPE IN AN AREA SUBJECT TO VEHICULAR TRAFFIC OR OTHER LOADING, APPROPRIATE COVER DEPTH AND PIPE MATERIAL MUST BE SPECIFIED.
5. OUTLET PIPES MUST BE EQUIPPED WITH CLEANOUTS, SEE CLEANOUT DETAILS (**GC 5.2**).
6. DESIGNER SHALL EVALUATE BUOYANCY OF STRUCTURES FOR SITE SPECIFIC APPLICATION AND SPECIFY THICKENED OR EXTENDED BASE / ANTI-FLOTATION COLLAR, AS NECESSARY.
7. SAND TRAP REQUIREMENTS (12 INCH SUMP AND CAST IRON HOOD/TRAP) MAY BE ELIMINATED WHEN OVERFLOW DIRECTLY DISCHARGES TO DOWNSTREAM JURISDICTIONAL SAND TRAP.
8. LOCATE ALL OVERFLOW PIPES AT AN ELEVATION HIGHER THAN THE SEWER HYDRAULIC GRADE LINE TO PREVENT BACKFLOW INTO THE BIORETENTION FACILITY.
9. USE CURB CUT INLET/OUTLET WITH METAL PLATE TOP (BC 2.2.1) WHEN ADJACENT TO VEHICLE PARKING AND LOADING AREAS

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ OUTLET STRUCTURE TYPE/MATERIAL, DIAMETER, AND DEPTH
- ☐ ATRIUM GRATE MANUFATURER, MODEL NO., AND SIZE
- ☐ SAND TRAP COMPONENTS AND DIMENSIONS
- ☐ FRAME AND GRATE TYPE, MODEL NO., AND SIZE
- ☐ CONTROL ELEVATIONS FOR OUTLET STRUCTURE RIMS
- ☐ MATERIAL AND DIAMETER FOR ALL PIPES

  WATER TIGHT CONNECTOR TYPE FOR ALL WALL PENETRATIONS (E.G., GROUTED, COMPRESSION, BOOT), SEE GC 2.9 AND GC 2.10
- ☐ CURB CUT WITH OR WITHOUT METAL PLATE TOP MODIFICATION

EDGE TREATMENTS							INLETS					OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS				NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.2.1	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BC 3.1)

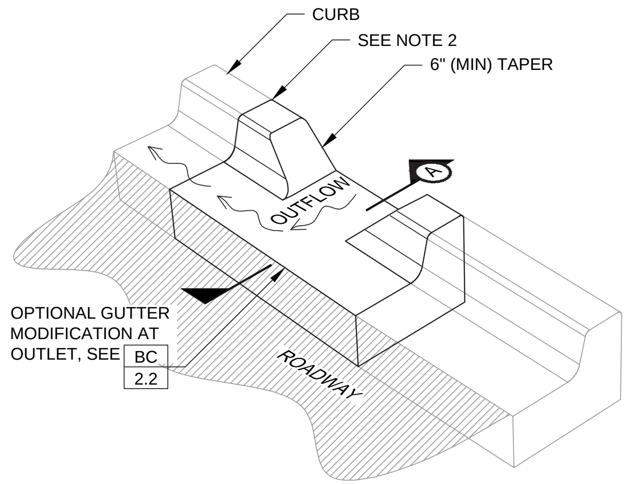
DATE JANUARY 2019

VERSION

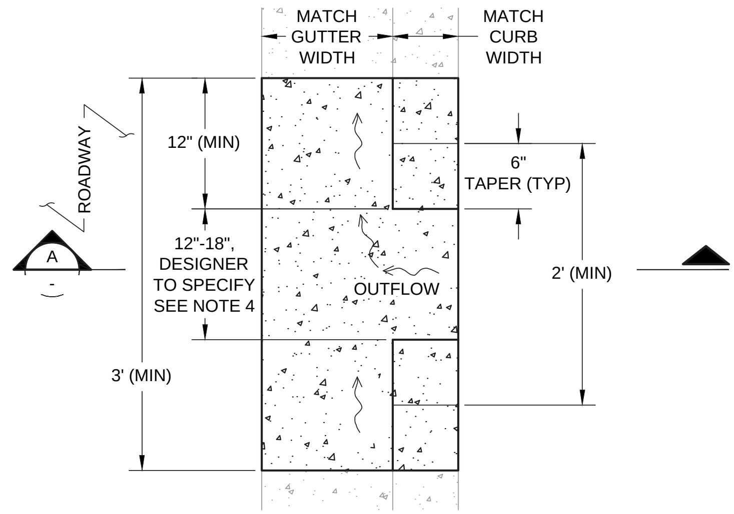
REVISED

BIORETENTION COMPONENTS
OUTLETS
DESIGNER NOTES

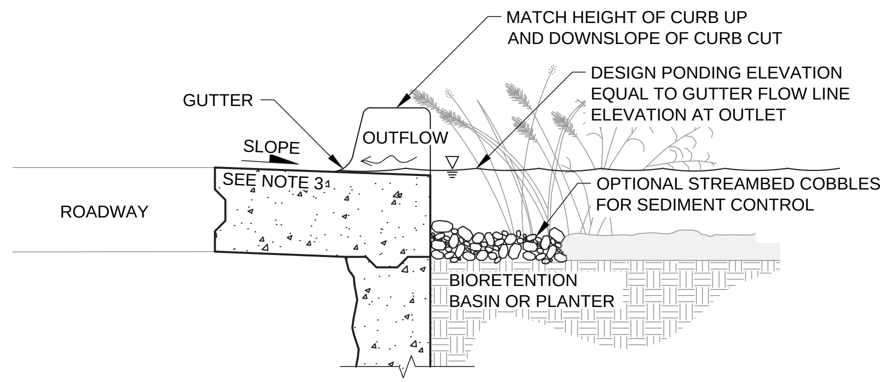
DWG NO. BC 3.1



ISOMETRIC



PLAN



SECTION A

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
3. MATCH GUTTER SLOPE UP AND DOWNSLOPE OF CURB CUT SLOPE SIMILAR TO INLET DETAIL UNLESS MODIFYING GUTTER
4. OUTLET CURB CUT WIDTH SHALL BE18" ON GUTTER SLOPES ≥ 5%

OUTLET - CURB CUT (1)

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

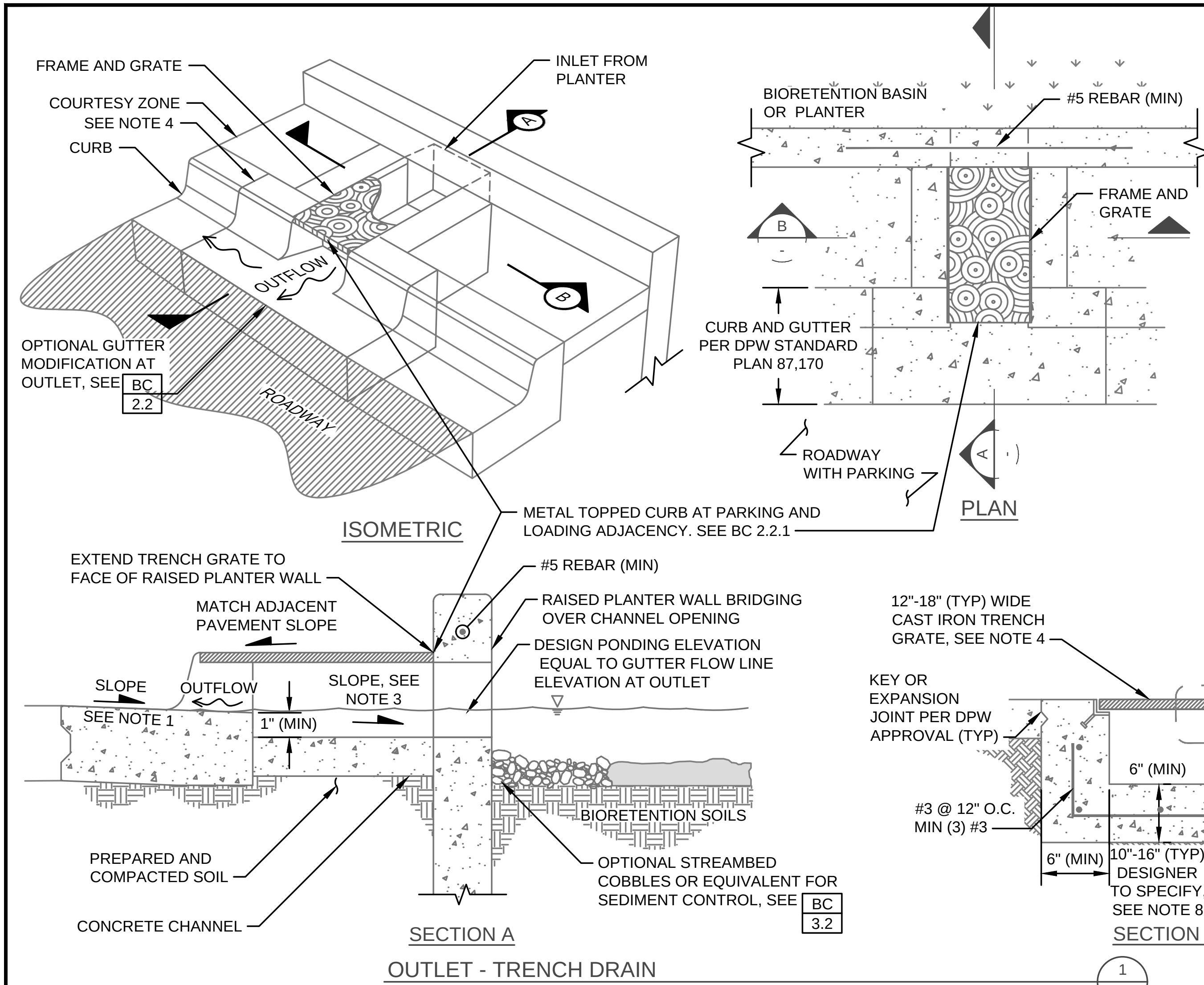
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS

OUTLETS
CURB CUT

DWG NO. BC 3.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. MATCH GUTTER SLOPE UP AND DOWNSLOPE (UNLESS MODIFYING GUTTER SLOPE INLET DETAIL).
3. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR A MINIMUM OF 2 PERCENT, WHICHEVER IS LARGER.
4. ALL TRENCH GRATES SHALL BE REMOVABLE, RATED PER THE ANTICIPATED LOADING, AND BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM, FLUSH OR RECESSED IN GRATE.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
7. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
8. INLET CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE 16" (MIN) ON GUTTER SLOPES ≥ 5%.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

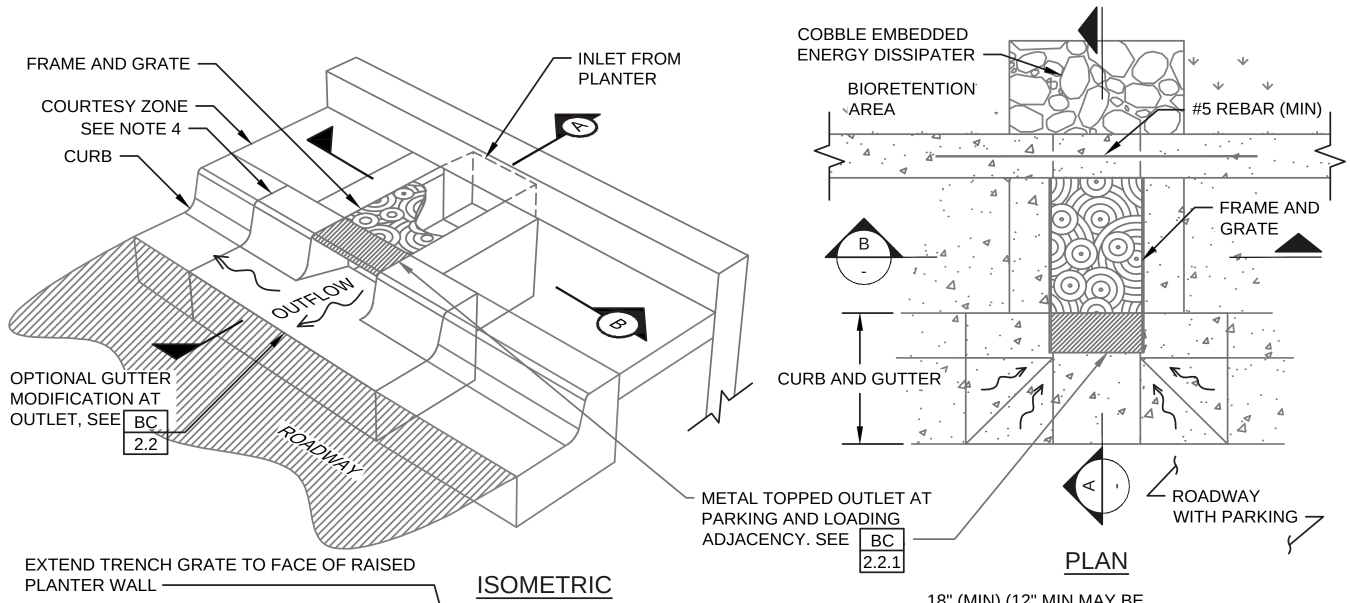
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

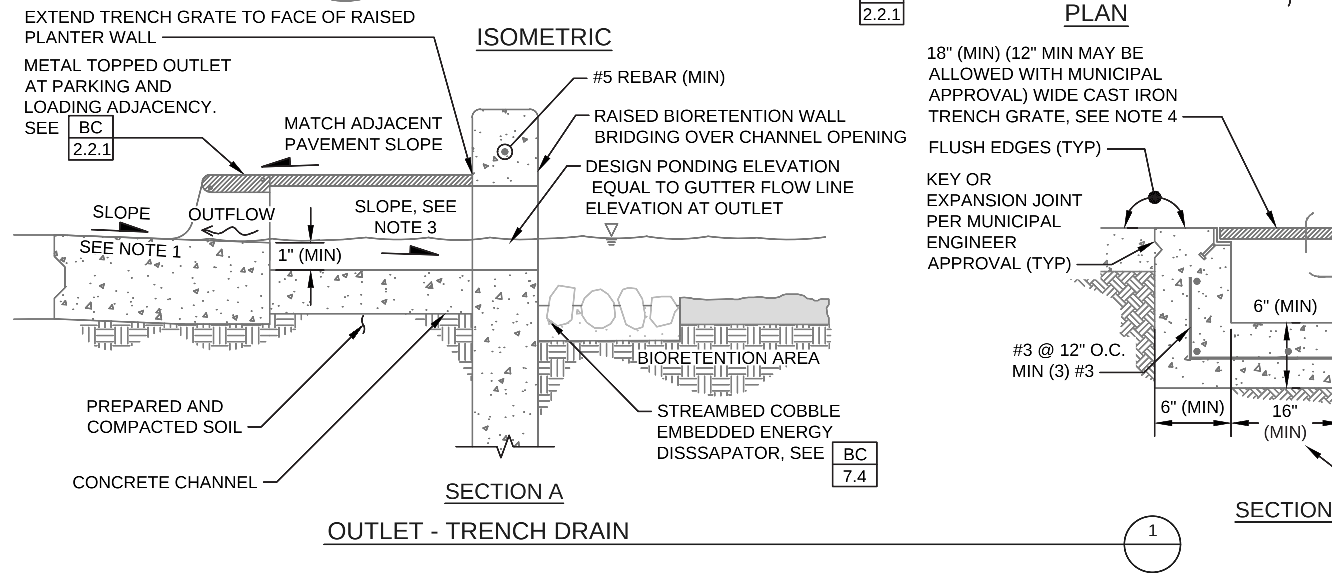
DATE SEPTEMBER 2016
VERSION 2.0
REVISED OCTOBER 2018

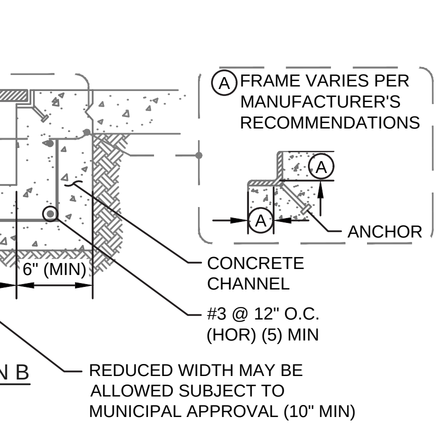
BIORETENTION COMPONENTS

OUTLETS
CURB CUT WITH TRENCH DRAIN

DWG NO. BC 3.3







OUTLET - TRENCH DRAIN (1)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO MUNICIPAL'S STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. MATCH GUTTER SLOPE UP AND DOWNSLOPE (UNLESS MODIFYING GUTTER SLOPE INLET DETAIL).
3. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR A MINIMUM OF 2 PERCENT, WHICHEVER IS LARGER.
4. ALL TRENCH GRATES SHALL BE REMOVABLE, RATED PER THE ANTICIPATED LOADING, AND BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM, FLUSH OR RECESSED IN GRATE.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
7. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
8. OUTLET CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE INCREASED ON STEEPER GUTTER SLOPES. DESIGNER TO SPECIFY.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

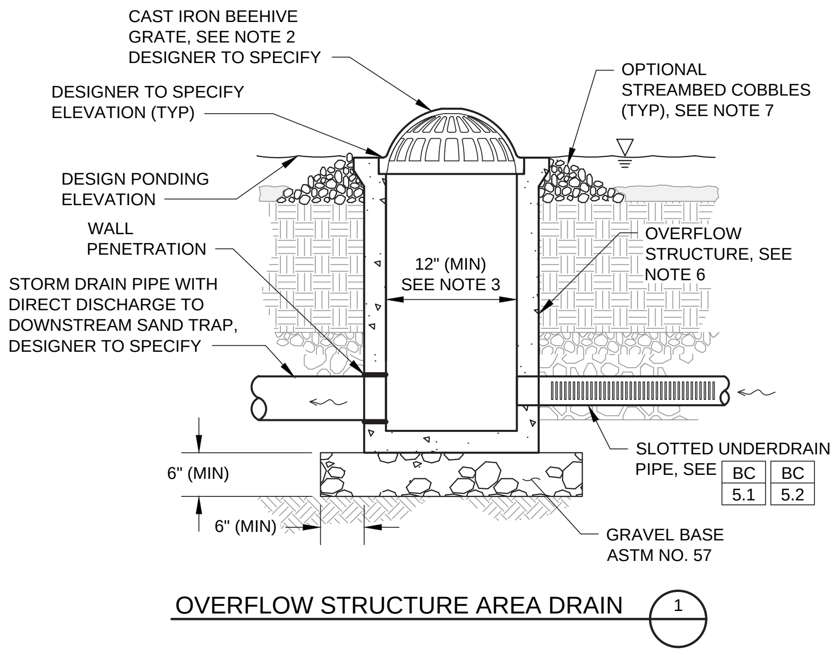
EDGE TREATMENTS								INLETS					OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS							NOTES	COMPONENTS				NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.2.1	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.2.1	BC 2.3	BC 2.4.1	BC 3.1	BC 3.2	BC 3.3.1	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(BC 3.3)

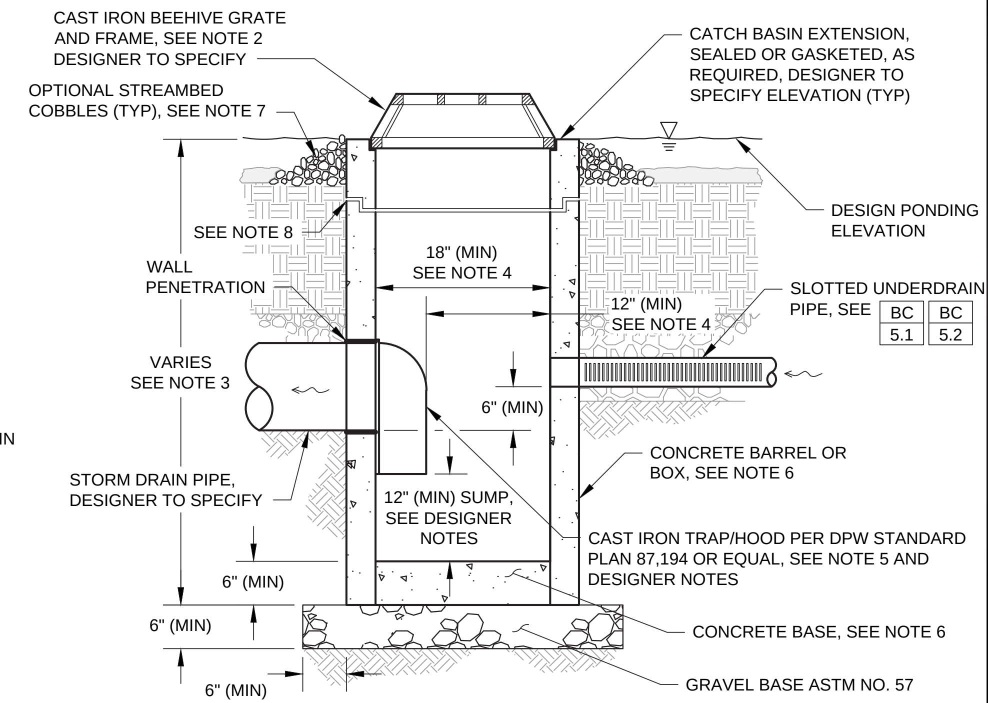
DATE JANUARY 2019
VERSION 2.0
REVISED OCTOBER 2019

BIORETENTION COMPONENTS
OUTLETS - CURB CUT WITH TRENCH DRAIN MODIFICATION AND METAL PLATE TOP OUTLET

DWG NO. BC 3.3.1



OVERFLOW STRUCTURE AREA DRAIN (1)



OVERFLOW STUCTURE WITH INTERGAL SAND TRAP (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. SIZE OF ATRIUM GRATE SHALL MATCH SIZE OF RISER SPECIFIED IN PLANS, SHALL BE REMOVABLE TO PROVIDE MAINTENANCE ACCESS, AND SHALL BE BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM. MAXIMUM GRATE OPENING SHALL BE 4 INCHES.
3. IF INTERIOR DEPTH OF OVERFLOW STRUCTURE EXCEEDS 5 FEET, A PERMANENT BOLTED LADDER AND MINIMUM CLEAR SPACE OF 30 INCH BY 30 INCH IN SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
4. 12 INCH (MIN) CLEARANCE WITHIN OVERFLOW STRUCTURE SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
5. INSTALL CAST IRON TRAP/HOOD PER MANUFACTURER'S RECOMMENDATIONS.
6. BARREL/BOX AND BASE OF CATCH BASIN MAY BE PRE-CAST WITH REINFORCING STEEL PER MANUFACTURER'S RECOMMENDATIONS, POURED IN PLACE CONCRETE WITHOUT STEEL PER SAN FRANCISCO STANDARD PLANS AND SPECIFICATIONS, OR NYLOPLAST DRAIN BASIN (2812AG OR EQUAL). ENGINEER TO SPECIFY.
7. MINIMUM STREAMBED COBBLE DIAMETER SHALL BE LARGER THAN MAXIMUM GRATE OPENING.
8. GROUT ALL PENETRATIONS, CRACKS, SEAMS, AND JOINTS WITH CLASS "C" MORTAR.

EDGE TREATMENTS							INLETS				OUTLETS			AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS		COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

Note: BC 3.4 is highlighted in the OUTLETS components group (BC 3.2, BC 3.3, BC 3.4).

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

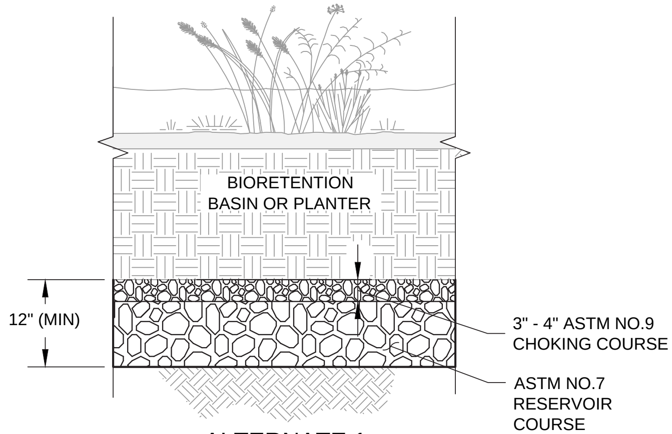
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS

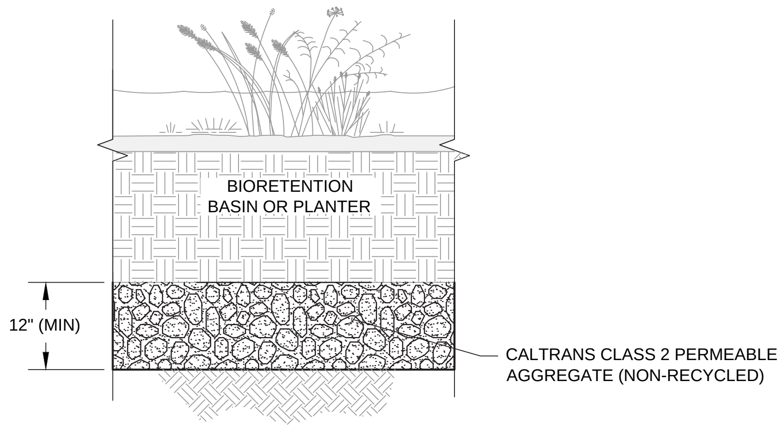
OUTLETS
OVERFLOW STRUCTURES

DWG NO. BC 3.4

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

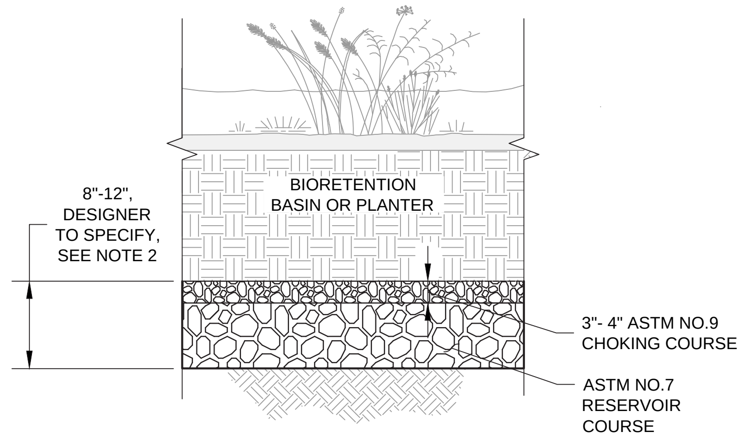


ALTERNATE 1



ALTERNATE 2

FOR USE IN SEPARATE SEWER SYSTEM AREAS



FOR USE IN COMBINED SEWER SYSTEM AREAS

DESIGNER NOTES & GUIDELINES:

1. DESIGNER SHALL INCORPORATE APPROPRIATE AGGREGATE STORAGE LAYER SECTION INTO BIORETENTION PLANTER OR BIORETENTION BASIN DETAIL.
2. TOTAL AGGREGATE STORAGE DEPTH IN COMBINED SEWER SYSTEM (INCLUDING CHOKING COURSE) SHALL BE 8 TO 12 INCHES FOR FACILITIES WITH UNDERDRAINS. DEPTH MAY BE INCREASED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS.
3. AGGREGATE STORAGE IS OPTIONAL FOR FACILITIES NOT REQUIRING UNDERDRAINS IN COMBINED SEWER SYSTEM AREAS.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

BIORETENTION COMPONENTS

AGGREGATE STORAGE LAYERS

DWG NO. BC 4.1

PURPOSE:

UNDERDRAINS ARE USED TO COLLECT STORMWATER THAT HAS BEEN FILTERED THROUGH BIORETENTION SOIL AND CONVEY THAT TREATED STORMWATER TO A DESIGNATED OUTLET (E.G., PLANTER OVERFLOW STRUCTURE).

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER SHOULD INCLUDE UNDERDRAINS IN FACILITY DESIGN IN THE FOLLOWING SCENARIOS:
   - INFILTRATION IS PROHIBITED OR IMPRUDENT (E.G., FACILITY NEAR SENSITIVE INFRASTRUCTURE OR STEEP SLOPES, RISK OF CONTAMINATION IS HIGH OR SITE GROUNDWATER/SOILS ARE CONTAMINATED, THERE IS POOR INFILTRATION CAPACITY DUE TO SOILS OR HIGH GROUNDWATER).
   - SUBGRADE MEASURED (I.E., UNCORRECTED) INFILTRATION RATE IS LESS THAN 0.5 INCHES PER HOUR.
   - MAXIMUM SURFACE POOL DRAWDOWN PERIOD CANNOT BE ACHIEVED (SEE **BB 1.1**, **BP 1.1**, AND **BP 5.1**).

3. AN OUTLET STRUCTURE AND/OR CLEANOUT(S) TO ALLOW MAINTENANCE ACCESS TO ALL PIPES IS REQUIRED FOR FACILITIES WITH UNDERDRAINS.
4. UNDERDRAIN PIPE SHALL HAVE A SMOOTH INTERIOR WALL TO FACILITATE MAINTENANCE WITH PRESSURIZED WATER OR ROOT CUTTING EQUIPMENT.
5. DESIGNER SHOULD CONSIDER THE INSTALLED ELEVATION OF THE UNDERDRAIN PIPE WITHIN THE BIORETENTION FACILITIES AGGREGATE STORAGE LAYER TO PROMOTE INFILTRATION, BELOW THE UNDERDRAIN, WHEN FEASIBLE. DESIGNER SHOULD ALSO CONSIDER THE USE OF ORIFICES OR OTHER CONTROL STRUCTURES TO PROVIDE ADDITIONAL INFILTRATION AND FLOW CONTROL BENEFITS WHERE APPLICABLE.
6. PIPE MATERIAL SHALL BE DESIGNED PER SAN FRANCISCO ENVIRONMENTAL CODE (CHAPTER 5, SECTION 509 AND CHAPTER 7, SECTION 706).

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ UNDERDRAIN MATERIAL TYPE AND SIZE
- ☐ UNDERDRAIN ELEVATION, SLOPE, AND LOCATION WITHIN BASIN OR PLANTER
- ☐ PIPE BEDDING MATERIAL SPECIFICATION (i.e. AGGREGATE STORAGE LAYER)
- ☐ DISCHARGE LOCATION TO OVERFLOW STRUCTURE
- ☐ CLEANOUT LOCATIONS AND MAINTENANCE ACCESS
- ☐ ORIFICE FLOW CONTROL STRUCTURE(S), AS APPLICABLE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

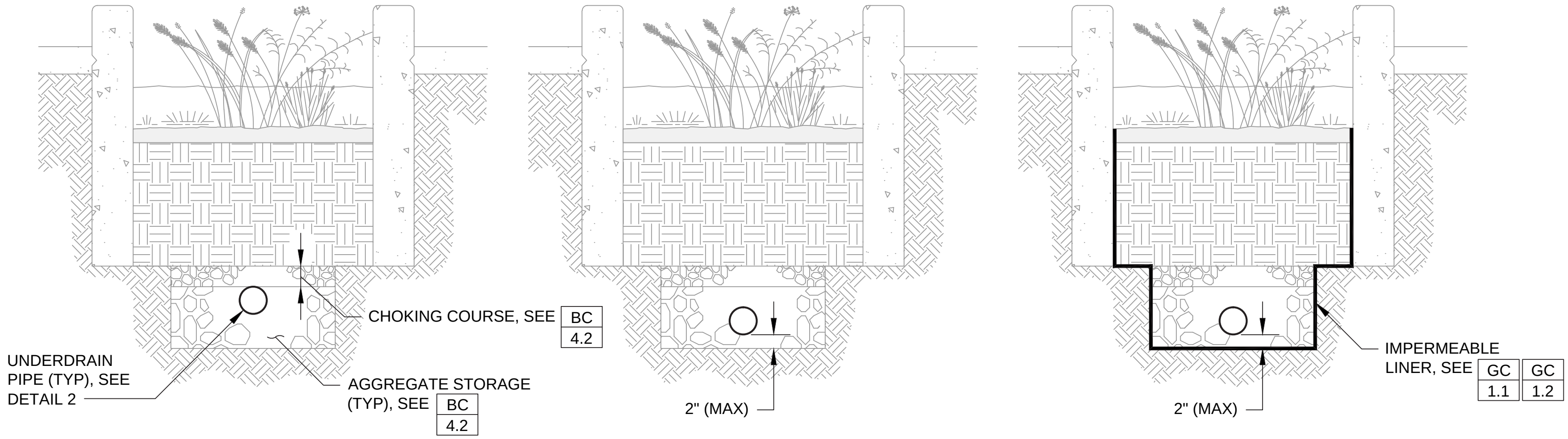
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

BIORETENTION COMPONENTS
UNDERDRAINS
DESIGNER NOTES

DWG NO. BC 5.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



ELEVATED UNDERDRAIN
TYPE B/C SOILS (WHEN REQUIRED)

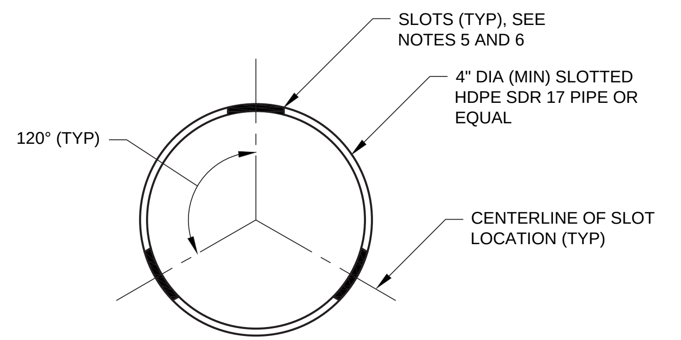
BOTTOM UNDERDRAIN
TYPE D SOILS

UNDERDRAIN WITH LINER
WHERE INFILTRATION PROHIBITED

UNDERDRAIN PLACEMENT ALTERNATIVES

CONSTRUCTION NOTES:

1. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE MATERIAL PER ENGINEERS SPECIFICATION.
2. ALL MATERIAL AND WORKMANSHIP FOR UNDERDRAINS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
3. SET CROWN OF UNDERDRAIN PIPE AT OR BELOW BOTTOM OF CHOKING COURSE. SEE DESIGNER NOTES FOR ADDITIONAL GUIDANCE ON LOCATING UNDERDRAIN PIPE IN GRAVEL STORAGE.
4. LONGITUDINAL SLOPE OF UNDERDRAIN PIPE SHALL BE 0.5% MINIMUM.
5. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE MATERIAL PER ENGINEERS SPECIFICATION. SINGLE WALL AND DUAL WALL CORRUGATED HDPE PIPE (AASHTO M252 AND M294 TYPES C, S, AND D) ARE NOT ACCEPTABLE.
6. UNDERDRAIN PIPE SHALL BE SLOTTED TYPE, MEASURING 0.032 INCH WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDING A MINIMUM INLET AREA OF 5.0 SQUARE INCH PER LINEAR FOOT OF PIPE.
7. SLOTS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.



SLOTTED UNDERDRAIN PIPE 2

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS
UNDERDRAINS

DWG NO. BC 5.2

PURPOSE:

CHECK DAMS ARE OFTEN USED IN BIORETENTION FACILITIES AT SLOPED LOCATIONS (ALIGNED PERPENDICULAR TO THE LONGITUDINAL SLOPE OF THE FACILITY) TO REDUCE FLOW VELOCITIES (AND EROSION) THROUGH THE FACILITY AND TO PROMOTE SURFACE PONDING, SUBSURFACE STORAGE, AND INFILTRATION OF STORMWATER. CHECK DAMS CAN BE CONSTRUCTED OF A VARIETY OF MATERIALS INCLUDING CONCRETE, WOOD, METAL, ROCK, OR COMPACTED SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST ESTABLISH THE HEIGHT AND SPACING OF CHECK DAMS BASED ON THE PONDING DEPTH REQUIRED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS AND THE MAXIMUM DESIRED DROP FROM THE SURROUNDING GRADE TO THE FACILITY BOTTOM. REFER TO CHECK DAM SPACING GUIDANCE PROVIDED ON THIS DRAWING FOR FURTHER GUIDANCE.
3. FOR BIORETENTION SWALES (SLOPED BOTTOM), THE AVERAGE DEPTH OF PONDING ACROSS THE FACILITY AREA MUST MEET THE REQUIRED STORAGE DEPTH.
4. CONCRETE CHECK DAM SHALL MEET STRUCTURAL REQUIREMENTS FOR LATERAL BRACING WHEN USED AS LATERAL BRACING. SEE **BC 1.6** AND **BC 1.7**.

THE DESIGNER SHALL SPECIFY THE FOLLOWING, AS APPLICABLE:

- ☐ CHECK DAM TYPE AND MATERIAL
- ☐ CHECK DAM HEIGHT, WIDTH, AND ELEVATION
- ☐ CHECK DAM SPACING

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

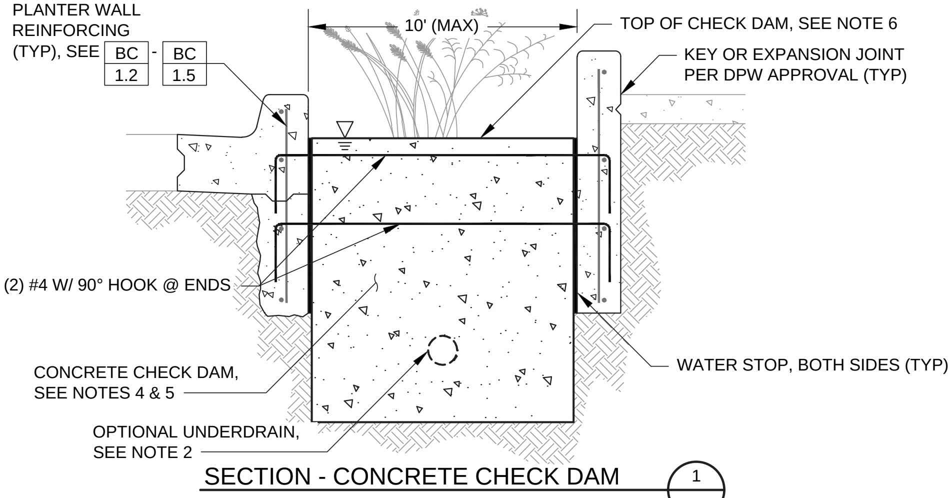
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

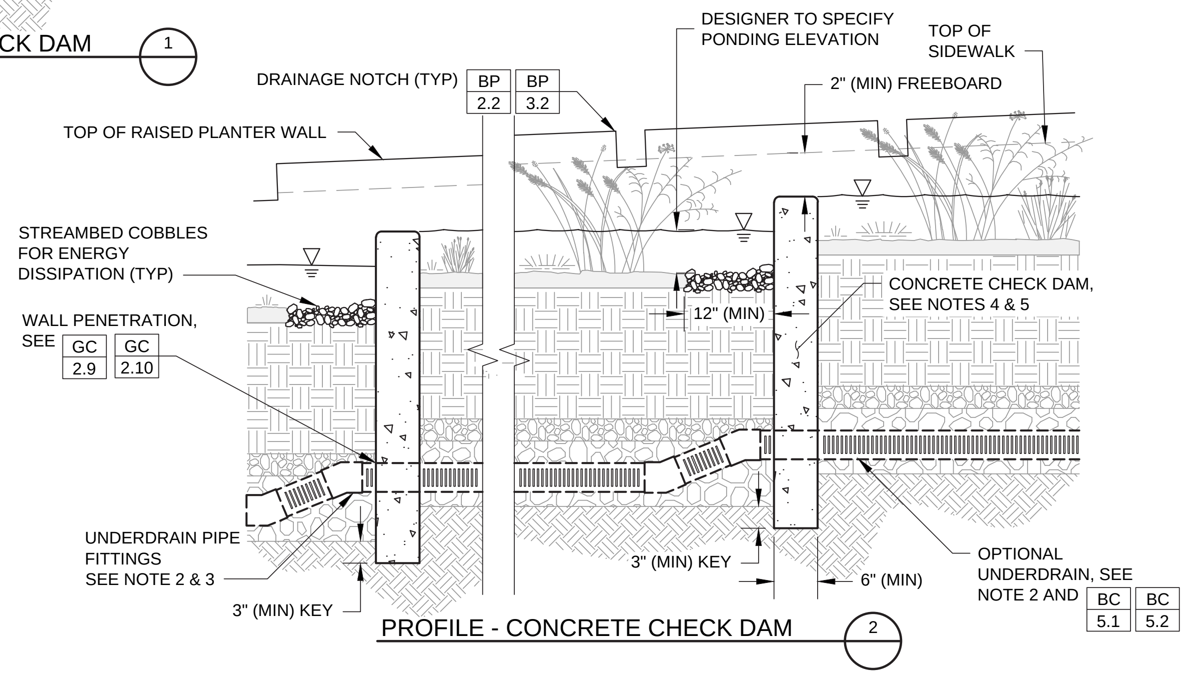
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS
CHECK DAMS
DESIGNER NOTES

DWG NO. BC 6.1



SECTION - CONCRETE CHECK DAM (1)



PROFILE - CONCRETE CHECK DAM (2)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CHECK DAM ASSEMBLY SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. UNDERDRAIN TO PASS THROUGH CHECK DAM IN NON-PERFORATED HDPE SDR 17 PIPE.
3. PIPE FITTINGS SHALL BE USED TO ACCOMMODATE CHANGES IN GRADE, AS NEEDED.
4. CONCRETE CHECK DAM SHALL BE CONTINUOUS (NO JOINTS) AND REINFORCED WITH #4 BAR, PLACED AT 18 INCHES ON CENTER, EACH WAY.
5. CONCRETE CHECK DAM SHALL MEET STRUCTURAL REQUIREMENTS FOR LATERAL BRACING WHEN USED AS LATERAL BRACING. COORDINATE WITH ENGINEER.
6. TOP OF CHECK DAM TO BE LEVEL WITH CREST ELEVATION MATCHING PONDING ELEVATION UNLESS NOTCH SIZED TO CONVEY DESIGN FLOWS PROVIDED.

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

BIORETENTION COMPONENTS

CHECK DAMS

DWG NO. BC 6.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

BIORETENTION OUTLET MONITORING SYSTEMS ARE DESIGNED TO MONITOR FLOWS IN THE UNDERDRAIN, OVERFLOW, AND OTHER OUTLET PIPES. THESE FLOWS ARE TYPICALLY VERY SMALL, REQUIRING THE USE OF SENSITIVE EQUIPMENT (WEIRS, STILLING WELLS, AND HIGHLY SENSITIVE PRESSURE TRANSDUCERS) TO PRODUCE ACCURATE FLOW ESTIMATES. THESE GUIDELINES WILL HELP THE DESIGNER TO DESIGN A SYSTEM WHICH WILL BE CONDUCIVE TO FLOW MEASUREMENT USING THIS EQUIPMENT.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT THE SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST CONSULT WITH EQUIPMENT MANUFACTURER'S REPRESENTATIVE AND MONITORING PROFESSIONAL OR TECHNICIAN PRIOR TO COMPLETION OF DESIGN.
3. UNDERDRAIN AND BYPASS FLOW SHOULD BE MEASURED WITH THE USE OF VOLUMETRIC PIPE WEIRS, STILLING WELLS, AND PRESSURE TRANSDUCERS.
4. **THE OUTLET AND UNDERDRAIN PIPES SHALL BE AT LEAST 6 INCHES IN DIAMETER AT BIORETENTION MONITORING WEIR LOCATIONS.** A REDUCER COUPLING MAY BE USED TO TRANSITION FROM PIPE DIAMETERS LESS THAN 6 INCHES TO 6 INCHES MINIMUM DIAMETER PROVIDED TRANSITION OCCURS A MINIMUM OF 3 FEET UPSTREAM OF WEIR. THE DESIGNER MUST EVALUATE AND MITIGATE THE IMPACT OF THE PIPE WEIRS ON PIPE CONVEYANCE CAPACITY AND PIPE INVERT ELEVATION.
5. PRESSURE TRANSDUCERS MAY BE VENTED OR UNVENTED. IF UNVENTED, A NEARBY BAROMETRIC TRANSDUCER OF THE SAME MAKE SHOULD BE INSTALLED FOR ATMOSPHERIC PRESSURE CORRECTION.
6. WHEN MEASURING FLOW ENTERING THE MONITORING STRUCTURE:
   - PVC STILLING WELLS MUST BE VENTED ABOVE THE HIGH WATER LINE AND WATER TIGHT BELOW THE HIGH WATER LINE (OR WATER TIGHT WITHIN THE SUMP, IF PERFORATED).
   - INSTALL FLEXIBLE TUBING THROUGH FACE OF PIPE WEIR AND STILLING WELL WALL WITH WATERTIGHT FITTINGS. TUBE SHALL PASS THROUGH WEIR AND EXTEND 2 INCHES BEYOND WEIR FACE TO AVOID MEASURING WATER DEPTH NEAR NAPPE OF WEIR. TUBE SHALL PASS THROUGH THE FACE OF THE WEIR AS FAR FROM WEIR CREST AS PRACTICABLE TO AVOID IMPACTS ON FLOW DYNAMICS.
7. WHEN MEASURING FLOW EXITING THE MONITORING STRUCTURE:
   - PVC STILLING WELLS MUST BE PERFORATED BELOW THE INVERT OF THE OUTLET PIPE. PERFORATIONS SHOULD ALWAYS BE ABOVE THE TOP OF THE PRESSURE TRANSDUCER HOUSING TO PROVIDE A PERMANENT WET POOL FOR THE TRANSDUCER.
   - THE STRUCTURE SHALL BE WATER TIGHT. CALIBRATION OF THE WEIR IN THE OUTLET PIPE WILL BE DIFFICULT IF LARGE VOLUMES OF WATER ARE NEEDED TO INCREASE THE WATER LEVEL IN THE STRUCTURE TO THE INVERT OF THE PIPE WEIR.
8. THE MONITORING STRUCTURE SHOULD BE LARGE ENOUGH TO PROVIDE ACCESS FOR INSTALLATION, MAINTENANCE, AND REMOVAL OF MONITORING EQUIPMENT.
9. THE DESIGNER MUST ENSURE THAT BACKWATER CONDITIONS DO NOT OCCUR IN THE MONITORING STRUCTURE. IF THE VOLUMETRIC WEIRS ARE SUBMERGED DUE TO BACKWATER THEY WILL NOT FUNCTION PROPERLY.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ MONITORING STRUCTURE TYPE/MATERIAL, DIAMETER, AND DEPTH
- ☐ PRESSURE TRANSDUCER TYPE AND SPECIFICATIONS
- ☐ WEIR TYPE, SIZE, AND RATING CURVES
- ☐ CONTROL ELEVATIONS FOR WEIRS, STILLING WELLS, AND PRESSURE TRANSDUCERS
- ☐ MATERIAL TYPE AND SIZE FOR ALL PIPES AND TUBING
- ☐ DIAGRAM WITH ALL OUTLET MONITORING ASSEMBLY COMPONENTS IDENTIFIED OR REQUEST FOR CONTRACTOR SUBMITTAL OF MONITORING ASSEMBLY

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

EDGE TREATMENTS							INLETS				OUTLETS				AGGREGATE STORAGE	UNDERDRAINS		CHECK DAM		MONITORING		
NOTES	COMPONENTS						NOTES	COMPONENTS			NOTES	COMPONENTS			COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	NOTES	COMPONENTS	
BC 1.1	BC 1.2	BC 1.3	BC 1.4	BC 1.5	BC 1.6	BC 1.7	BC 2.1	BC 2.2	BC 2.3	BC 2.4	BC 3.1	BC 3.2	BC 3.3	BC 3.4	BC 4.1	BC 5.1	BC 5.2	BC 6.1	BC 6.2	BC 7.1	BC 7.2	BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016

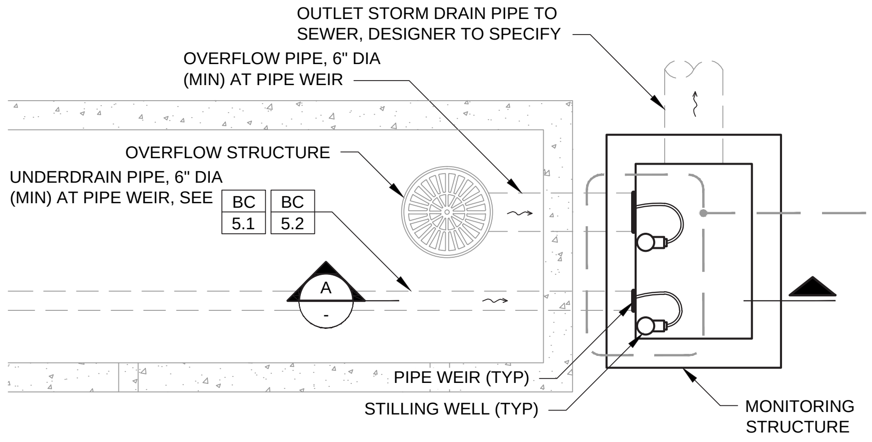
VERSION: 2.0

REVISED:

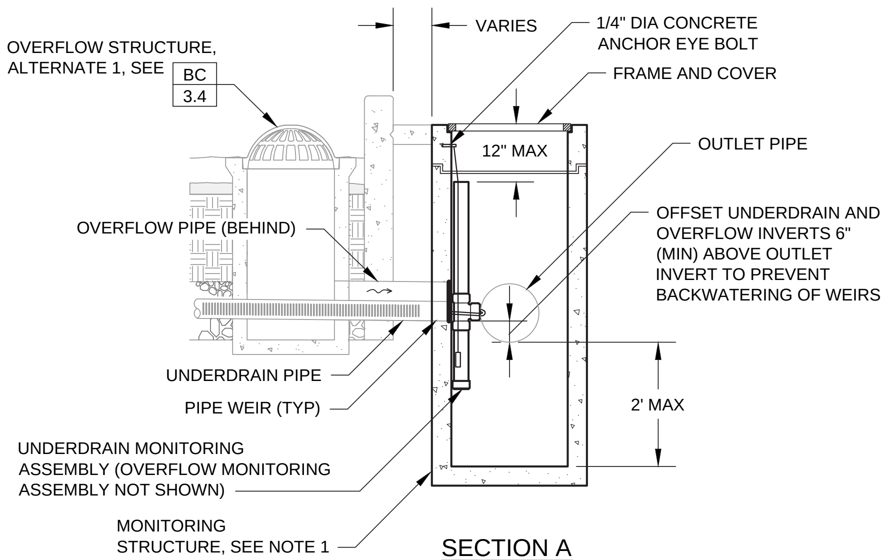
BIORETENTION COMPONENTS

OUTLET MONITORING DESIGNER NOTES

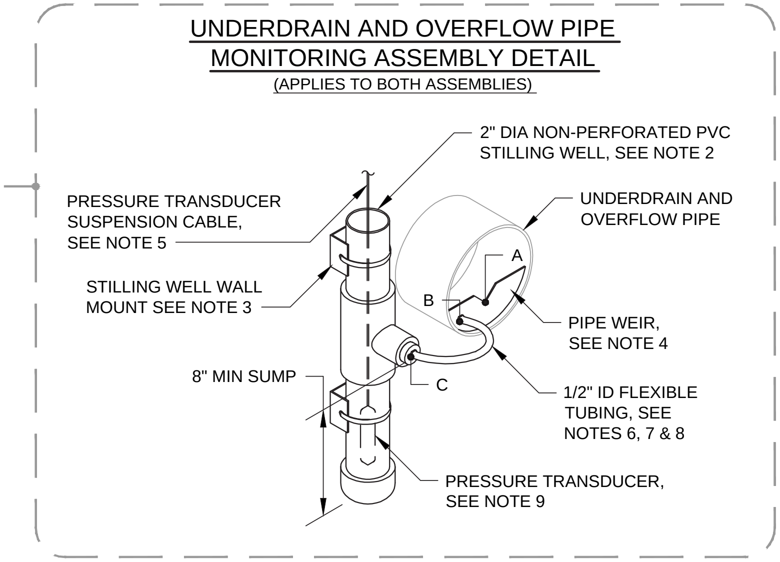
DWG NO. BC 7.1



PLAN



SECTION A



CONSTRUCTION NOTES:

1. MONITORING STRUCTURES WITH AN INTERIOR DEPTH GREATER THAN 5 FEET SHALL HAVE A MINIMUM CLEAR SPACE OF 30 INCH BY 30 INCH ACCESSIBLE BY A PERMANENT BOLTED LADDER.
2. STILLING WELL SHALL BE MOUNTED VERTICALLY AND ALL FITTINGS SHALL BE WATERTIGHT.
3. ATTACH STILLING WELL WITH PREFABRICATED METAL STRUT CHANNEL AND PIPE CLAMPS (2 MINIMUM) PER MANUFACTURERS RECOMMENDATION.
4. PIPE WEIR SHALL BE INSTALLED LEVEL AND WITHIN 1 INCH OF END OF PIPE.
5. PRESSURE TRANSDUCER SUSPENSION CABLE SHALL BE 1/16 INCH COATED STAINLESS STEEL CABLE WITH FERRULED CABLE LOOP AND COMPATIBLE OVAL CARABINER FOR CONNECTION TO CONCRETE ANCHOR EYE BOLT.
6. INSTALL FLEXIBLE TUBING THROUGH FACE OF PIPE WEIR AND STILLING WELL WALL WITH WATERTIGHT FITTINGS. TUBE SHALL PASS THROUGH WEIR AND EXTEND 2 INCHES BEYOND WEIR FACE .TUBE SHALL BE INSTALLED AS FAR FROM WEIR CREST AS PRACTICABLE, SEE DESIGNER NOTES.
7. ATTACH TUBE BELOW WEIR NOTCH (POINT B SHALL BE BELOW POINT A).
8. PROVIDE NEGATIVE SLOPE IN TUBE (POINT C SHALL BE BELOW POINT B).
9. PRESSURE TRANSDUCER SHALL BE RATED FOR ZERO TO 21 PSI OF PRESSURE AND AN ACCURACY OF ±0.1 PERCENT FULL SCALE RANGE OR BETTER AT 25°C.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

Section	Notes	Components
EDGE TREATMENTS	BC 1.1	BC 1.2, BC 1.3, BC 1.4, BC 1.5, BC 1.6, BC 1.7
INLETS	BC 2.1	BC 2.2, BC 2.3, BC 2.4
OUTLETS	BC 3.1	BC 3.2, BC 3.3, BC 3.4
AGGREGATE STORAGE COMPONENTS		BC 4.1
UNDERDRAINS	BC 5.1	BC 5.2
CHECK DAM	BC 6.1	BC 6.2
MONITORING	BC 7.1	BC 7.2, BC 7.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

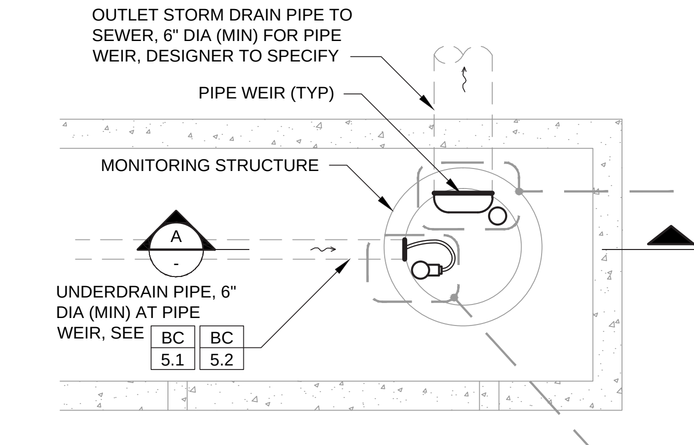
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

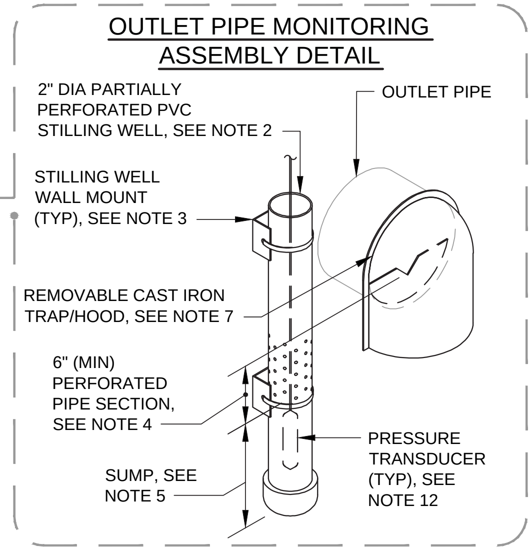
BIORETENTION COMPONENTS

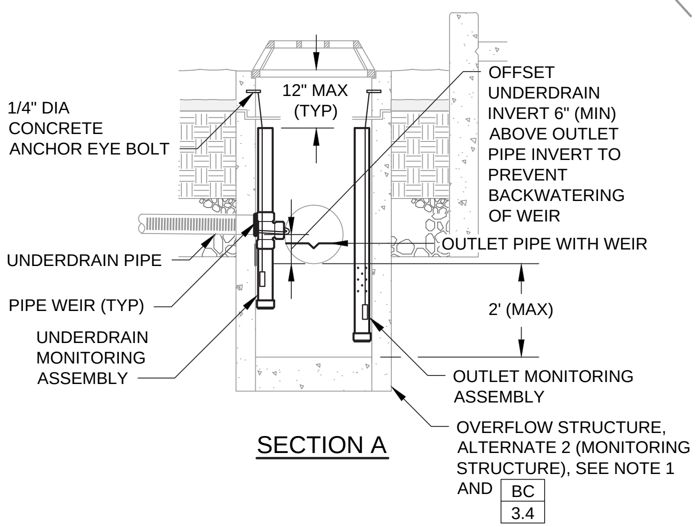
OUTLET MONITORING EXTERNAL ACCESS STRUCTURE

DWG NO. BC 7.2

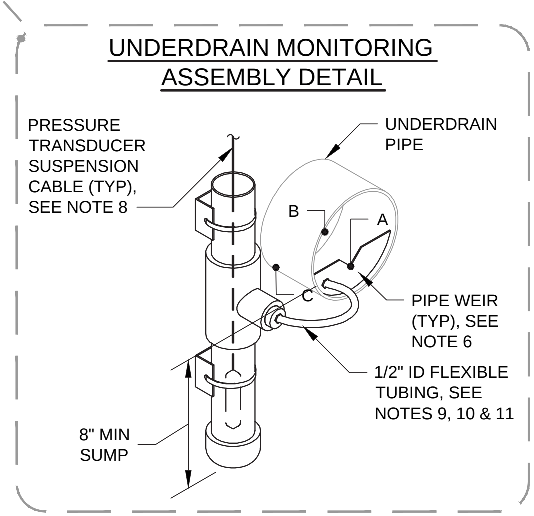


PLAN





SECTION A



CONSTRUCTION NOTES:

1. MONITORING STRUCTURES WITH AN INTERIOR DEPTH GREATER THAN 5 FEET SHALL HAVE A MINIMUM CLEAR SPACE OF 30 INCH BY 30 INCH ACCESSIBLE BY A PERMANENT BOLTED LADDER.
2. STILLING WELL SHALL BE MOUNTED VERTICALLY AND ALL FITTINGS SHALL BE WATERTIGHT.
3. ATTACH STILLING WELL WITH PREFABRICATED METAL STRUT CHANNEL AND PIPE CLAMPS (2 MINIMUM) PER MANUFACTURERS RECOMMENDATION.
4. PROVIDE PERFORATIONS ALONG CIRCUMFERENCE OF STILLING WELL BETWEEN OUTLET PIPE INVERT AND PRESSURE TRANSDUCER SUMP. PERFORATIONS SHALL MEASURE 1/4 INCH DIAMETER (MINIMUM) AT 1 INCH (MAXIMUM) ON-CENTER SPACING, ALL DIRECTIONS.
5. STILLING WELL SUMP SHALL BE NON-PERFORATED AND EXTEND 4 INCHES (MINIMUM) BELOW AND 2 INCHES (MINIMUM) ABOVE PRESSURE TRANSDUCER HOUSING TO ALLOW FOR SEDIMENT ACCUMULATION IN THE BOTTOM OF THE WELL AND PROVIDE A PERMANENT WET POOL FOR THE TRANSDUCER.
6. PIPE WEIR SHALL BE INSTALLED LEVEL AND WITHIN 1 INCH OF END OF PIPE.
7. REMOVABLE CAST IRON TRAP/HOOD SHALL BE NEENAH R-3701 SERIES, NEENAH R-3711 SERIES OR EQUAL. INSTALL TRAP/HOOD PER MANUFACTURERS RECOMMENDATION.
8. PRESSURE TRANSDUCER SUSPENSION CABLE SHALL BE 1/16 INCH COATED STAINLESS STEEL CABLE WITH FERRULED CABLE LOOP AND COMPATIBLE OVAL CARABINER FOR CONNECTION TO CONCRETE ANCHOR EYE BOLT.
9. INSTALL FLEXIBLE TUBING THROUGH FACE OF PIPE WEIR AND STILLING WELL WALL WITH WATERTIGHT FITTINGS. TUBE SHALL PASS THROUGH WEIR AND EXTEND 2 INCHES BEYOND WEIR FACE. TUBE SHALL BE INSTALLED AS FAR FROM WEIR CREST AS PRACTICABLE, SEE DESIGNER NOTES.
10. ATTACH TUBE BELOW WEIR NOTCH (POINT B SHALL BE BELOW POINT A).
11. PROVIDE NEGATIVE SLOPE IN TUBE (POINT C SHALL BE BELOW POINT B).
12. PRESSURE TRANSDUCER SHALL BE RATED FOR ZERO TO 21 PSI OF PRESSURE AND AN ACCURACY OF ±0.1 PERCENT FULL SCALE RANGE OR BETTER AT 25°C.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE	AUGUST 2016
VERSION	2.0
REVISED	

BIORETENTION COMPONENTS

OUTLET MONITORING
INTERNAL CATCH BASIN MONITORING

DWG NO. BC 7.3

PURPOSE:

SUBSURFACE INFILTRATION SYSTEMS, ALSO KNOWN AS DRY WELLS, STORMWATER DRAINAGE WELLS, INFILTRATION GALLERIES, AND SEEPAGE PITS, CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF THROUGH SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS ALSO TREATED AS IT FILTERS THROUGH THE GRAVEL, SAND (IF PROVIDED), AND NATIVE SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. SUBSURFACE INFILTRATION SYSTEMS ARE CONSIDERED CLASS V INJECTION WELLS AND SUBJECT TO THE U.S. EPA UNDERGROUND INJECTION CONTROL (UIC) PROGRAM. SUBSURFACE INFILTRATION SYSTEMS MUST BE REGISTERED WITH EPA REGION IX PRIOR TO COMING ONLINE.
3. FIELD-TESTED INFILTRATION RATES OF NATIVE SOILS MUST BE BETWEEN 0.5 (INCHES PER HOUR) AND 5 (INCHES PER HOUR). FOR SITES WITH INFILTRATION RATES GREATER THAN 5 IN/HR, SUBSURFACE INFILTRATION SYSTEMS MAY STILL BE ALLOWED PROVIDED THAT THE RUNOFF IS FULLY TREATED USING UPSTREAM BMPS OR BY INSTALLING A MINIMUM OF 18 INCHES OF ASTM C33 SAND WITH AN INFILTRATION RATE LESS THAN 5 INCHES PER HOUR AT THE BASE OF THE FACILITY.
4. SUBSURFACE STORAGE DRAWDOWN TIME (I.E. TIME FOR MAXIMUM SUBSURFACE STORAGE VOLUME TO INFILTRATE INTO SUBGRADE AFTER THE END OF A STORM) SHOULD NOT EXCEED 48 HOURS. DRAWDOWN TIME IS CALCULATED AS THE MAXIMUM SUBSURFACE STORAGE DEPTH DIVIDED BY THE NATIVE SOIL INFILTRATION RATE.
5. SUBSURFACE INFILTRATION SYSTEM SUBGRADES SHOULD BE LEVEL, REGARDLESS OF ANY LONGITUDINAL SLOPE OF THE SITE, TO PROMOTE EQUAL SUBSURFACE DISTRIBUTION OF RUNOFF.
6. DEPENDING ON THE HEIGHT AND AREA OF THE PROPOSED SUBSURFACE INFILTRATION SYSTEM, ADDITIONAL STRUCTURAL CONSIDERATIONS MAY BE REQUIRED TO ADDRESS EARTH PRESSURE AND/OR SURFACE LOADING.
7. SUBSURFACE INFILTRATION SYSTEMS ARE MOST COMMONLY USED TO MANAGE STORMWATER RUNOFF FROM ROOFS AND PARKING LOTS, BUT CAN BE USED IN OTHER APPLICATIONS. IN AREAS WITH HIGH SEDIMENT LOADS, RUNOFF SHOULD PASS THROUGH STORMWATER PRE-TREATMENT MEASURES TO REMOVE COARSE SEDIMENT THAT CAN CLOG PORE SPACES. REFER TO THE STORMWATER MANAGEMENT REQUIREMENTS APPENDIX A: BMP FACT SHEETS FOR ADDITIONAL REQUIREMENTS.
8. SUBSURFACE INFILTRATION SYSTEMS ARE NOT APPROVED AS TREATMENT MEASURES FOR RUNOFF FROM INDUSTRIAL AREAS, AREAS SUBJECT TO HIGH (GREATER THAN 15,000 VEHICLES PER DAY) TRAFFIC LOADING, AUTOMOTIVE REPAIR SHOPS, CAR WASHES, FLEET STORAGE AREAS, NURSERIES, SITES THAT STORE CHEMICALS OR HAZARDOUS MATERIALS, OR OTHER LAND USES THAT POSE A HIGH THREAT TO WATER QUALITY.
9. SUBSURFACE INFILTRATION SYSTEMS SHOULD NOT BE USED IN AREAS OF KNOWN OR PRESUMED CONTAMINATED SOIL OR GROUNDWATER, AREAS WITH CURRENT OR HISTORICAL INDUSTRIAL USE, AREAS WITHIN 100 FEET OF CURRENT OR HISTORICAL UNDERGROUND STORAGE TANKS, FILLED FORMER BAY, MARSH OR CREEK AREAS, OR AREAS WITHIN 150 FEET OF A CURRENT OR HISTORICAL HIGHWAY. SEE SETBACK REQUIREMENTS TABLE ON **SI 1.2**.
10. SMALL SYSTEMS (TYPICALLY A FEW FEET IN WIDTH) ARE KNOWN AS DRY WELLS AND ARE RECOMMENDED FOR SMALL DRAINAGE AREAS WITH LOW POLLUTANT LOADINGS, SUCH AS ROOFTOPS LESS THAN 0.25 ACRES IN SIZE. LARGER SYSTEMS (TYPICALLY 10 TO 100 FEET IN WIDTH) ARE KNOWN AS INFILTRATION GALLERIES AND CAN BE USED TO RECEIVE RUNOFF FROM DRAINAGE AREAS TYPICALLY UP TO 5 ACRES IN SIZE.
11. THE DRAWINGS PROVIDED DO NOT COVER DESIGNS THAT UTILIZE PROPRIETARY STORAGE, DISTRIBUTION, AND/OR STRUCTURAL SYSTEMS OTHER THAN PREFABRICATED DRY WELL STRUCTURES, WHICH HAVE BEEN SHOWN IN A GENERIC WAY. REFER TO THE MANUFACTURER'S RECOMMENDATIONS FOR ALL PROPRIETARY SYSTEMS.

GENERAL UTILITY NOTES:

1. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS, OTHER GOVERNING UTILITY STANDARD, AND OTHER UTILITY PROVIDER REQUIREMENTS. SEE UTILITY CROSSING DESIGNER NOTES ON **GC 2.1**.
2. PROVIDE UTILITY TRENCH DAM, ANTI-SEEP COLLAR, OR EQUIVALENT TO PREVENT PREFERENTIAL FLOW OF WATER FROM INFILTRATIVE FACILITY INTO UTILITY TRENCH FROM CAUSING DAMAGE DOWNSTREAM. ENGINEER TO EVALUATE SITE CONDITIONS AND NEED FOR TRENCH DAM. REFER TO **GC2.12** FOR GUIDANCE ON UTILITY TRENCH DAM DESIGN.
3. PROPOSED UTILITY LINES TO BE LOCATED OUTSIDE OF FACILITY.

RELATED COMPONENTS	
UTILITY CROSSINGS:	GC 2.1 - GC 2.12
OBSERVATION PORTS:	GC 3.1 - GC 3.3
UTILITY CONFLICTS:	GC 4.1 - GC 4.4
CLEANOUTS:	GC 5.2

NOTES: SI 1.1, SI 1.2
LARGE SYSTEMS — PLAN: SI 2.1, SECTIONS: SI 2.2
SMALL SYSTEMS — PLAN: SI 3.1, SECTIONS: SI 3.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

SUBSURFACE INFILTRATION SYSTEMS
DESIGNER NOTES (1 OF 2)

DWG NO. SI 1.1

LAYOUT REQUIREMENTS:

REFER TO STORMWATER MANAGMENT REQUIRMENTS APPENDIX C: CRITERIA FOR INFILTRATION - BASED BMPS OR LOCAL JURISDICTION'S REQUIREMENTS AS DIRECTED BY CITY ENGINEER FOR MORE DETAILED INFORMATION ON SITING AND DESIGN REQUIREMENTS FOR INFILTRATION BASED BMPS.

1. STANDARD SETBACK REQUIREMENTS PER THE STORMWATER MANAGEMENT REQUIREMENTS:

SETBACK DISTANCE (FEET)	SETBACK FROM:
5	PROPERTY LINE
10	DOWNGRADIENT FROM ADJACENT FOUNDATIONS
100	UPGRADIENT FROM ADJACENT FOUNDATIONS
100	UPGRADIENT FROM GROUND SLOPES >15%
150	DRINKING WATER WELL

2. REFER TO APPENDIX C OF THE STORMWATER MANAGEMENT REQUIREMENTS FOR CONDITIONAL SETBACK REQUIREMENTS AND THE RESPONSIBLE AGENCY ASSET PROTECTION STANDARDS FOR ADDITIONAL SETBACK REQUIREMENTS REGARDING WATER AND SEWER INFRASTRUCTURE.
3. MINIMUM 4-FOOT VERTICAL SEPARATION FROM BASE OF SUBSURFACE INFILTRATION SYSTEM TO BEDROCK IS REQUIRED.
4. VERTICAL SEPARATION TO SEASONAL HIGH GROUND WATER:
   - MINIMUM 10-FOOT VERTICAL SEPARATION FROM BASE OF SUBSURFACE INFILTRATION SYSTEM TO SEASONAL HIGH GROUNDWATER TABLE IS REQUIRED.
   - IF GROUNDWATER IS ENCOUNTERED, A PERMIT FROM THE LOCAL PERMITTING AGENCY IS REQUIRED.
5. IF DISTANCE BETWEEN BOTTOM OF INFILTRATION SYSTEM AND GROUND SURFACE IS 10' OR GREATER, A PERMIT FROM THE LOCAL PERMITTING AGENCY IS REQUIRED.
6. COORDINATE WITH COUNTY OF SAN MATEO ENVIRONMENTAL HEALTH ON ANY DRY WELL.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ SUBSURFACE INFILTRATION SYSTEM WIDTH AND LENGTH
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE LAYER
- ☐ DEPTH AND TYPE OF FILTER SAND, IF REQUIRED
- ☐ ELEVATIONS AND CONTROL POINTS AT EVERY CORNER
- ☐ AGGREGATE STORAGE SPECIFICATIONS AND/OR DRY WELL TYPE AND DIMENSIONS
- ☐ ELEVATIONS OF EACH PIPE INLET AND OVERFLOW INVERT
- ☐ TYPE AND DESIGN OF SUBSURFACE INFILTRATION COMPONENTS (E.G. INLETS, OVERFLOWS, OBSERVATION WELLS)
- ☐ SETBACK DIMENSIONS TO BEDROCK, SEASONAL HIGH GROUNDWATER TABLE, PROPERTY LINES, FOUNDATIONS, WATER SUPPLY WELLS, SEWER MAINS, AND GROUND SLOPES OF 15% OR GREATER, AS APPLICABLE. SEE COUNTY AND LOCAL JURISDICTION ASSET PROTECTION STANDARDS PER CITY ENGINEER.
- ☐ TYPE AND SIZE OF PRETREATMENT MEASURE, AS NECESSARY.
- ☐ NEED FOR SAN MATEO COUNTY ENVIRONMENTAL HEALTH PERMIT (IF ANY WELL/BORING WILL ENCOUNTER GROUND WATER OR ANY WELL/BORING IS 10 FEET OR DEEPER.)

SOIL TYPE GUIDANCE:

HYDROLOGIC SOIL GROUP	SOIL TYPE	CORRESPONDING UNIFIED SOIL CLASSIFICATION	DESCRIPTION
A	SAND, LOAMY SAND, OR SANDY LOAM	GW - WELL-GRADED GRAVELS, SANDY GRAVELS GP - GAP-GRADED OR UNIFORM GRAVELS, SANDY GRAVELS GM - SILTY GRAVELS, SILTY SANDY GRAVELS SW - WELL-GRADED, GRAVELLY SANDS SP - GAP-GRADED OR UNIFORM SANDS, GRAVELLY SANDS	LOW RUNOFF POTENTIAL. SOILS HAVING HIGH INFILTRATION RATES EVEN WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF DEEP, WELL TO EXCESSIVELY DRAINED SANDS OR GRAVELS.
B	SILT LOAM OR LOAM	SM - SILTY SANDS, SILTY GRAVELLY SANDS MH - MICACEOUS SILTS, DIATOMACEOUS SILTS, VOLCANIC ASH	SOILS HAVING MODERATE INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF MODERATELY DEEP TO DEEP, MODERATELY WELL TO WELL-DRAINED SOILS WITH MODERATELY FINE TO MODERATELY COARSE TEXTURES.
C	SANDY CLAY LOAM	ML - SILTS, VERY FINE SANDS, SILTY AND CLAYEY FINE SANDS	SOILS HAVING SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF SOILS WITH A LAYER THAT IMPEDES DOWNWARD MOVEMENT OF WATER, OR SOILS WITH MODERATELY FINE TO FINE TEXTURES.
D	CLAY LOAM, SANDY CLAY, SILTY CLAY, OR CLAY	GC - CLAYEY GRAVELS, CLAYEY SANDY GRAVELS SC - CLAYEY SANDS, CLAYEY GRAVELLY SANDS CL - LOW PLASTICITY CLAYS, SANDY OR SILTY CLAYS OL - ORGANIC SILTS AND CLAYS OF LOW PLASTICITY CH - HIGHLY PLASTIC LAYS AND SANDY CLAYS OH - ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY	HIGH RUNOFF POTENTIAL. SOILS HAVING VERY SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF CLAY SOILS WITH A HIGH SWELLING POTENTIAL, SOILS WITH A PERMANENT HIGH WATER TABLE, AND SHALLOW SOILS OVER NEARLY IMPERVIOUS MATERIAL.

NOTES: SI 1.1, SI 1.2
LARGE SYSTEMS — PLAN SECTIONS: SI 2.1, SI 2.2
SMALL SYSTEMS — PLAN SECTIONS: SI 3.1, SI 3.2, SI 4.1

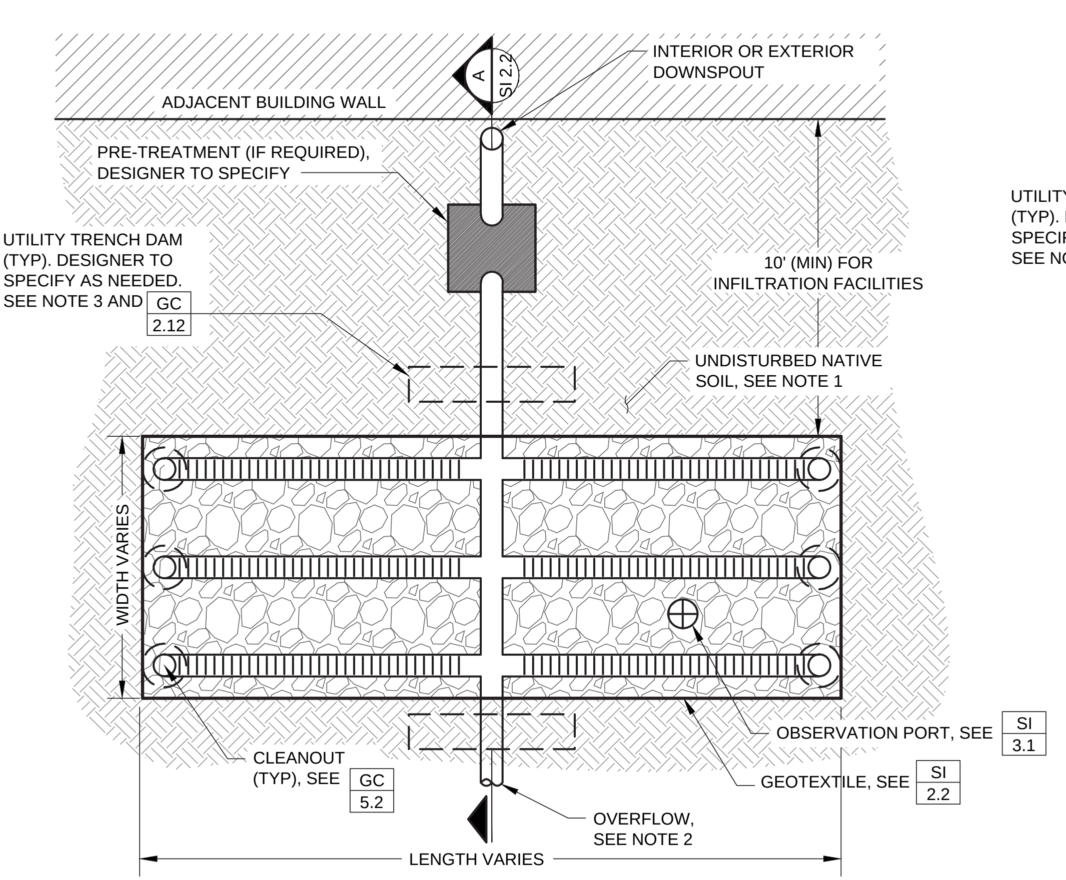
NOT FOR CONSTRUCTION - REFER TO USER GUIDE

DETAIL ADAPTED FROM:
SAN FRANCISCO PUBLIC UTILITIES COMMISSION
(SI 1.2)

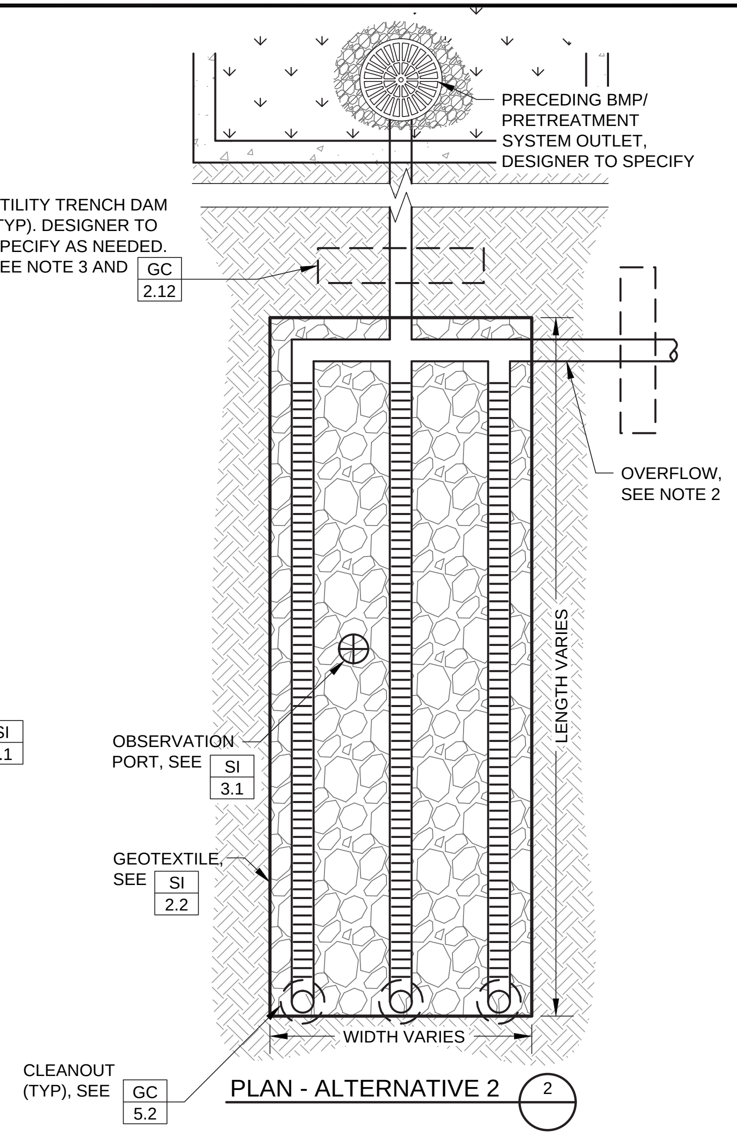
DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED: OCT 2019

SUBSURFACE INFILTRATION SYSTEMS
DESIGNER NOTES (2 OF 2)

DWG NO. SI 1.2



PLAN- ALTERNATIVE 1 (1)



PLAN - ALTERNATIVE 2 (2)

CONSTRUCTION NOTES:

1. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL WITHIN 5 FEET ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
2. ROUTE OVERFLOW PIPE TO THE STORM SEWER OR TO ANOTHER BMP FOR FURTHER TREATMENT AS SHOWN ON THE DESIGN PLANS.
3. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.

NOTES		LARGE SYSTEMS		SMALL SYSTEMS	
		PLAN	SECTIONS	PLAN	SECTIONS
SI 1.1	SI 1.2	SI 2.1	SI 2.2	SI 3.1	SI 3.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

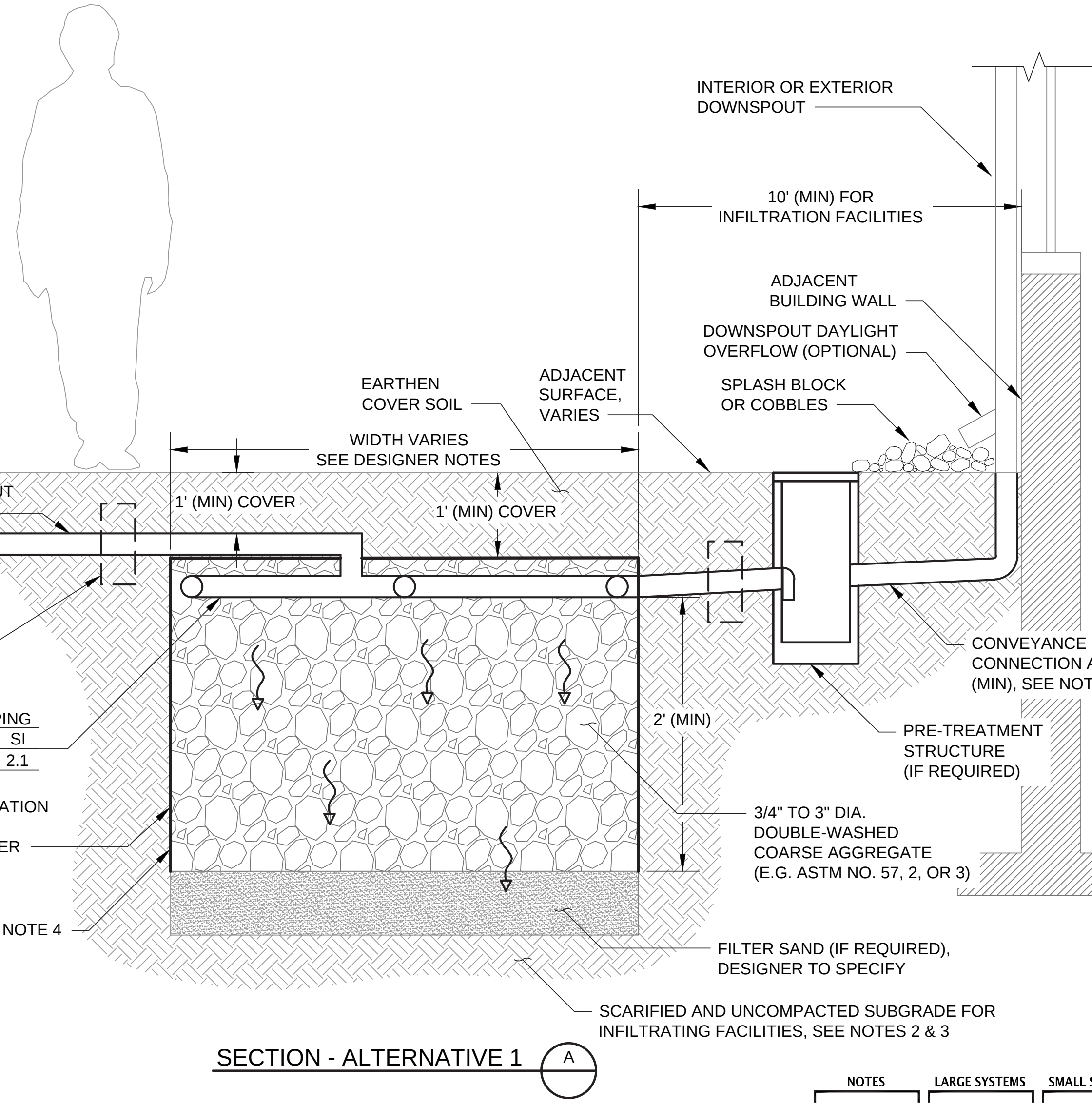
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

SUBSURFACE INFILTRATION SYSTEM
INFILTRATION GALLERY
LARGE SYSTEM - PLAN

DWG NO. SI 2.1

CONSTRUCTION NOTES:

1. REFER TO APPLICABLE SAN FRANCISCO DBI CODES AND PUBLIC WORKS REQUIREMENTS FOR CONVEYANCE CONNECTION REQUIREMENTS.
2. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
3. SCARIFY SUBGRADE TO A DEPTH OF 6 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE.
4. SIDEWALLS AND TOP OF AGGREGATE STORAGE SHALL BE LINED WITH A GEOTEXTILE TO PREVENT MIGRATION OF ADJACENT SOILS INTO SUBSURFACE INFILTRATION SYSTEM.
5. SUBSURFACE DISTRIBUTION PIPING SHALL BE A 6 INCHES (MIN) IN DIAMETER.
6. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.



SECTION - ALTERNATIVE 1 (A)

NOTES		LARGE SYSTEMS PLAN	LARGE SYSTEMS SECTIONS	SMALL SYSTEMS PLAN	SMALL SYSTEMS SECTIONS
SI 1.1	SI 1.2	SI 2.1	SI 2.2	SI 3.1	SI 3.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

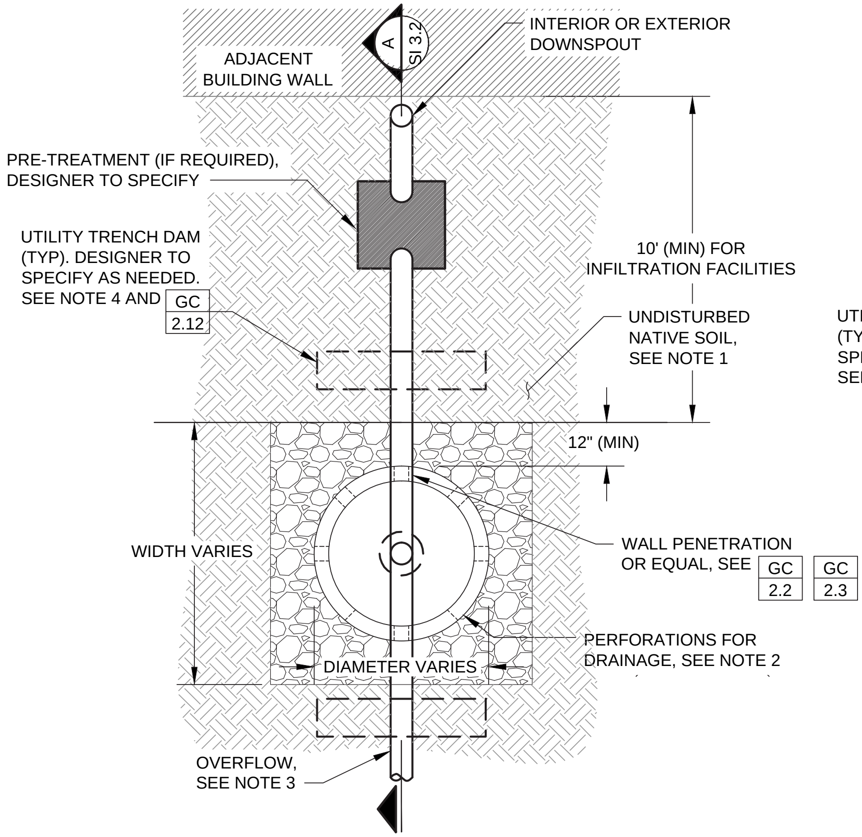
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

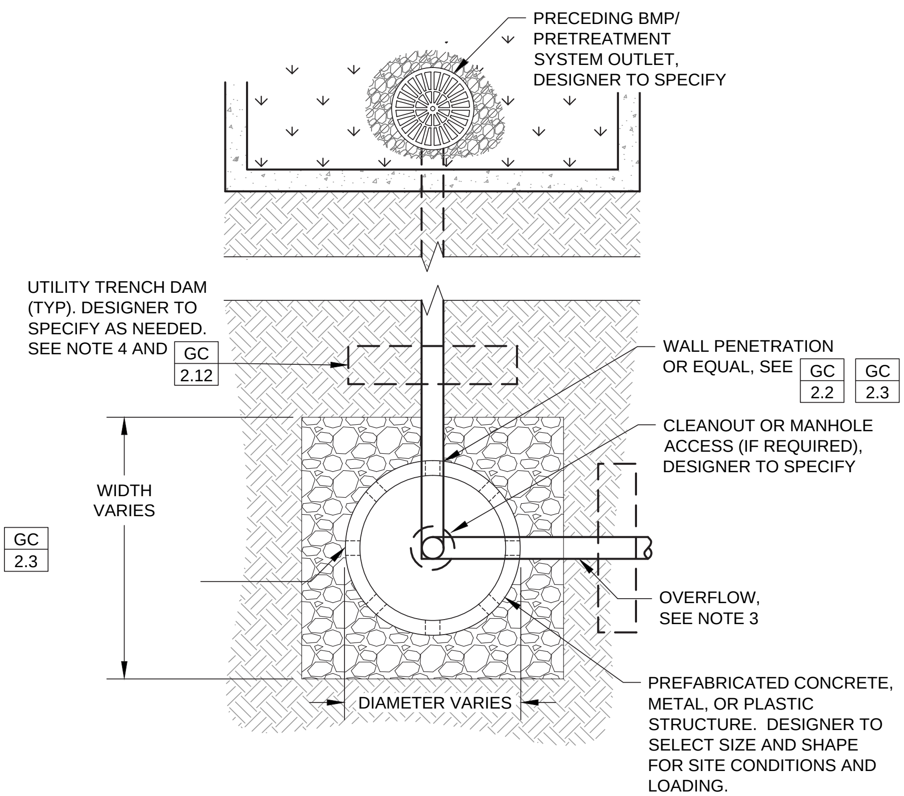
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

SUBSURFACE INFILTRATION SYSTEM
INFILTRATION GALLERY
LARGE SYSTEM - SECTION

DWG NO. SI 2.2



PLAN- ALTERNATIVE 1 (1)



PLAN - ALTERNATIVE 2 (2)

CONSTRUCTION NOTES:

1. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL WITHIN 5 FEET ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
2. PREFABRICATED DRY WELLS SHALL HAVE SMALL DIAMETER PERFORATIONS TO PREVENT LATERAL MOVEMENT OF AGGREGATE INTO WELL AND SHALL BE SUFFICIENT IN NUMBER TO ALLOW FOR THE DRAINAGE OF THE STRUCTURE WITHIN 48 HOURS.
3. ROUTE OVERFLOW PIPE TO THE STORM SEWER OR TO ANOTHER BMP FOR FURTHER TREATMENT AS SHOWN ON THE DESIGN PLANS.
4. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.

NOTES		LARGE SYSTEMS PLAN SECTIONS		SMALL SYSTEMS PLAN SECTIONS	
SI 1.1	SI 1.2	SI 2.1	SI 2.2	SI 3.1	SI 3.2

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

SUBSURFACE INFILTRATION SYSTEM

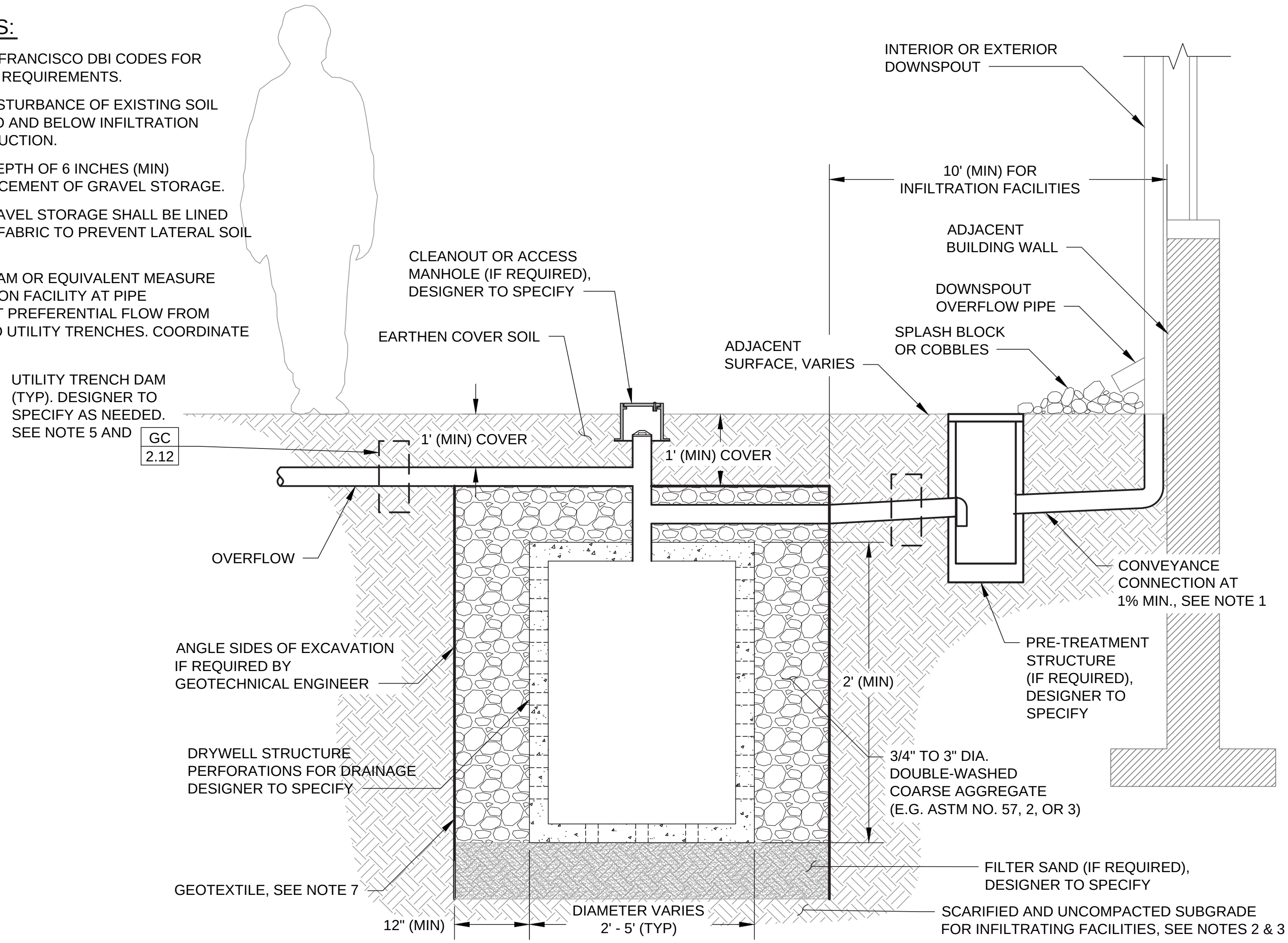
DRY WELL

SMALL SYSTEM - PLAN

DWG NO. SI 3.1

CONSTRUCTION NOTES:

1. REFER TO APPLICABLE SAN FRANCISCO DBI CODES FOR CONVEYANCE CONNECTION REQUIREMENTS.
2. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL WITHIN 5 FEET ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
3. SCARIFY SUBGRADE TO A DEPTH OF 6 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF GRAVEL STORAGE.
4. SIDEWALLS AND TOP OF GRAVEL STORAGE SHALL BE LINED WITH A PERMEABLE FILTER FABRIC TO PREVENT LATERAL SOIL MOVEMENT.
5. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.



SECTION - ALTERNATIVE 1 (A)

NOTES		LARGE SYSTEMS PLAN SECTIONS		SMALL SYSTEMS PLAN SECTIONS	
SI 1.1	SI 1.2	SI 2.1	SI 2.2	SI 3.1	SI 3.2

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

SUBSURFACE INFILTRATION SYSTEMS
DRY WELL
SMALL SYSTEM - SECTION

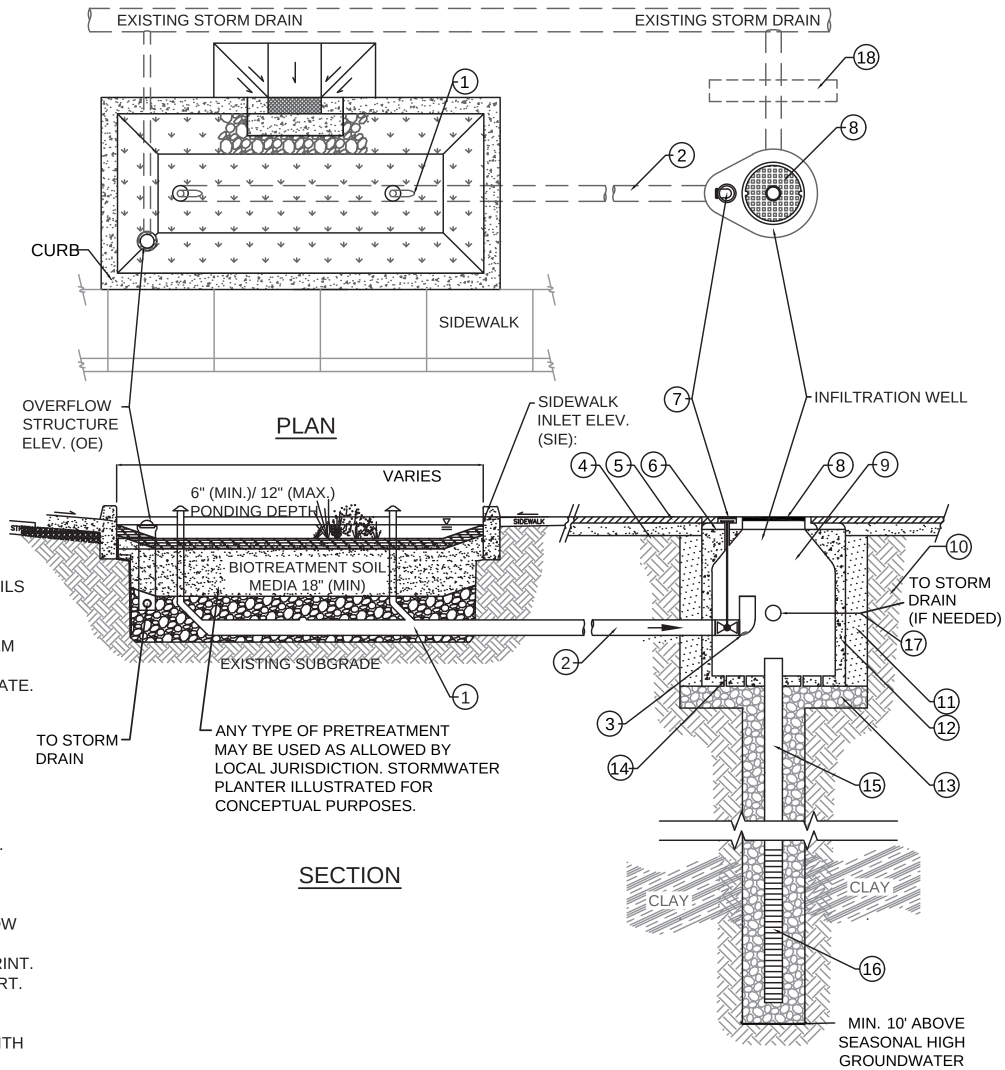
DWG NO. SI 3.2

KEY:

1. UNDERDRAIN, MIN. 4” DIA. PVC SDR 35 SLOTTED OR PERFORATED PIPE OR LARGER AS NEEDED TO CONVEY PEAK TREATED FLOWRATE WITH MINIMAL HEAD LOSS.
2. 6” MIN SOLID INLET PIPE. DESIGNER TO SPECIFY AS NEEDED.
3. LOW FLOW ORIFICE. (SEE DESIGN NOTE 11).
4. STABILIZED BACKFILL - TWO-SACK SLURRY MIX.
5. SIDEWALK PER MUNICIPAL STANDARDS.
6. COMPACTED BASE MATERIAL.
7. ACCESS HATCH WITH SHUT OF VALVE SWITCH. CONNECTED TO SHUT OF VALVE IN INLET PIPE.
8. MAINTENANCE HOLE COS TYPE 204-204 MH A OR B. ¾” I.D. MIN OBSERVATION PORT.
9. MANHOLE CONE - MODIFIED FLAT BOTTOM.
10. EXISTING SOILS.
11. COMPACTED BACKFILL
12. PRE-CAST OR INSITU CAST CONTROL VAULT (SEE DESIGN NOTE 8)
13. ROCK - WASHED, SIZED BETWEEN 3/8” AND 1-1/2"
14. PERFORATED BASE OF CONTROL VAULT
15. DRILLED SHAFT WITH 6” WELDED STEEL OR THREADED PVC CASING (SEE DESIGN NOTE 13)
16. 6 - 8” O.D. WELDED WIRE STAINLESS STEEL WELL SCREEN OR THREADED PVC SLOTTED SCREEN. SCREEN LENGTH + LENGTH + SLOT WIDTH TO BE DETERMINED IN ACCORDANCE WITH LOCAL CONSTRAINTS .I.E. DISTANCE BETWEEN CLAY LAYER AND MIN. 10FT ABOVE SEASONAL HIGH GROUNDWATER LEVEL
17. PVC STORMDRAIN CONNECTOR PIPE. SAME DIAMETER AS INFLOW PIPE TO CONTROL VAULT
18. UTILITY TRENCH DAM PER GC 2.12. DESIGNER TO SPECIFY AS NEEDED.

CONSTRUCTION AND DESIGNER NOTES:

1. ADDITIONAL DESIGN GUIDANCE FOR BIOFILTRATION SYSTEM PROVIDED IN OTHER DETAILS INCLUDED IN THIS DOCUMENT
2. BOTTOM WIDTH - PROVIDE 2 FT MINIMUM FLAT BREGENALL
3. BOTTOM WITH A MAX 3:1 SLOPE FOR SURFACE FINISHING WITHIN BIOFILTRATION SYSTEM
4. IF CALTRANS CLASS 2 PERMEABLE IS NOT AVAILABLE, SUBSTITUTE CLASS 3 PERMEABLE WITH AN OVERLYING 3” DEEP LAYER OF ¾” (NO. 4) OPEN-GRADED AGGREGATE.
5. PROVIDE SPOT ELEVATIONS AT INLETS ON CIVIL PLANS (FE, OE, GIE, SIE).
6. EDGE CONDITION WILL VARY FOR NEW AND RETROFIT PROJECTS. CURB, WALL, AND SIDEWALK DETAILS MAY BE MODIFIED FOR PROJECT BY CIVIL AND GEOTECHNICAL ENGINEERS.
7. PROVIDE MONITORING WELL IN EACH FACILITY.
8. LONGITUDINAL SLOPE 6% WITH CHECK DAMS.
9. IF CHECK DAMS ARE NEEDED, SEE CONCRETE CHECK DAM DETAIL.
10. DESIGNER TO ADAPT DRAWINGS AND NOTES TO ADDRESS SITE-SPECIFIC CONDITIONS. VARIATIONS IN DRY WELL DESIGN SHOULD BE MADE TO ACCOMMODATE STORAGE VOLUME DESIGN AND TO SUIT LOCAL CONDITIONS AND CONSTRAINTS.
11. IN AREAS WITHOUT A STORMDRAIN, THE SYSTEM SHOULD ONLY BE CONSTRUCTED WHERE THE MAINTENANCE HOLE SURFACE INVERT IS ABOVE THE BIOFILTER OVERFLOW ELEVATION.
12. ALTERNATIVE VAULT LOCATIONS POSSIBLE INCLUDING WITHIN THE BIOFILTER FOOTPRINT.
13. VALVE CAN BE MOVED TO THE BIOFILTER IF DESIRED. REQUIRES STRUCTURAL SUPPORT.
14. ALTERNATIVE PRODUCTS SUCH AS VENDOR-SUPPLIED DRY WELL PRODUCTS MAY BE USED AS A SUBSTITUTE PROVIDED THAT THE ALTERNATIVE PRODUCT IS EQUAL.
15. THIS DESIGN IS LIKELY TO QUALIFY AS A CLASS V WELL SUBJECT TO REGISTRATION WITH THE USEPA.
16. SEE ALSO SI 1.1 AND SI 1.2 FOR ADDITIONAL DESIGNER NOTES.
17. SAN MATEO COUNTY ENVIRONMENTAL HEALTH'S POLICY STANDARD IS THAT ANY WELL/BORING THAT DOES OR WILL ENCOUNTER GROUNDWATER, OR ANY WELL/BORING 10' OR DEEPER MUST BE PERMITTED THROUGH ENVIRONMENTAL HEALTH OR OTHER RESPONSIBLE LOCAL PERMITTING AGENCY.



NOTES		LARGE SYSTEMS PLAN SECTIONS		SMALL SYSTEMS PLAN SECTIONS		
SI 1.1	SI 1.2	SI 2.1	SI 2.2	SI 3.1	SI 3.2	SI 4.1

DETAIL ADAPTED FROM CENTRAL COAST LOW IMPACT DEVELOPMENT STORMWATER MANAGEMENT STANDARD DETAILS (SW-27)

DATE: APRIL, 2019
VERSION:
REVISED: OCT 2019

SUBSURFACE INFILTRATION SYSTEM
DEEP DRY WELL
SMALL SYSTEM - PLAN & SECTION

DWG NO. SI 4.1

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

PURPOSE:

IMPERMEABLE LINERS IN GREEN INFRASTRUCTURE CAN BE USED TO RESTRICT MOVEMENT OF WATER INTO UNDERLYING AND/OR ADJACENT SOILS AND/OR AGGREGATES TO PROTECT SENSITIVE INFRASTRUCTURE (E.G., IMPERMEABLE ROADWAY BASE, FOUNDATIONS, UTILITIES), MITIGATE RISK OF GEOLOGIC HAZARDS (E.G., STEEP SLOPES, CONTAMINATED SOILS), OR OTHER SITE-SPECIFIC CONDITIONS)

DESIGNER NOTES & GUIDELINES:

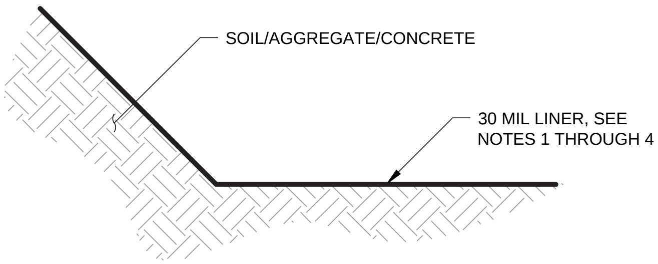
1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER AND/OR GEOTECHNICAL ENGINEER SHOULD ASSESS THE RISK OF WATER LEAKAGE FROM THE PLANTER AND DETERMINE THE LINER EXTENTS AND LINER CONNECTION REQUIREMENTS (E.G., WATER TIGHT, SOIL TIGHT), DEPENDING ON DEGREE OF PROTECTION NECESSARY TO PROTECT ADJACENT INFRASTRUCTURE.
6. CONSIDER PLACING GEOTEXTILE ON PREPARED SUBGRADE PRIOR TO PLACEMENT OF LINER TO PROTECT LINER FROM DAMAGE DURING INSTALLATION.
7. DEPENDING ON ANTICIPATED FACILITY MAINTENANCE, IT MAY BE PRUDENT TO INCLUDE A GEOTEXTILE OVER THE LINER TO PROVIDE AN ADDITIONAL BARRIER BETWEEN LINER AND MAINTENANCE EQUIPMENT OR TO PROTECT AGAINST AGGRESSIVE PUNCTURES DURING PLACEMENT AND COMPACTION.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

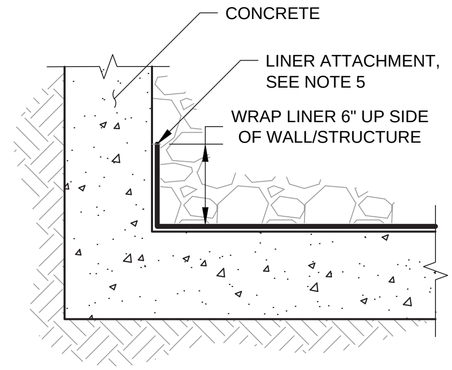
- ☐ LINER TYPE AND EXTENTS (E.G., FULL LINER, PARTIAL LINER)
- ☐ LINER ANCHOR TYPE (E.G., WATER TIGHT, SOIL TIGHT)
- ☐ LINER JOINT WELDING/SEALING REQUIREMENTS
- ☐ OTHER CRITICAL PROJECT-SPECIFIC PLACEMENT REQUIREMENTS

NOTES COMPONENTS
GC 1.1 GC 1.2

San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	GENERAL COMPONENTS LINERS DESIGNER NOTES	DWG NO. GC 1.1



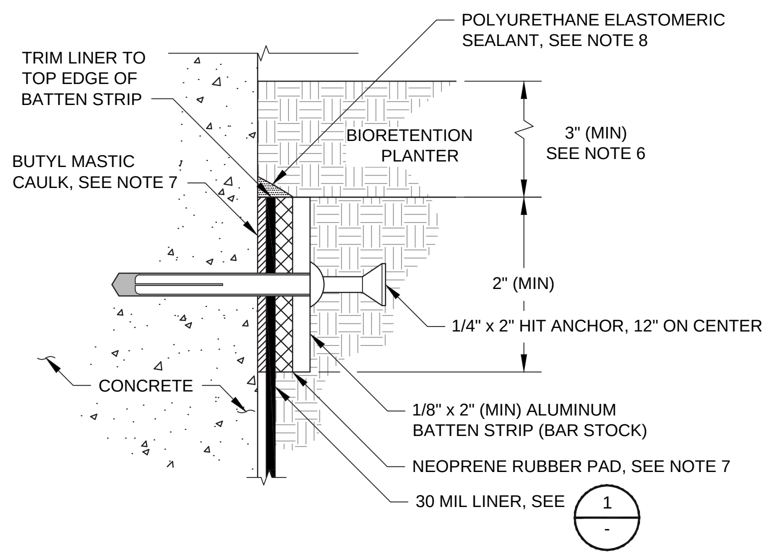
IMPERMEABLE LINER (1)



SOIL TIGHT LINER ATTACHMENT AT WALL/STRUCTURE (2)

CONSTRUCTION NOTES:

1. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM17.
2. LINER SHALL LAY FLUSH WITH GROUND WITH NO AIR VOIDS BELOW THE LINER PRIOR TO BACKFILLING MATERIAL ABOVE THE LINER. CONTOUR THE SUBGRADE AS NEEDED TO ENSURE LINER LAYS FLUSH WITH GROUND.
3. OVERLAP LINER PER MANUFACTURER'S RECOMMENDATIONS.
4. ALL SEAMS SHALL BE WELDED PER MANUFACTURER'S RECOMMENDATIONS UNLESS OTHERWISE SPECIFIED.
5. SECURE LINER CONTINUOUSLY WITH DOUBLE-SIDED TAPE ALONG LINER EDGE AND SINGLE SIDED TAPE ALONG THE TOP EDGE OF LINER TO HOLD LINER IN PLACE DURING BACKFILLING.
6. TOP OF LINER TO BE AT LEAST 3" BELOW FINISH GRADE OF BIORETENTION SOIL EXCEPT WHEN ADJACENT TO BUILDING WALL. WHEN ADJACENT TO BUILDING WALL, LINER OR EQUAL WATERPROOFING SHALL EXTEND TO TOP OF FREEBOARD ELEVATION.
7. APPLY BUTYL MASTIC CAULK, BATTEN STRIP, AND NEOPRENE RUBBER PAD CONTINUOUSLY ALONG TOP EDGE OF LINER.
8. APPLY BEAD OF POLYURETHANE ELASTOMERIC SEALANT CONTINUOUSLY ALONG TOP EDGE OF BATTEN STRIP ASSEMBLY.



WATER TIGHT LINER ATTACHMENT AT WALL/STRUCTURE (3)

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES	COMPONENTS
GC 1.1	GC 1.2

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

GENERAL COMPONENTS
LINERS
LINERS AND ATTACHMENTS

DWG NO. GC 1.2

PURPOSE:

WHEN SITING GREEN INFRASTRUCTURE (GI) FACILITIES, THE DESIGNER SHOULD LOCATE AND ASSESS ALL KNOWN UTILITY CROSSINGS AND CONFLICTS AND ADJUST THE DESIGN TO AVOID AS MANY EXISTING UTILITIES AS POSSIBLE. THE CRITICALITY OF UTILITY CONFLICTS IN TERMS OF THEIR POTENTIAL IMPACT TO THE PROJECT'S DESIGN PERFORMANCE, COST, AND SCHEDULE SHOULD BE CAREFULLY EVALUATED DURING THE PLANNING PHASE.

THE PURPOSE OF THE FOLLOWING TYPICAL UTILITY CROSSING DETAILS IS TO ALERT THE DESIGNERS TO COMMON UTILITY CROSSINGS THAT OCCUR ON GI PROJECTS WITHIN THE PUBLIC RIGHT-OF-WAY AND PROVIDE GENERAL GUIDANCE ON THE PROTECTION OF THESE UTILITIES. THEY ARE PROVIDED AS TYPICAL APPLICATIONS AND DO NOT REPRESENT APPROVED CITY UTILITY STANDARDS AND SPECIFICATIONS. IN ADDITION TO THESE TYPICAL DETAILS, DESIGNERS MUST FOLLOW ALL APPLICABLE LOCAL AND FEDERAL REGULATIONS ASSOCIATED WITH THEIR PROJECT.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS AND UTILITY REQUIREMENTS AND OBTAIN APPROVAL FROM ALL RELEVANT UTILITY PROVIDERS PRIOR TO CONSTRUCTION. COORDINATION AND APPROVAL FROM THE FOLLOWING UTILITY PROVIDERS MAY BE NECESSARY, BUT NOT EXCLUSIVELY:
   - SFPUC CITY DISTRIBUTION DIVISION (CDD) FOR DOMESTIC/RECYCLED/FIRE WATER
   - SFPUC WASTEWATER ENTERPRISE (WWE) FOR SANITARY/STORM/SEWER
   - PACIFIC GAS ELECTRIC (PGE) FOR ELECTRIC/GAS/UTILITY POLES
   - SFMTA FOR TRAFFIC SIGNAL/STREET SIGNS/PARKING METERS/BUS STOPS AND CATENARY POLES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS. NOTE WHICH UTILITY APPURTENANCES (I.E. CLEANOUT VENTS, WATER METER BOXES, HYDRANTS, VALVES, ETC.) ARE NOT ALLOWED WITHIN BIORETENTION PLANTERS. REFER TO THE SFPUC SEWER LATERAL DETAILS FOR THE PLACEMENT OF CLEANOUT VENTS WITHIN BIORETENTION PLANTERS. PER CURRENT STANDARDS, POTABLE WATER DISTRIBUTION MAINS ARE NOT PERMITTED TO RUN UNDER OR THROUGH BIORETENTION PLANTERS.
3. UTILITY CONFLICTS SHALL BE MITIGATED PER SFPUC SURFACE IMPROVEMENT STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. ENGINEER TO EVALUATE CONDITIONS AND NEED TO INCLUDE MEASURES TO ENSURE WATER TIGHT UTILITY PENETRATIONS THROUGH PLANTER WALL, AS NEEDED AND TO PREVENT PREFERENTIAL FLOW INTO UTILITY TRENCHES (E.G., WATER STOP, TRENCH BLOCK, OR TRENCH COLLAR). (REFER TO **GC 2.9** - **2.12**)
4. THE DESIGNER MUST DETERMINE THE TYPE OF PROTECTION MEASURE(S) REQUIRED BASED ON THE SITE-SPECIFIC CONDITIONS, UTILITY REQUIREMENTS, AND THE FUNCTION THE PROTECTION MEASURE MUST PERFORM. THE FOLLOWING ARE BRIEF DESCRIPTIONS OF THE PROTECTION MEASURES INCLUDED IN THESE DETAILS:
   a. SOIL OR ENGINEERED FILL WITH OVERLYING IMPERMEABLE LINER: PROTECTS UTILITY FROM DAMAGE DURING FUTURE TRENCHING, EXCAVATION, AND LANDSCAPE ACTIVITIES. THE LINER PREVENTS PREFERENTIAL FLOW OF WATER INTO THE UTILITY TRENCH. THESE METHODS ARE GENERALLY ONLY ACCEPTABLE WHEN THE FACILITY DOES NOT INCLUDE AN UNDERDRAIN OR WHEN THE LINER CAN BE LOCATED BELOW THE INVERT OF THE UNDERDRAIN.
   b. SLEEVE/CASING: BY HOUSING THE UTILITY PIPE WITHIN A LARGER CARRIER PIPE OR APPROVED SPLIT SLEEVE PRODUCT, THE UTILITY PIPE CAN BE REPLACED IF NEEDED IN THE FUTURE WITHOUT SIGNIFICANT IMPACT TO THE OVERLYING INFRASTRUCTURE. THE SLEEVE ALSO PROTECTS THE PIPE FROM IMPACT DURING CONSTRUCTION AND FUTURE TRENCHING, EXCAVATION, AND LANDSCAPE ACTIVITIES. ADDITIONALLY, SLEEVES CAN BE USED TO SEAL THE UTILITY FROM THE INFILTRATED STORMWATER AND/OR PROTECT THE INFILTRATION FACILITY FROM SEWER LATERAL LEAKAGES. SEE THE UTILITY SLEEVE GUIDANCE.
   c. UTILITY TRENCH DAM: WHERE UTILITY TRENCHES CROSS UNDER INFILTRATIVE FACILITIES, SUBSURFACE WATER MAY PREFERENTIALLY FLOW THROUGH THE TRENCH AND CAUSE DAMAGE TO DOWNSTREAM INFRASTRUCTURE. RISKS INCLUDE BACKFILL EROSION, CREATION OF VOIDS, THE DEGRADATION OF OVERLYING FILL/PAVEMENT, AND SUBSURFACE WATER BEING DIRECTED TO BUILDING FOUNDATIONS OR BASEMENTS. UTILITY TRENCH DAMS PLACED OUTSIDE OF THE INFILTRATION FACILITY FOOTPRINT PREVENT WATER FROM TRAVELING FURTHER ALONG THE UTILITY TRENCH.
   d. INSULATING WRAP: PROVIDES IMPACT AND WATER PROTECTION FOR EXISTING SHALLOW UTILITY SERVICE LINES THAT ARE REMAINING IN PLACE WITHIN INFILTRATION FACILITIES.

6. FOR PERMEABLE PAVEMENT FACILITIES, UTILITY CROSSINGS SHOULD BE BELOW THE BOTTOM OF THE STRUCTURAL PAVEMENT SECTION, WHENEVER POSSIBLE. IF UTILITIES ENCROACH INTO THIS SECTION, THE ENGINEER SHALL CONFIRM THAT THE STRUCTURAL INTEGRITY OF THE PAVEMENT CAN BE MAINTAINED OVER THE UTILITY.
7. THE AREA OF SUBBASE COVERED BY SUBSURFACE CHECK DAMS, IMPERMEABLE LINERS, COMPACTED ENGINEERED FILL, CONCRETE PADS AND OTHER UTILITY INFRASTRUCTURE SHOULD BE EXCLUDED FROM HYDROLOGIC PERFORMANCE CALCULATIONS WHEN THE AREA IS SIGNIFICANT (GREATER THAN 10 PERCENT) RELATIVE TO THE INFILTRATIVE AREA.

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

GENERAL COMPONENTS

UTILITY CROSSINGS

DESIGNER NOTES (1 OF 2)

DWG NO. GC 2.1

UTILITY SLEEVE NOTES AND GUIDANCE:

THE DESIGNER MUST SPECIFY THE TYPE OF SLEEVE METHOD AND MATERIALS THAT SHALL BE USED FOR ALL APPLICABLE NEW AND EXISTING UTILITIES TO REMAIN IN PLACE WITHIN THE FOOTPRINT OF INFILTRATION FACILITIES. DEPENDING ON THE SPECIFIC SITE CONDITIONS AND GOVERNING UTILITY STANDARDS, EXISTING UTILITIES TO REMAIN IN PLACE SHALL BE SLEEVED THE ENTIRE LENGTH WITHIN THE INFILTRATION FACILITY USING ONE OF THE FOLLOWING METHODS OR AN APPROVED EQUAL:

a. PLASTIC PIPE, 1 - 2 SIZES LARGER THAN UTILITY PIPE, CUT IN HALF, PLACED AROUND UTILITY PIPE, SEALED ALONG JOINTS WITH ADHESIVE, AND CLAMPED TOGETHER WITH STAINLESS STEEL BANDS/HOSE CLAMPS. PIPE SUPPORTS (E.G. CLOSED CELL FOAM BLOCKING) WITHIN THE SLEEVE PER UTILITY PROVIDER'S REQUIREMENTS.

b. GEORGE FISCHER "CONTAIN-IT" PIPE CONTAINMENT SYSTEM PRODUCT, PART NO. 8326-040AA OR 8326-060AA OR EQUAL, INSTALLED PER MANUFACTURER'S RECOMMENDATIONS.

c. STAINLESS STEEL SPLIT SLEEVE PRODUCT INSTALLED AROUND THE EXISTING PIPE AND POSITIONED IN THE FORM TO CENTER THE UTILITY PIPE. AFTER INSTALLATION, THE MANUFACTURER'S RECOMMENDED MATERIAL IS USED TO SEAL THE ANNULAR SPACE BETWEEN THE SPLIT SLEEVE AND PIPE. USE PIPE SEAL AND INSULATOR INC., WS SPLIT SEALWALL SLEEVE, OR EQUAL.

EXISTING UTILITY COORDINATION NOTES:

1. THE DESIGNER SHALL LOCATE ALL EXISTING UTILITIES WITHIN THE PROJECT AREA TO THE MOST PRACTICAL EXTENT POSSIBLE UTILIZING SITE SURVEYS, AS-BUILT PLANS, SITE INVESTIGATIONS, POTHOLING, UTILITY AGENCY DATA, ETC. AND PRESENT THIS INFORMATION AND SOURCE (I.E. AS-BUILT VS. ASSUMED LOCATION) CLEARLY ON THE DESIGN DRAWINGS. THE ASSUMED LOCATION OF EXISTING UTILITIES SHALL BE PROVIDED IN THE SAME COORDINATE SYSTEM AS THE REST OF THE DESIGN DRAWINGS. DESIGN DRAWINGS SHALL ALSO INCLUDE CONTACT INFORMATION FOR ANY UTILITIES AFFECTED BY THE PROJECT.
2. IF AN EXISTING UTILITY HAS THE POTENTIAL TO IMPACT THE PROJECT DESIGN AND/OR THE PERFORMANCE OF THE GI FACILITY, THE EXACT LOCATION, DEPTH, AND CONDITION OF THIS UTILITY SHOULD BE FIELD VERIFIED DURING THE DESIGN PHASE (VIA POTHOLING OR OTHER APPROVED METHOD) TO PREVENT COSTLY REDESIGNS AND/OR PROJECT DELAYS DURING CONSTRUCTION.
3. THE CONTRACTOR SHALL VERIFY THE LOCATIONS AND DEPTH OF EXISTING UTILITIES AT THE START OF CONSTRUCTION PER THE PROJECT SPECIFICATIONS. ANY DISCREPANCIES BETWEEN THE EXISTING UTILITIES SHOWN IN THE DESIGN DRAWINGS AND THE ACTUAL FIELD CONDITIONS SHOULD BE COMMUNICATED TO THE ENGINEER IMMEDIATELY.
4. THE CHECK DAM SPACING AND HEIGHT SPECIFIED ON THE DESIGN PLANS MUST BE MAINTAINED. IF THE CHECK DAM PROTECTING THE EXISTING UTILITY WILL IMPACT THE CHECK DAM SPACING SPECIFIED ON THE PLANS, THE ENGINEER MUST EVALUATE ITS IMPACT ON THE HYDROLOGIC PERFORMANCE AND APPROVE THE VARIANCE. SEE **PC 2.1** AND **PC 2.2** FOR FURTHER DETAILS.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ LINER EMBEDMENT DEPTH INTO SUBGRADE SOILS
- ☐ PIPE AND SLEEVE MATERIALS AND DIAMETER FOR ALL WALL PENETRATIONS
- ☐ WALL PENETRATION TYPE (E.G., GROUTED, COMPRESSION, BOOT) SEE **GC 2.9 - 2.11**.
- ☐ GEOTEXTILE FABRICS AND/OR LINER MATERIALS
- ☐ ENGINEERED BACKFILL MATERIAL
- ☐ DIMENSIONS OF ALL PROTECTION MEASURES
- ☐ MINIMUM SETBACKS TO ADJACENT INFRASTRUCTURE, PAVEMENT BASES, SURFACES
- ☐ MINIMUM PIPE COVER AS REQUIRED BY UTILITY PROVIDER

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

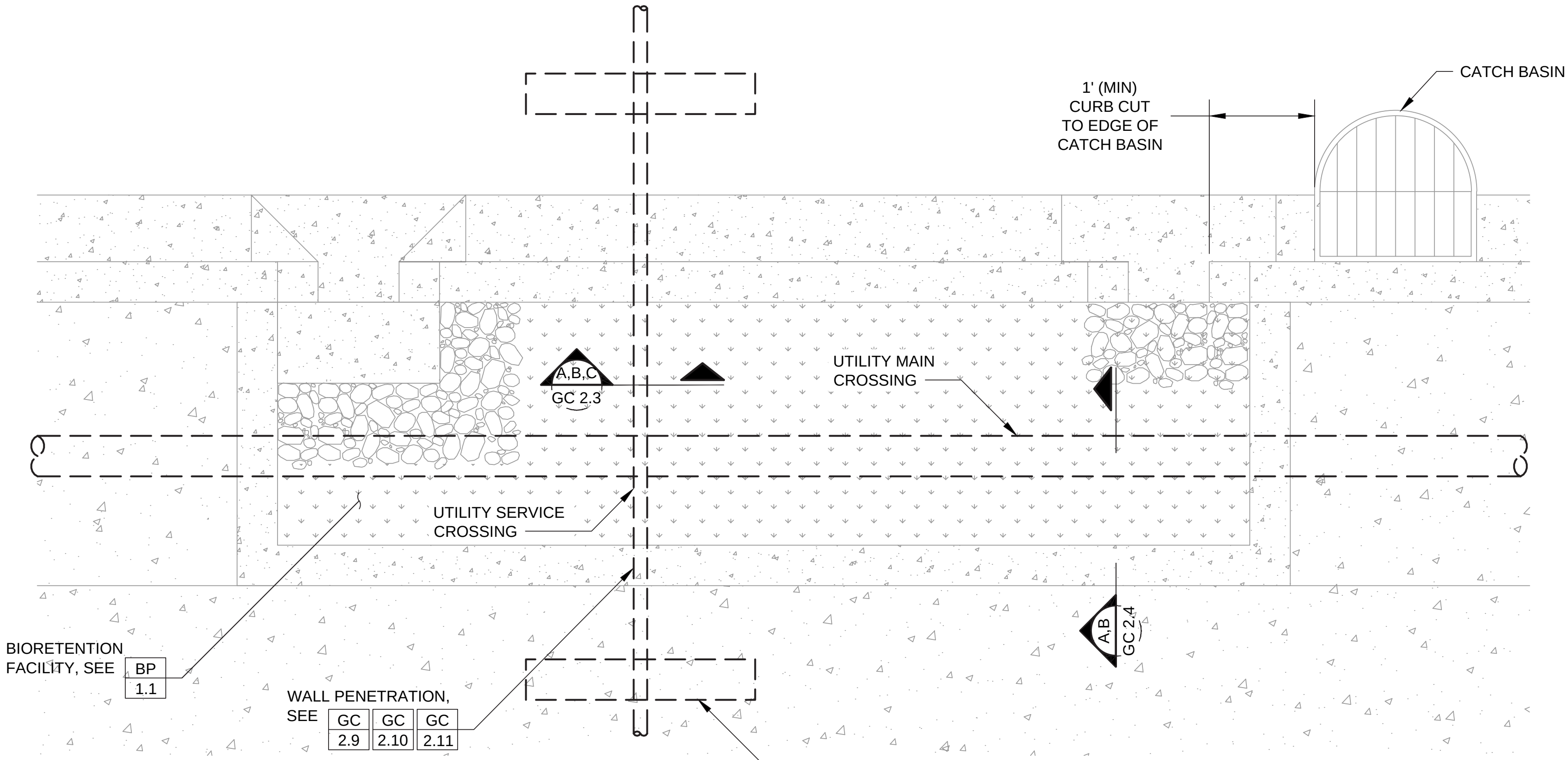
GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

GENERAL COMPONENTS
UTILITY CROSSINGS
DESIGNER NOTES (2 OF 2)

DWG NO. GC 2.2

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CONSTRUCTION NOTES:

1. ABANDONED UTILITIES WITHIN FOOTPRINT OF FACILITY AND OBSERVED DURING CONSTRUCTION MUST BE REMOVED. COORDINATE WITH MUNICIPAL OR PRIVATE OWNER AND ENGINEER.
2. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

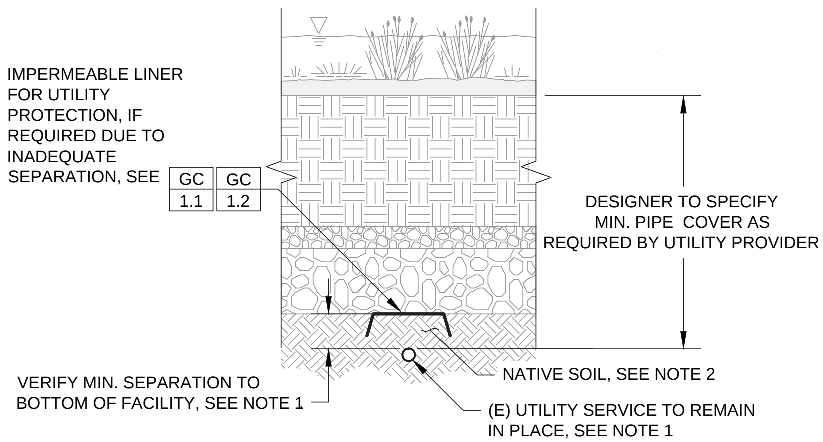
DATE	SEPTEMBER 2016
VERSION	2.0
REVISED	

GENERAL COMPONENTS

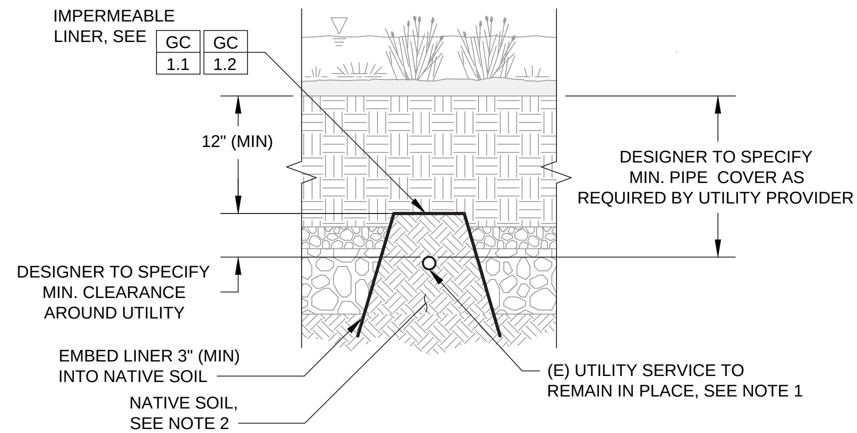
UTILITY CROSSINGS

BIORETENTION

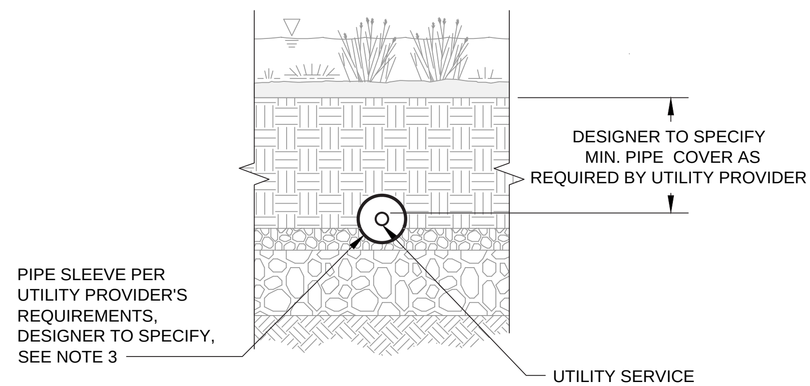
DWG NO. GC 2.3



SHALLOW UTILITY SERVICE
UNDER BIORETENTION FACILITY (A)



SHALLOW UTILITY SERVICE
WITHIN BIORETENTION FACILITY (B)



SLEEVED UTILITY SERVICE
WITHIN BIORETENTION FACILITY (C)

CONSTRUCTION NOTES:

1. CONTRACTOR SHALL LOCATE AND DETERMINE DEPTH OF EXISTING UTILITY WITHIN THE FOOTPRINT OF THE BIORETENTION FACILITY WHILE LIMITING THE AMOUNT OF DISTURBANCE TO THE SOIL/BACKFILL MATERIAL OVER AND AROUND THE UTILITY PIPE. IF ELECTROMAGNETIC UTILITY LOCATING, POTHOLING, OR OTHER METHOD REVEALS THAT THE UTILITY PIPE DOES NOT MEET THE REQUIRED CLEARANCE FROM THE BOTTOM OF THE BIORETENTION FACILITY, THE UTILITY PROVIDER MAY REQUIRE THAT PROTECTION MEASURES, SUCH AS THOSE SHOWN ON THIS PLAN, BE IMPLEMENTED PER THEIR STANDARDS. ANY DISCREPANCIES BETWEEN THE EXISTING UTILITIES SHOWN IN THE DESIGN DRAWINGS AND THE ACTUAL FIELD CONDITIONS SHOULD BE COMMUNICATED TO THE ENGINEER IMMEDIATELY.
2. EXISTING UTILITIES AND NATIVE SOIL AROUND EXISTING UTILITIES SHOULD REMAIN IN PLACE WHERE POSSIBLE. IF A PORTION OR ALL OF THE UTILITY IS UNCOVERED DURING EXCAVATION OR EXISTING SOIL WITHIN 1 FOOT OF THE KNOWN EXISTING UTILITY IS SCARIFIED, NATIVE SOIL OR APPROVED ENGINEERED BACKFILL SHALL BE CAREFULLY PLACED AND COMPACTED AROUND THE UTILITY PER THE UTILITY PROVIDER'S REQUIREMENTS.
3. UTILITY PROVIDER MAY ALLOW UTILITY SERVICES TO BE LEFT IN PLACE AND WRAPPED WITH A WATERTIGHT WRAP OR TAPE IN LIEU OF A SLEEVE. THIS MUST BE APPROVED PRIOR TO THE START OF CONSTRUCTION.

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

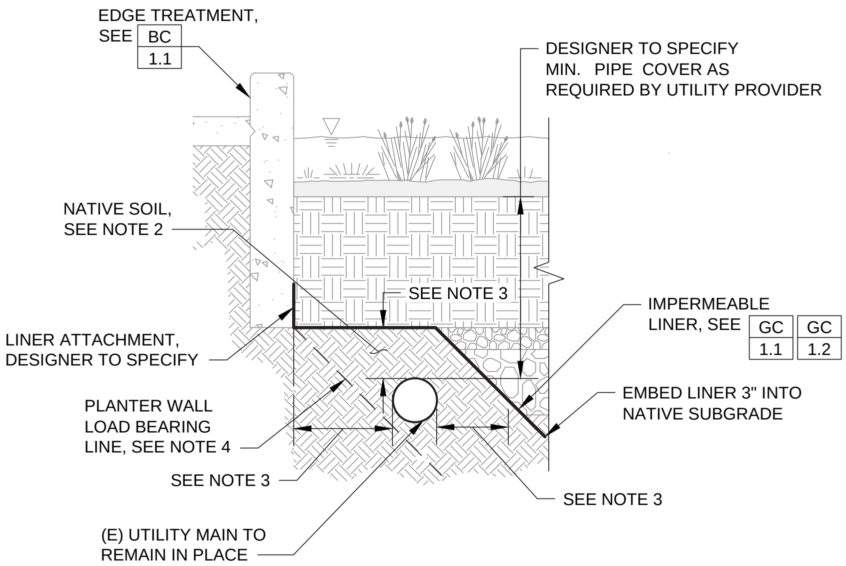
REVISED

GENERAL COMPONENTS

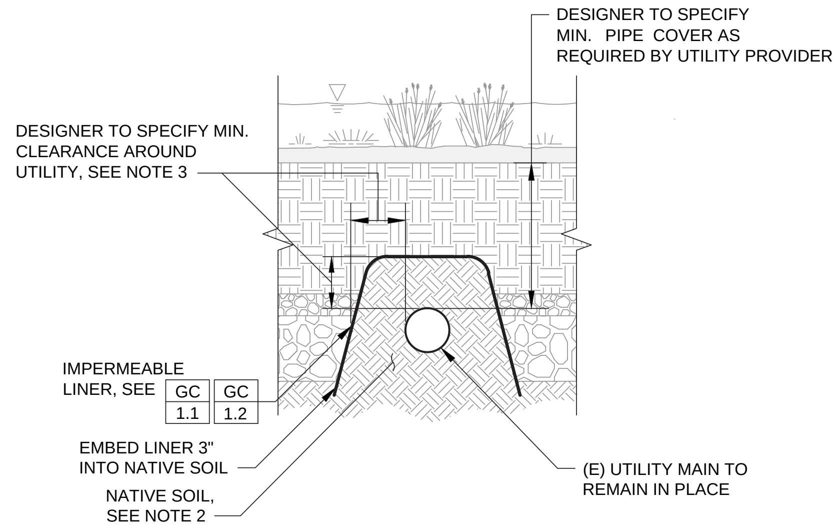
UTILITY CROSSINGS

BIORETENTION SECTIONS (1 OF 2)

DWG NO. GC 2.4



UTILITY MAIN ADJACENT TO PLANTER WALL (A)



SHALLOW UTILITY MAIN WITHIN BIORETENTION FACILITY (B)

CONSTRUCTION NOTES:

1. ANY DISCREPANCIES BETWEEN THE EXISTING UTILITIES SHOWN IN THE DESIGN DRAWINGS AND THE ACTUAL FIELD CONDITIONS SHOULD BE COMMUNICATED TO THE ENGINEER IMMEDIATELY.
2. EXISTING UTILITIES AND NATIVE SOIL AROUND EXISTING UTILITIES SHOULD REMAIN IN PLACE WHERE POSSIBLE. IF A PORTION OR ALL OF THE UTILITY IS UNCOVERED DURING EXCAVATION OR EXISTING SOIL WITHIN 1 FOOT OF THE KNOWN EXISTING UTILITY IS SCARIFIED, NATIVE SOIL OR APPROVED ENGINEERED BACKFILL SHALL BE CAREFULLY PLACED AND COMPACTED AROUND THE UTILITY PER THE UTILITY PROVIDER'S REQUIREMENTS.
3. PROVIDE THE MINIMUM CLEARANCE AROUND THE UTILITY MAIN AND SETBACKS FROM STRUCTURAL ELEMENTS PER THE UTILITY PROVIDER'S REQUIREMENTS.
4. UTILITY MAINS SHALL NOT BE SUBJECT TO LOADING FROM NEW PLANTER WALLS. LOAD BEARING LINES TO BE DETERMINED BY THE GEOTECHNICAL ENGINEER.

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

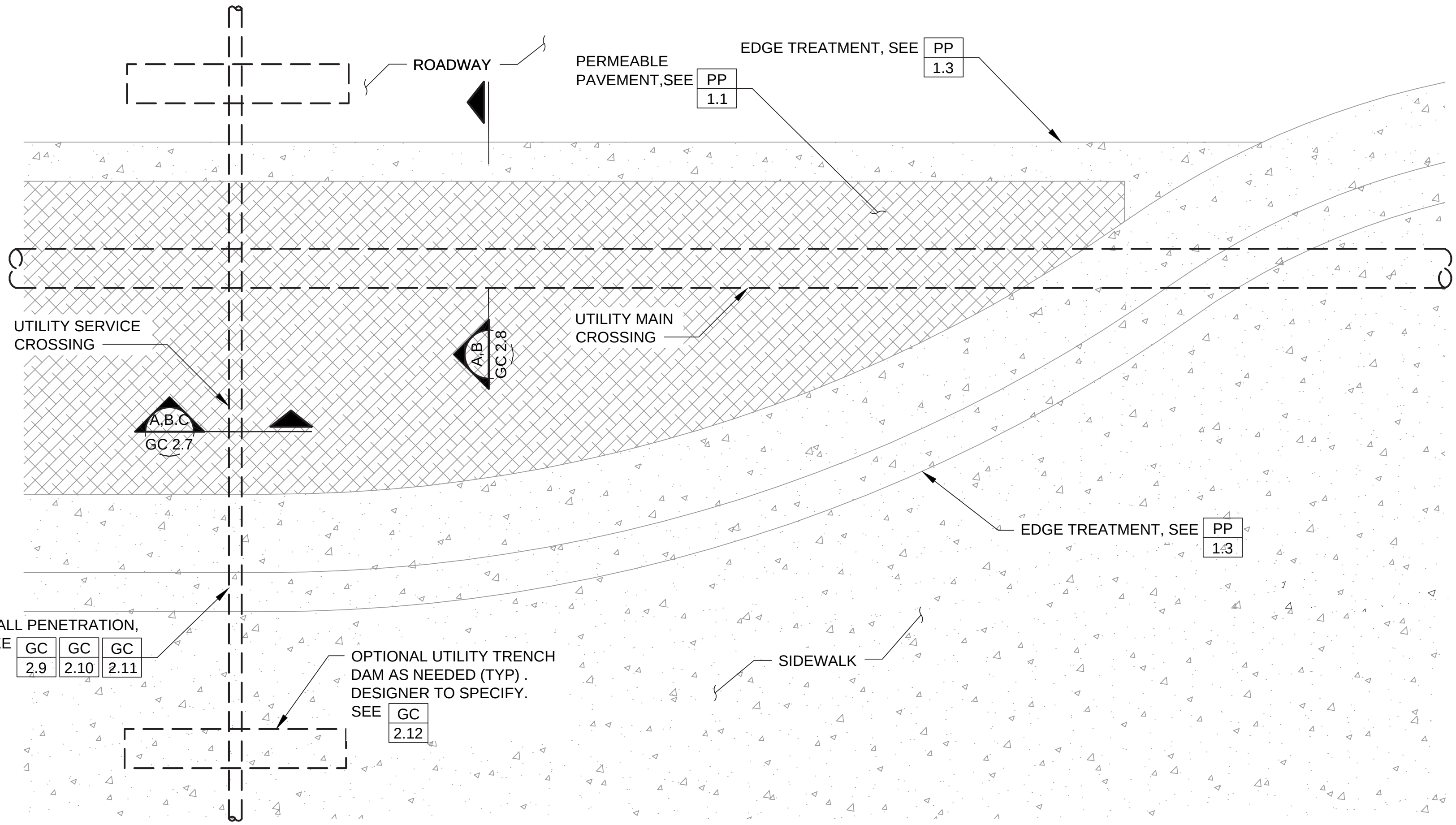
REVISED

GENERAL COMPONENTS

UTILITY CROSSINGS

BIORETENTION SECTIONS (2 OF 2)

DWG NO. GC 2.5

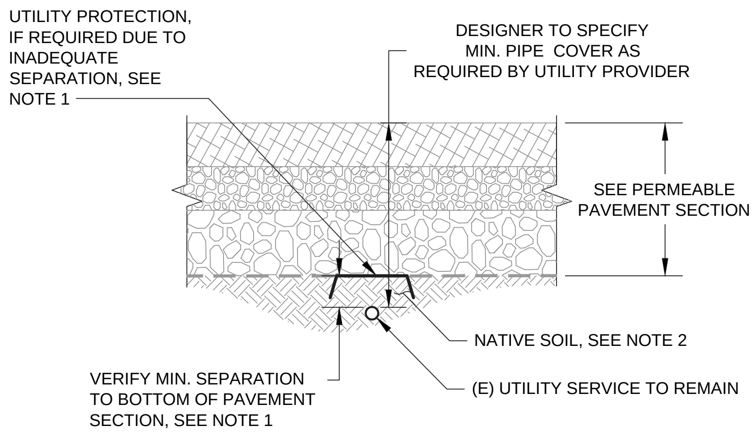


CONSTRUCTION NOTES:

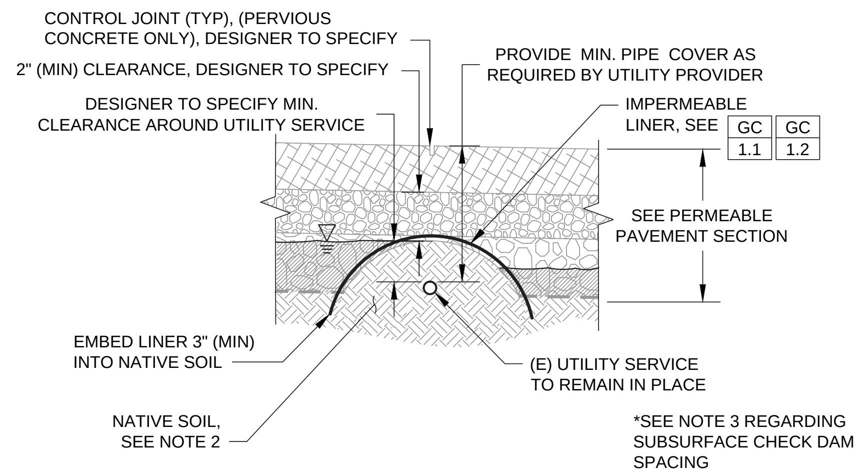
1. ABANDONED UTILITIES WITHIN FOOTPRINT OF FACILITY AND OBSERVED DURING CONSTRUCTION MUST BE REMOVED. COORDINATE WITH MUNICIPAL OR PRIVATE OWNER AND ENGINEER.
2. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

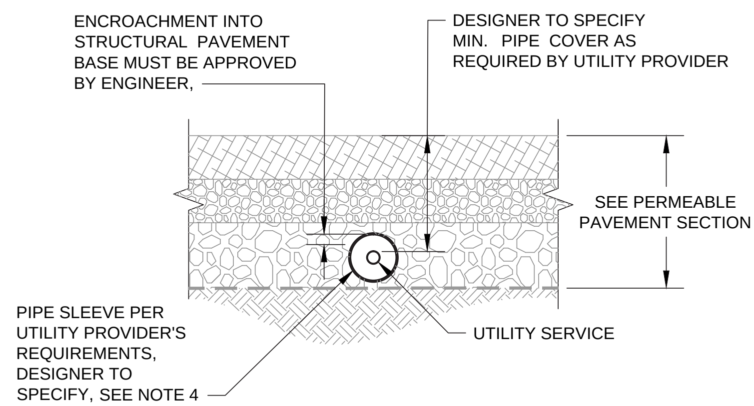
San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	GENERAL COMPONENTS UTILITY CROSSINGS PERMEABLE PAVEMENT	DWG NO. GC 2.6



SHALLOW UTILITY SERVICE UNDER PERMEABLE PAVEMENT (A)



SHALLOW UTILITY SERVICE WITHIN SUBSURFACE CHECK DAM (B)



SLEEVED UTILITY SERVICE WITHIN PERMEABLE PAVEMENT (C)

CONSTRUCTION NOTES:

1. CONTRACTOR SHALL LOCATE AND DETERMINE DEPTH OF EXISTING UTILITY WITHIN THE FOOTPRINT OF THE PERMEABLE PAVEMENT FACILITY WHILE LIMITING THE AMOUNT OF DISTURBANCE TO THE SOIL/BACKFILL MATERIAL OVER AND AROUND THE UTILITY PIPE. IF ELECTROMAGNETIC UTILITY LOCATING, POTHOLING, OR OTHER METHOD REVEALS THAT THE UTILITY PIPE DOES NOT MEET THE REQUIRED SETBACK FROM THE BOTTOM OF THE PERMEABLE PAVEMENT SECTION, THE UTILITY PROVIDER MAY REQUIRE THAT PROTECTION MEASURES, SUCH AS THOSE SHOWN ON THIS PLAN, BE IMPLEMENTED.
2. EXISTING UTILITIES AND NATIVE SOIL AROUND EXISTING UTILITIES SHOULD REMAIN IN PLACE WHERE POSSIBLE. IF A PORTION OR ALL OF THE UTILITY IS UNCOVERED DURING EXCAVATION OR EXISTING SOIL WITHIN 1 FOOT OF THE KNOWN EXISTING UTILITY IS SCARIFIED, NATIVE SOIL OR APPROVED ENGINEERED BACKFILL SHALL BE CAREFULLY PLACED AND COMPACTED AROUND THE UTILITY PER THE UTILITY PROVIDER'S REQUIREMENTS.
3. THE CHECK DAM SPACING AND HEIGHT SPECIFIED ON THE DESIGN PLANS MUST BE MAINTAINED. IF THE CHECK DAM PROTECTING THE EXISTING UTILITY WILL IMPACT THE CHECK DAM SPACING SPECIFIED ON THE PLANS, COORDINATE WITH ENGINEER.
4. UTILITY PROVIDER MAY ALLOW SHALLOW UTILITY SERVICES TO BE LEFT IN PLACE AND WRAPPED WITH A WATERTIGHT WRAP OR TAPE IN LIEU OF A SLEEVE. THIS SHOULD BE APPROVED PRIOR TO THE START OF CONSTRUCTION.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

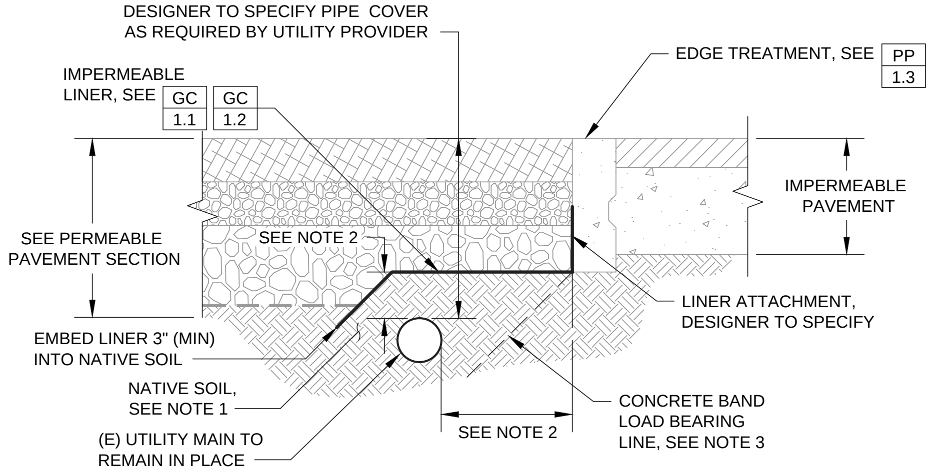
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

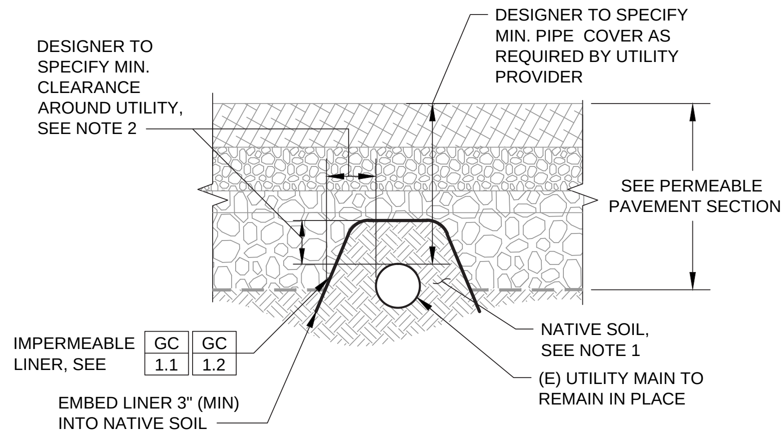
DATE SEPTEMBER 2016
VERSION 2.0
REVISED

GENERAL COMPONENTS
UTILITY CROSSINGS PERMEABLE PAVEMENT SECTIONS (1 OF 2)

DWG NO. GC 2.7



UTILITY MAIN WITHIN PERMEABLE PAVEMENT AND ADJACENT TO EDGE RESTRAINT (A)



UTILITY MAIN WITHIN PERMEABLE PAVEMENT (B)

CONSTRUCTION NOTES:

1. EXISTING UTILITIES AND NATIVE SOIL AROUND EXISTING UTILITIES SHOULD REMAIN IN PLACE WHERE POSSIBLE. IF A PORTION OR ALL OF THE UTILITY IS UNCOVERED DURING EXCAVATION OR EXISTING SOIL WITHIN 1 FOOT OF THE KNOWN EXISTING UTILITY IS SCARIFIED, NATIVE SOIL OR APPROVED ENGINEERED BACKFILL SHALL BE CAREFULLY PLACED AND COMPACTED AROUND THE UTILITY PER THE UTILITY PROVIDER'S REQUIREMENTS.
2. PROVIDE THE MINIMUM CLEARANCE AROUND THE UTILITY MAIN AND SETBACKS FROM STRUCTURAL ELEMENTS PER THE UTILITY PROVIDER'S REQUIREMENTS.
3. UTILITY MAINS SHALL NOT BE SUBJECT TO LOADING FROM NEW CURBS/WALLS. LOAD BEARING LINES TO BE DETERMINED BY THE GEOTECHNICAL ENGINEER.

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

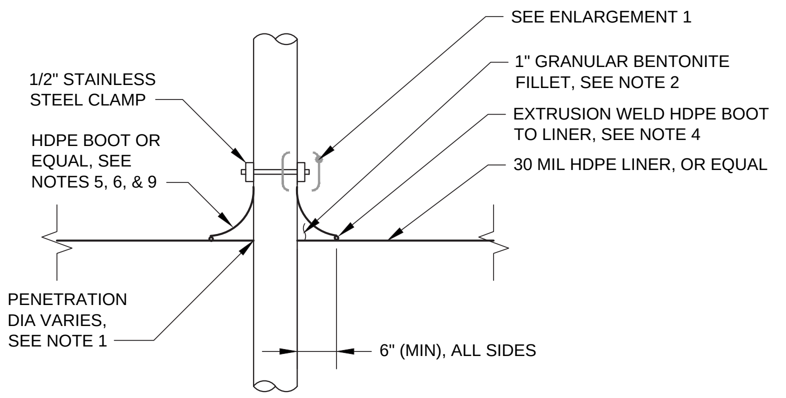
GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

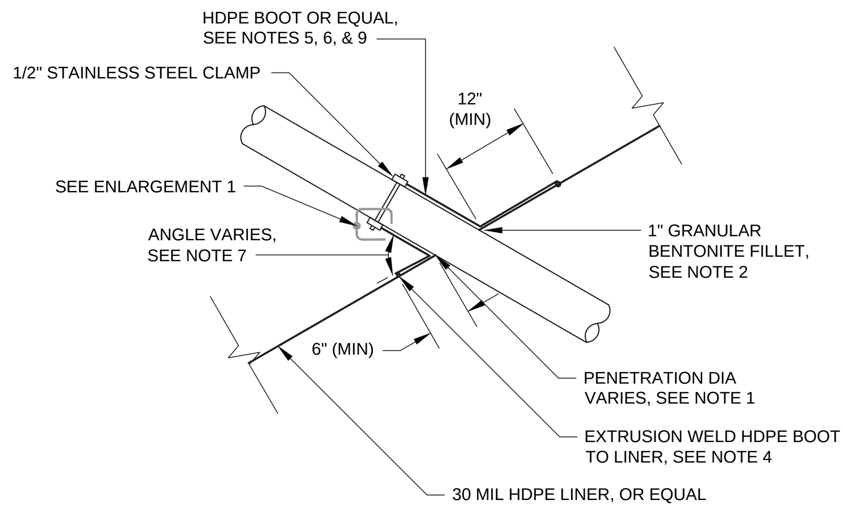
GENERAL COMPONENTS
UTILITY CROSSINGS PERMEABLE PAVEMENT SECTIONS (2 OF 2)

DWG NO. GC 2.8

NOT FOR CONSTRUCTION - REFER TO USER GUIDE



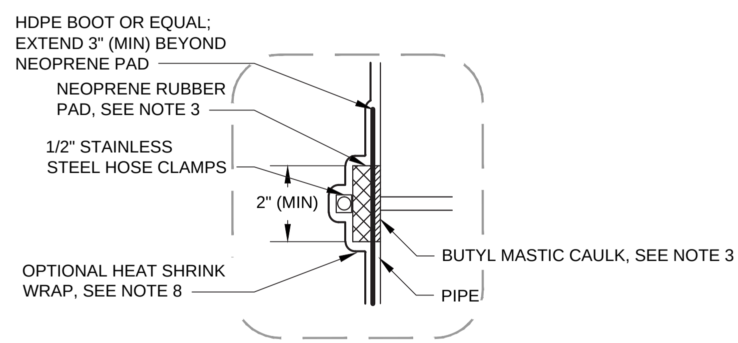
TYPICAL LINER PENETRATION - PERPENDICULAR (1)



TYPICAL LINER PENETRATION - ANGLED (2)

CONSTRUCTION NOTES:

1. CUT OPENING IN LINER FOR PIPE TO WITHIN 1/2" OF PIPE OUTSIDE DIAMETER.
2. FILL ANNULAR SPACE WITH 1" MINIMUM GRANULAR BENTONITE FILLET AS SHOWN.
3. APPLY BUTYL MASTIC CAULK AND NEOPRENE RUBBER PAD CONTINUOUSLY AROUND PIPE.
4. PROVIDE CONTINUOUS EXTRUSION WELD AT PIPE BOOT/LINER INTERFACE.
5. FORM BOOT WITH SUFFICIENT MATERIAL TO PREVENT OVERSTRESSING DURING BACKFILLING, BUT WITHOUT FOLDS OR WRINKLES.
6. CONSTRUCT BOOT FROM SAME MATERIAL AS THE LINER.
7. ANGLE SHOULD NOT BE LESS THAN 30°. IF ANGLE IS LESS THAN 30° ADD SOIL AROUND THE PIPE TO INCREASE THE ANGLE AND PREVENT STRESSING AND CRACKING .
8. SEAL CLAMP AND END OF BOOT WITH HEAT SHRINK WRAP. EXTEND HEAT SHRINK WRAP ONE PIPE DIAMETER (MINIMUM) BEYOND CLAMP.
9. CONTRACTOR MAY USE PREFABRICATED PIPE BOOTS IN LIEU OF FIELD-FABRICATED BOOTS. CONNECT PREFABRICATED BOOT TO LINER AND PIPE PER MANUFACTURER'S RECOMMENDATIONS.



ENLARGEMENT 1

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

VERSION 2.0

REVISED

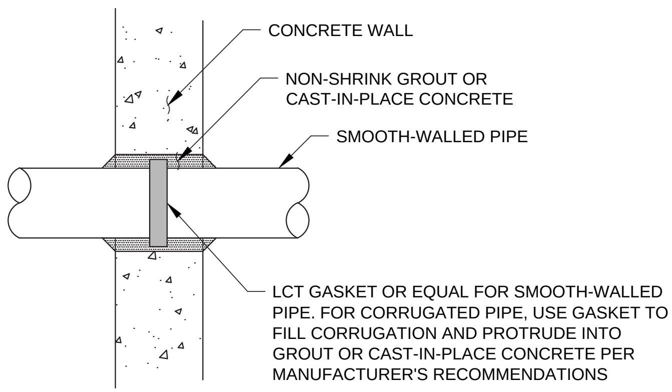
GENERAL COMPONENTS

UTILITY CROSSINGS

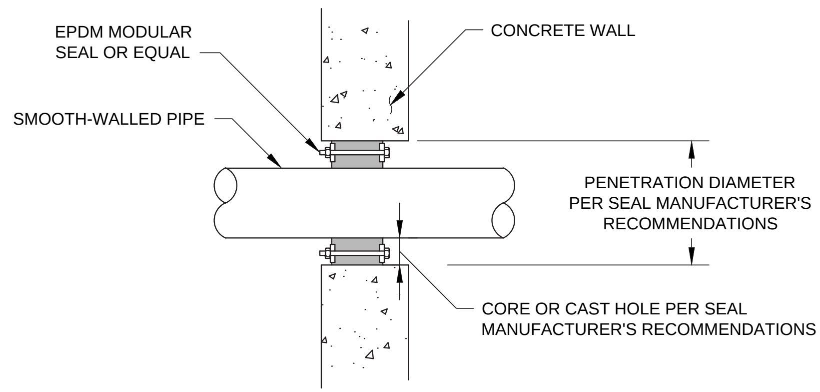
LINER PENETRATIONS

DWG NO. GC 2.9

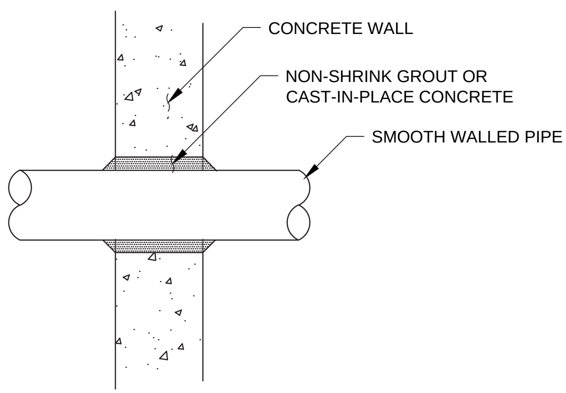
NOT FOR CONSTRUCTION - REFER TO USER GUIDE



TYPICAL WATERTIGHT WALL PENETRATION - ALTERNATE 1 (1)



TYPICAL WATERTIGHT WALL PENETRATION - ALTERNATE 2 (2)



TYPICAL SOIL TIGHT WALL PENETRATION (3)

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

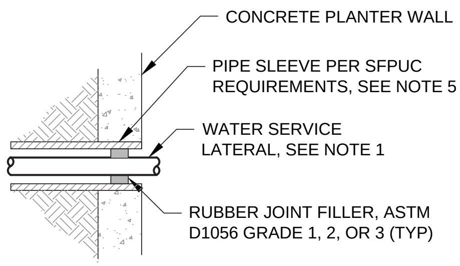
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

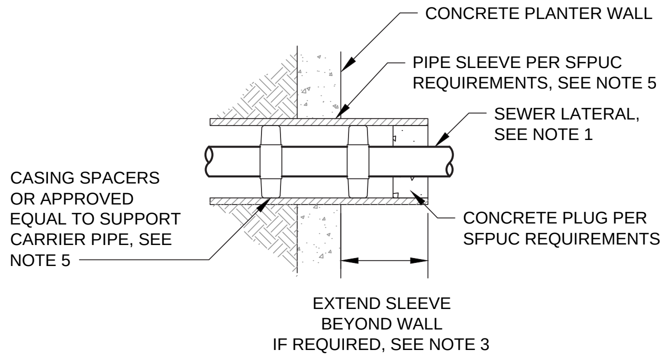
DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

GENERAL COMPONENTS
UTILITY CROSSINGS
WALL PENETRATIONS (1 OF 2)

DWG NO. GC 2.10



WALL PENETRATION FOR WATER LATERALS (1)



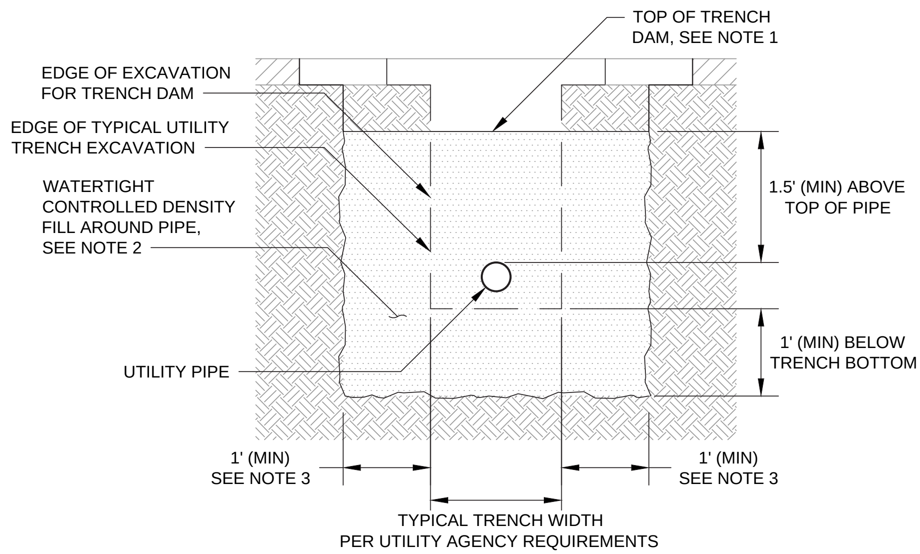
WALL PENETRATION FOR SEWER LATERALS (2)

CONSTRUCTION NOTES:

1. IN CASES WHERE SHALLOW EXISTING UTILITIES, SUCH AS STREET LIGHT CONDUIT, HAVE BEEN APPROVED TO REMAIN IN PLACE PER THE UTILITY PROVIDER, AND SLEEVING FROM ONE END IS NOT FEASIBLE, THE EXISTING UTILITIES SHALL BE CAREFULLY WRAPPED WITH AN INSULATION MATERIAL (MIN. 1" THICK) AND A WATERTIGHT TAPE UNTIL THE WALLS ARE FORMED AROUND THE PIPE CROSSINGS. ONCE THE WALLS ARE SET, THE INSULATION WRAP SHALL BE REMOVED AND THE WALL PENETRATIONS SEALED.
2. DETECTABLE UTILITY MARKING TAPE SHALL BE PLACED OVER ALL UTILITIES WITHIN THE FOOTPRINT OF BIORETENTION FACILITIES. REFER TO THE TAPE MANUFACTURER'S RECOMMENDATIONS FOR MAXIMUM TAPE BURIAL DEPTH.
3. IF SEWER LATERAL IS BELOW BOTTOM OF BIORETENTION FACILITY AND WALL PENETRATION IS NOT NECESSARY, THE CITY MAY REQUIRE THE SLEEVE AROUND NEW LATERAL PIPE TO BE EXTENDED BEYOND THE OUTSIDE OF THE PLANTER ON THE SIDEWALK SIDE. SEE DESIGN DRAWINGS FOR FURTHER DIRECTION.
4. ALL OTHER REPLACED OR NEW UTILITY SERVICES, SUCH AS GAS, TELECOM, ELECTRICAL, AND IRRIGATION RUNNING THROUGH A BIORETENTION FACILITY SHALL BE SLEEVED AND WALL PENETRATIONS SHALL BE DESIGNED TO MEET UTILITY PROVIDER'S REQUIREMENTS.
5. PIPE SLEEVE DESIGN AND MATERIALS, CONFORMING TO SFPUC STANDARDS, SHALL BE SPECIFIED ON THE DESIGN DRAWINGS.

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	GENERAL COMPONENTS UTILITY CROSSINGS WALL PENETRATIONS (2 OF 2)	DWG NO. GC 2.11



UTILITY TRENCH DAM (1)

CONSTRUCTION NOTES:

1. REFER TO DESIGN PLANS FOR TRENCH DAM LOCATIONS.
2. CONTROLLED DENSITY FILL SHALL BE 100 - 150 PSI STRENGTH WITH A WATER CONDUCTIVITY OF 1.0 X 10^{-6} CM/SEC (MAX).
3. TRENCH DAM SHALL EXTEND BEYOND THE EXISTING UTILITY TRENCH INTO THE NATIVE SOIL PER THE MINIMUM DIMENSIONS SHOWN. THE TRENCH DAM SHALL HAVE A MINIMUM THICKNESS OF 1' (MEASURED PARALLEL TO THE UTILITY PIPE LENGTH).

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES		BIORETENTION			PERMEABLE PAVEMENT			WALL PENETRATIONS			TRENCH DAM
GC 2.1	GC 2.2	GC 2.3	GC 2.4	GC 2.5	GC 2.6	GC 2.7	GC 2.8	GC 2.9	GC 2.10	GC 2.11	GC 2.12

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

GENERAL COMPONENTS
UTILITY CROSSINGS
UTILITY TRENCH DAM

DWG NO. GC 2.12

PURPOSE:

WHEN SITING GREEN INFRASTRUCTURE (GI) FACILITIES, THE DESIGNER SHOULD LOCATE AND ASSESS ALL KNOWN UTILITY CROSSINGS AND CONFLICTS AND ADJUST THE DESIGN TO AVOID AS MANY EXISTING UTILITIES, LIGHTS, POLES, SIGNS AND OTHER INFRASTRUCTURE AS POSSIBLE. THE CRITICALITY OF INFRASTRUCTURE CONFLICTS IN TERMS OF THEIR POTENTIAL IMPACT TO THE GI PROJECT'S DESIGN PERFORMANCE, COST, AND SCHEDULE SHOULD BE CAREFULLY EVALUATED DURING THE PLANNING PHASE.

THE PURPOSE OF THE FOLLOWING TYPICAL UTILITY CONFLICT DETAILS IS TO ALERT THE DESIGNERS TO COMMON UTILITY CONFLICTS THAT OCCUR ON GI PROJECTS WITHIN THE PUBLIC RIGHT-OF-WAY AND PROVIDE GENERAL GUIDANCE ON THE PROTECTION AND/OR RELOCATION OF THESE UTILITIES IN RELATION TO THE GI FACILITY. THEY ARE PROVIDED AS TYPICAL APPLICATIONS AND DO NOT REPRESENT APPROVED CITY UTILITY STANDARDS AND SPECIFICATIONS.

DESIGNER NOTES AND GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS AND UTILITY REQUIREMENTS AND OBTAIN APPROVAL FROM ALL RELEVANT UTILITY PROVIDERS PRIOR TO CONSTRUCTION. COORDINATION AND APPROVAL FROM THE FOLLOWING UTILITY PROVIDERS MAY BE NECESSARY, BUT NOT EXCLUSIVELY:
   - SFPUC CITY DISTRIBUTION DIVISION (CDD) FOR DOMESTIC/RECYCLED/FIRE WATER
   - SFPUC WASTEWATER ENTERPRISE (WWE) FOR SANITARY/STORM/SEWER
   - PACIFIC GAS ELECTRIC (PGE) FOR ELECTRIC/GAS/UTILITY POLES
   - SAN FRANCISCO PUBLIC WORKS FOR TRAFFIC SIGNAL/LIGHT POLE
   - SFMTA FOR STREET SIGNS/PARKING METERS/BUS STOP, CATENARY POLES
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT SFPUC ASSET PROTECTION STANDARDS.
3. THE AREA OF SUBBASE COVERED BY THE INFRASTRUCTURE FOOTINGS, COMPACTED ENGINEERED FILL, CONCRETE PADS AND OTHER UTILITY INFRASTRUCTURE SHOULD BE EXCLUDED FROM HYDROLOGIC PERFORMANCE CALCULATIONS WHEN THE AREA IS SIGNIFICANT (GREATER THAN 10 PERCENT) RELATIVE TO THE INFILTRATIVE AREA.
4. DESIGNER TO SPECIFY CONCRETE FOOTING DIMENSIONS AND REINFORCEMENT FOR ALL VERTICAL INFRASTRUCTURE.
5. SEE SAN FRANCISCO PUBLIC WORKS TRAFFIC LIGHT STANDARDS FOR REQUIRED SETBACKS FROM CURBS, GUARD POSTS REQUIREMENTS, AND FOOTING DESIGN STANDARDS.
6. ALL STREET SIGN PLACEMENTS SHALL BE APPROVED BY SFMTA PRIOR TO INSTALLATION.
7. ALL PARKING METER INSTALLATIONS OR RELOCATION DESIGNS SHALL CONFORM TO SFMTA STANDARDS.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ STREET LIGHT, SIGN, AND UTILITY POLE FOUNDATION DIMENSIONS, REINFORCEMENT, AND SPECIFICATIONS
- ☐ GEOTEXTILE FABRICS AND/OR LINER MATERIALS
- ☐ ENGINEERED BACKFILL MATERIAL
- ☐ DIMENSIONS OF ALL PROTECTION MEASURES
- ☐ MINIMUM SETBACKS TO ADJACENT INFRASTRUCTURE, PAVEMENT BASES, SURFACES

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: GC 3.1
COMPONENTS: GC 3.2 | GC 3.3 | GC 3.4

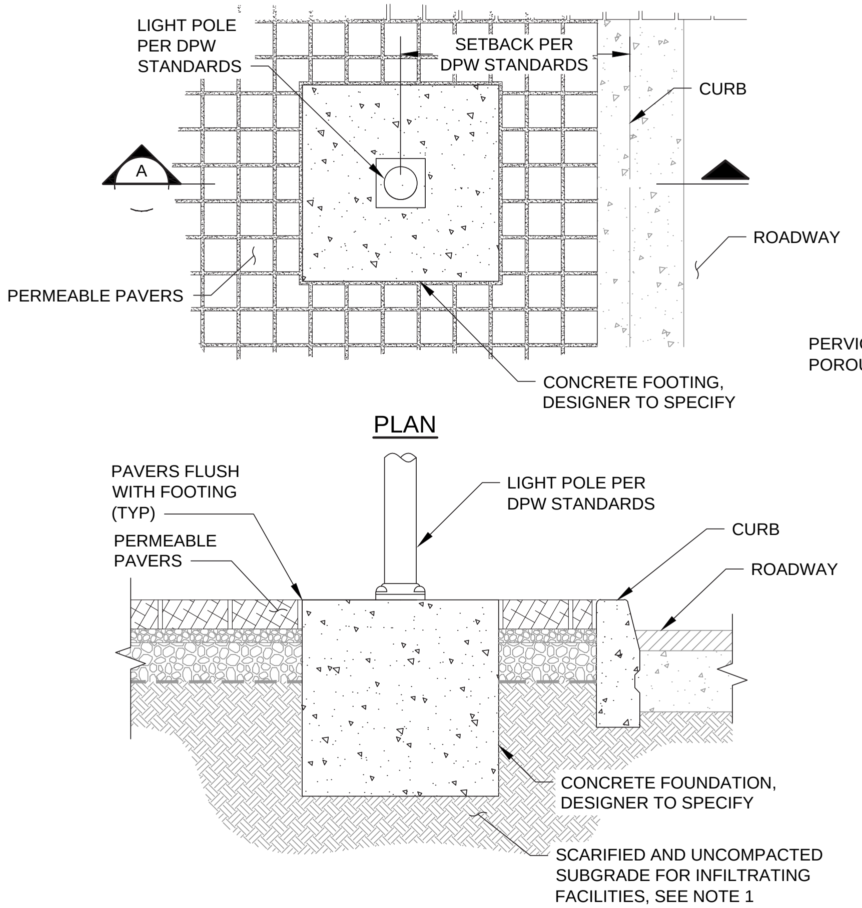
San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

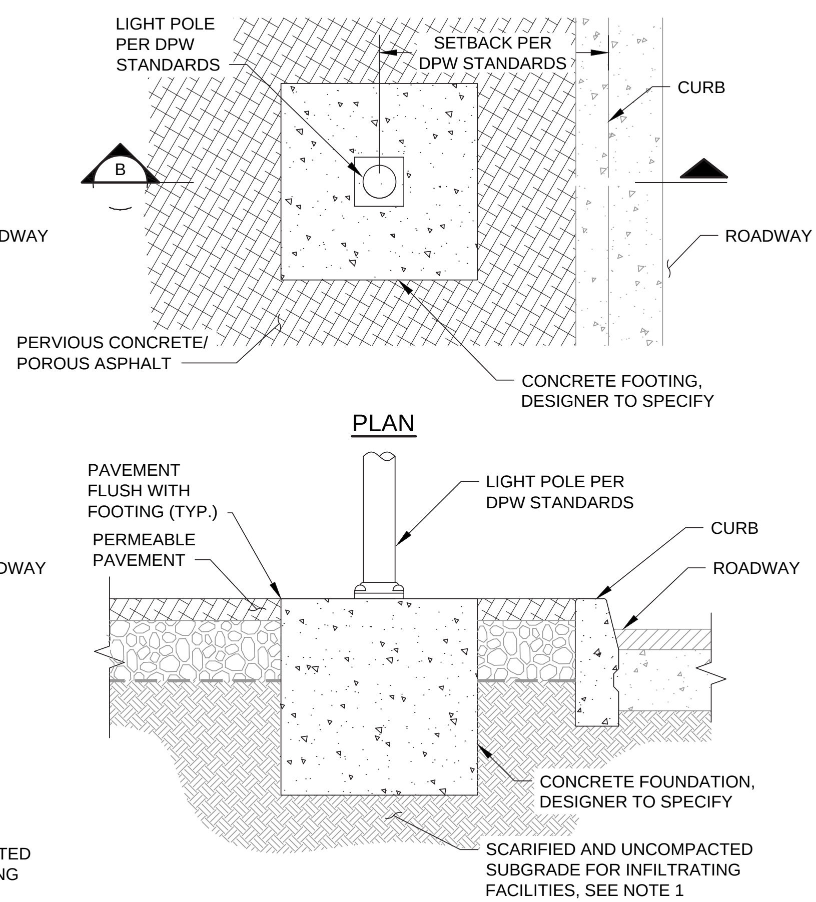
GENERAL COMPONENTS
UTILITY CONFLICTS
DESIGNER NOTES

DWG NO. GC 3.1



SECTION A

UTILITY POLE AT PERMEABLE PAVEMENT (1)



SECTION B

UTILITY POLE AT PERVIOUS CONCRETE/POROUS ASPHALT (2)

CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PERMEABLE PAVEMENT DURING CONSTRUCTION.

NOTES: GC 3.1

COMPONENTS: GC 3.2 | GC 3.3 | GC 3.4

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016

VERSION: 2.0

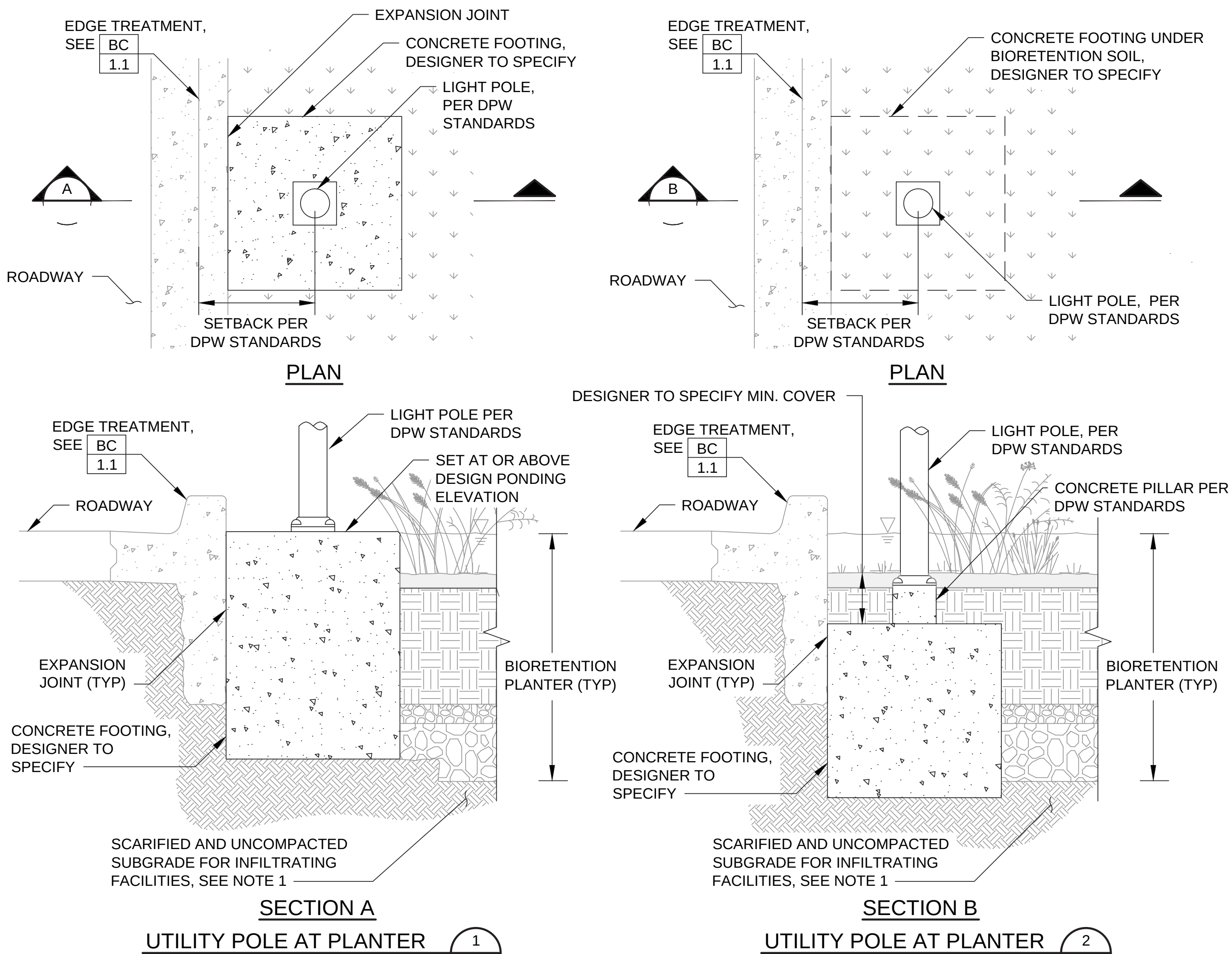
REVISED:

GENERAL COMPONENTS

UTILITY CONFLICTS

STREET/TRAFFIC LIGHT POLES (1 OF 2)

DWG NO. GC 3.2



SECTION A

UTILITY POLE AT PLANTER (1)

SECTION B

UTILITY POLE AT PLANTER (2)

CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: GC 3.1

COMPONENTS: GC 3.2 | GC 3.3 | GC 3.4

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016

VERSION: 2.0

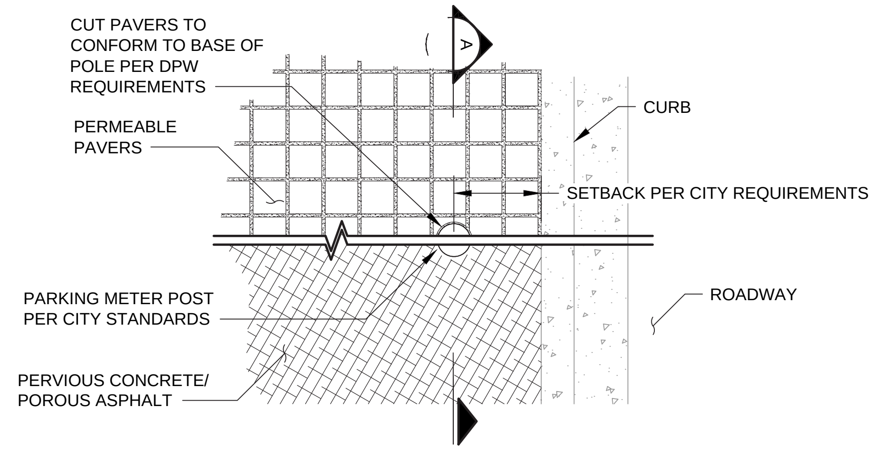
REVISED:

GENERAL COMPONENTS

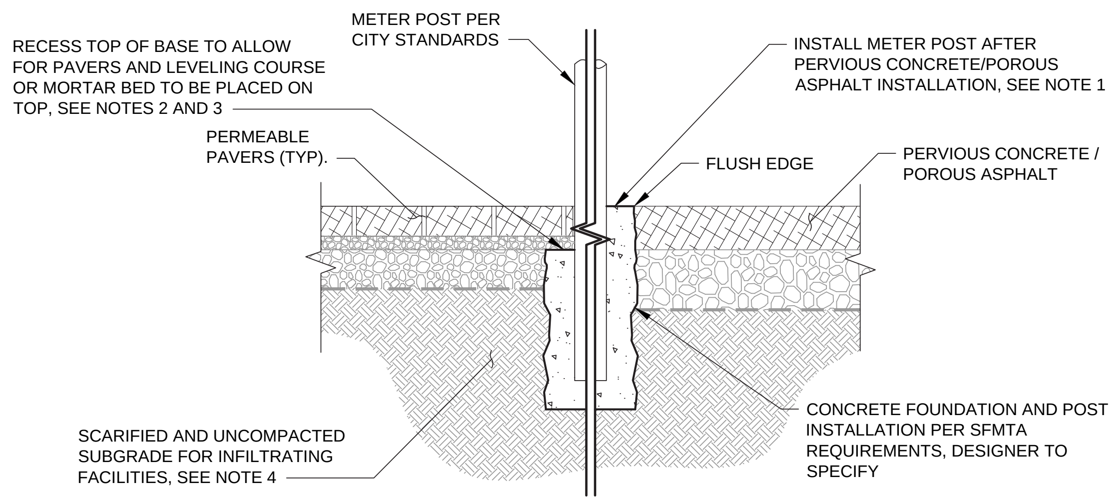
UTILITY CONFLICTS

STREET/TRAFFIC LIGHT POLES (2 OF 2)

DWG NO. GC 3.3



PLAN



SECTION A

PARKING METER AT PERMEABLE PAVEMENT (1)

CONSTRUCTION NOTES:

1. DUE TO THE ADDED COMPLEXITY OF INSTALLING PERVIOUS CONCRETE AND POROUS ASPHALT AROUND NUMEROUS POLES/POSTS, IT IS RECOMMENDED POST HOLES BE DRILLED OUT AFTER THE PERVIOUS CONCRETE/POROUS ASPHALT HAS CURED. IF POLES ARE INSTALLED PRIOR TO THE PLACEMENT OF PERVIOUS CONCRETE/POROUS ASPHALT, THE CONTRACTOR SHALL COORDINATE WITH THE DESIGNER ON HOW THE PERVIOUS CONCRETE/POROUS ASPHALT SHALL BE INSTALLED AROUND AND/OR OVER THE POLE BASES.
2. WHERE METER POLES ARE SHOWN WITHIN A PERMEABLE PAVER AREA, THE BASES OF THE POLES SHALL BE INSTALLED BEFORE THE PAVER INSTALLATION. THE DESIGNER MAY SPECIFY THAT THE TOP OF THE BASES BE SET (OR CUT DOWN) AT A DEPTH THAT ALLOWS THE PAVERS AND LEVELING COURSE TO COVER THE TOP OF THE BASE AND REMAIN FLUSH WITH THE SURROUNDING PAVEMENT.
3. INSTALL PERMEABLE PAVEMENT OVER TOP OF FOOTING PER PROJECT SPECIFICATIONS AND MANUFACTURER'S RECOMMENDATIONS.
4. AVOID OVER-COMPACTION OF EXISTING SUBGRADE BELOW PERMEABLE PAVEMENT DURING CONSTRUCTION.

NOTES: GC 3.1

COMPONENTS: GC 3.2 | GC 3.3 | GC 3.4

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

GENERAL COMPONENTS

UTILITY CONFLICTS
PARKING METERS

DWG NO. GC 3.4

PURPOSE:

OBSERVATION PORTS ALLOW FOR MEASUREMENT OF DRAWDOWN THROUGH A FACILITY (WHEN WATER LEVEL MEASUREMENTS ARE NOT OBSERVABLE AT THE SURFACE). THESE PORTS CAN ALSO BE USED FOR LONG-TERM MONITORING WITH A PRESSURE TRANSDUCER. FOR SYSTEMS INCLUDING UNDERDRAINS, CLEANOUTS MAY SERVE AS THE FACILITY OBSERVATION PORT PROVIDED LONG-TERM MONITORING IS NOT REQUIRED FOR THE FACILITY.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. OBSERVATION PORTS WITHIN A BIORETENTION FACILITY ARE NOT REQUIRED TO INCLUDE A SEPARATE LOCKING COVER ASSEMBLY. HOWEVER, DESIGNERS SHOULD CONSIDER REQUIRING A LOCKING OBSERVATION PORT CAP OR PLUG IF THE RISK OF TAMPERING IS CONSIDERED TO BE HIGH.
3. WHENEVER FEASIBLE, OBSERVATION PORTS SHOULD BE LOCATED OUTSIDE OF THE TRAVELED WAY. IF SITE CONSTRAINTS NECESSITATE INSTALLATION OF OBSERVATION PORTS IN AN AREA SUBJECT TO VEHICULAR TRAFFIC OR OTHER LOADING, OBSERVATION PORT COVER ASSEMBLIES AND MANHOLES MUST BE DESIGNED TO WITHSTAND ANTICIPATED LOADING (E.G., H-20).
4. OBSERVATION PORTS SHOULD INCLUDE A 12 INCH WATERTIGHT SUMP TO ACCOMMODATE CONTINUOUS WATER LEVEL MEASUREMENT WITH A PRESSURE TRANSDUCER.

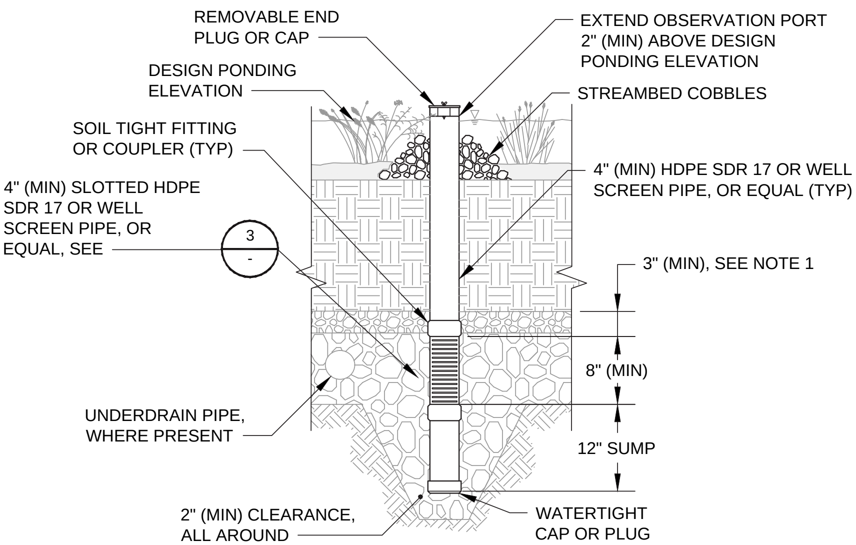
DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ OBSERVATION PORT MATERIAL, DIAMETER, AND DEPTH
- ☐ OBSERVATION PORT COVER ASSEMBLY/MANHOLE TYPE AND SIZE (IF APPLICABLE)
- ☐ CONTROL ELEVATIONS FOR OBSERVATION PORT RIMS
- ☐ TYPE OF MONITORING EQUIPMENT TO BE INSTALLED (IF APPLICABLE)

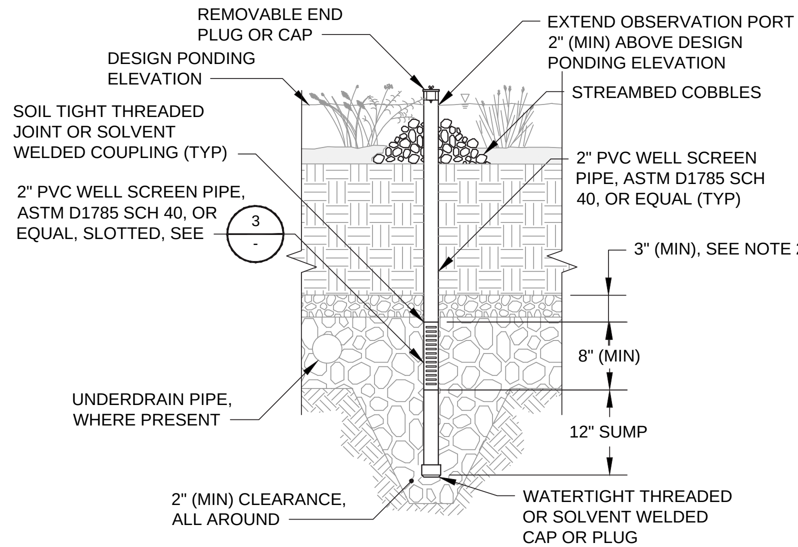
NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES: GC 4.1
COMPONENTS: GC 4.2 | GC 4.3

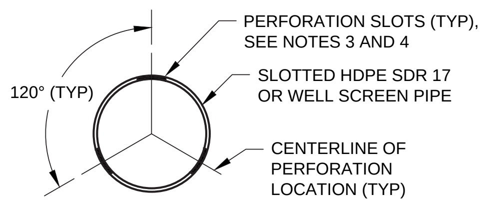
San Francisco Water Power Sewer	GREEN INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION	DATE SEPTEMBER 2016 VERSION 2.0 REVISED	GENERAL COMPONENTS OBSERVATION PORT DESIGNER NOTES	DWG NO. GC 4.1



HDPE OBSERVATION PORT (1)



PVC WELL CASING/SCREEN OBSERVATION PORT (2)



PIPE SLOT DETAIL (3)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OBSERVATION PORTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. PROVIDE 3 INCH MINIMUM COVER FROM BOTTOM OF BIORETENTION SOIL TO BEGINNING OF OBSERVATION PORT PERFORATIONS.
3. ALL PERFORATIONS SHALL BE SLOTTED TYPE, MEASURING 0.032 INCH WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDING A MINIMUM INLET AREA OF 5.0 SQUARE INCH PER LINEAR FOOT OF PIPE FOR PIPES 4 INCH IN DIAMETER AND LARGER AND 2.0 SQUARE INCHES PER LINEAR FOOT OF PIPE FOR PIPES SMALLER THAN 4 INCHES IN DIAMETER.
4. PERFORATIONS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.
5. ALL FITTINGS SHALL BE SOIL TIGHT, UNLESS NOTED OTHERWISE.

NOTES: GC 4.1
COMPONENTS: GC 4.2, GC 4.3

San Francisco Water Power Sewer

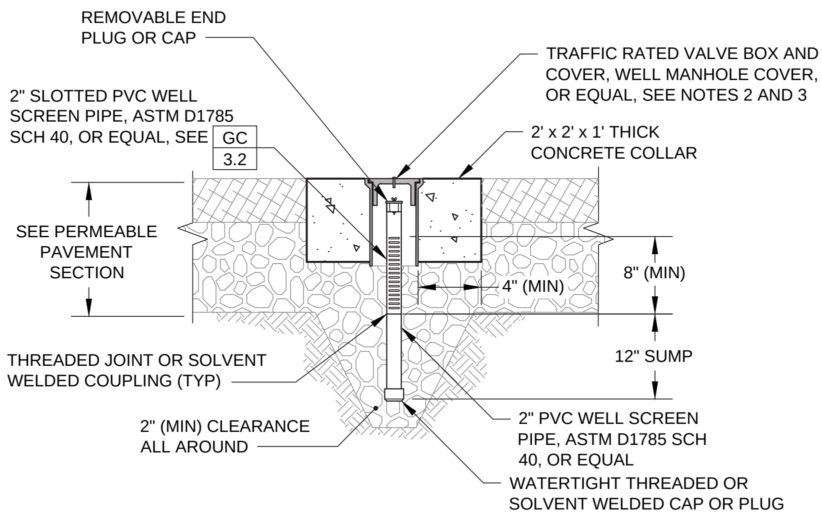
GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE: SEPTEMBER 2016
VERSION: 2.0
REVISED:

GENERAL COMPONENTS
OBSERVATION PORT
BIORETENTION

DWG NO. GC 4.2



PVC WELL SCREEN OBSERVATION PORT (1)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OBSERVATION PORTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. COVER SHALL BE TRAFFIC RATED WITH TAMPER RESISTANT LOCKING MECHANISM. COVER SHALL INCLUDE CASTING OF STANDARD TRIANGLE SYMBOL, "TEST WELL", "MONITORING WELL", OR EQUAL.
3. OBSERVATION PORT COVERS AND LIDS MUST COMPLY WITH SAN FRANCISCO DPW STANDARD ACCESSIBILITY REQUIREMENTS.
4. WELL SCREEN SLOTS SHALL BE 0.032 INCHES WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDE A MINIMUM INLET AREA OF 2.0 SQUARE INCH PER LINEAR FOOT OF PIPE.
5. ALL FITTINGS SHALL BE SOIL TIGHT, UNLESS NOTED OTHERWISE.

NOTES: GC 4.1
COMPONENTS: GC 4.2, GC 4.3

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

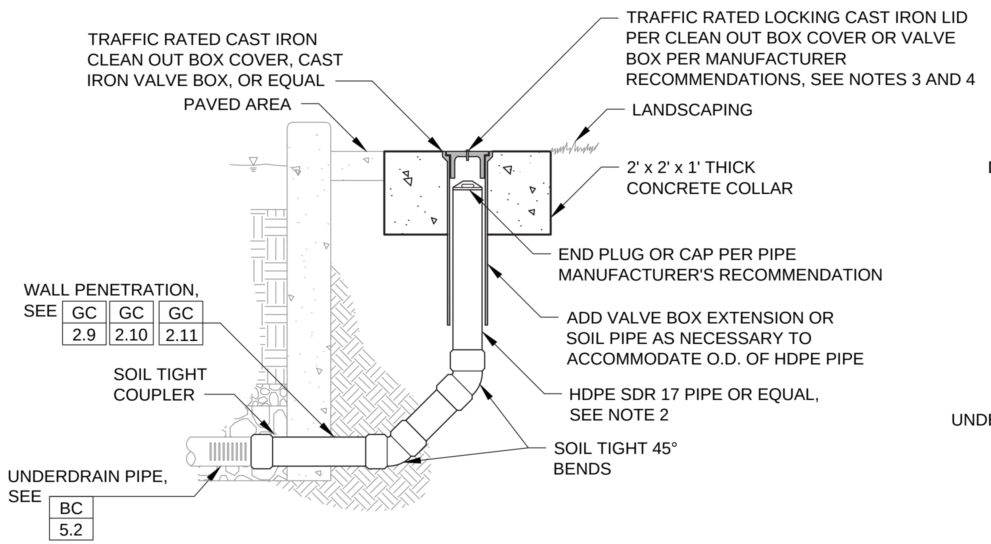
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

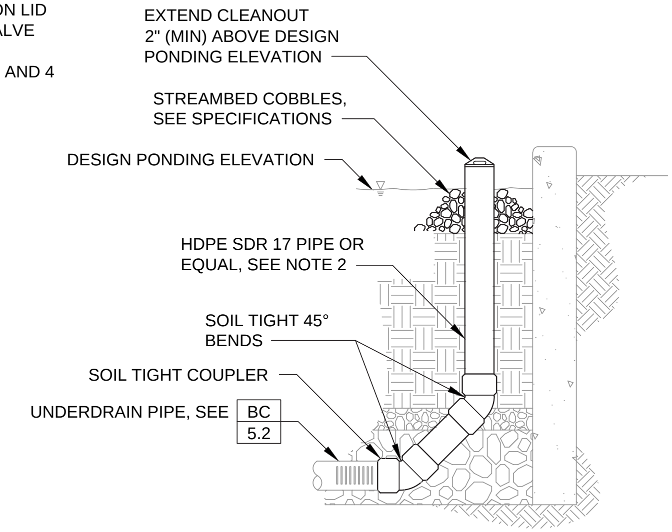
GENERAL COMPONENTS
OBSERVATION PORT
PERMEABLE PAVEMENT

DWG NO. GC 4.3

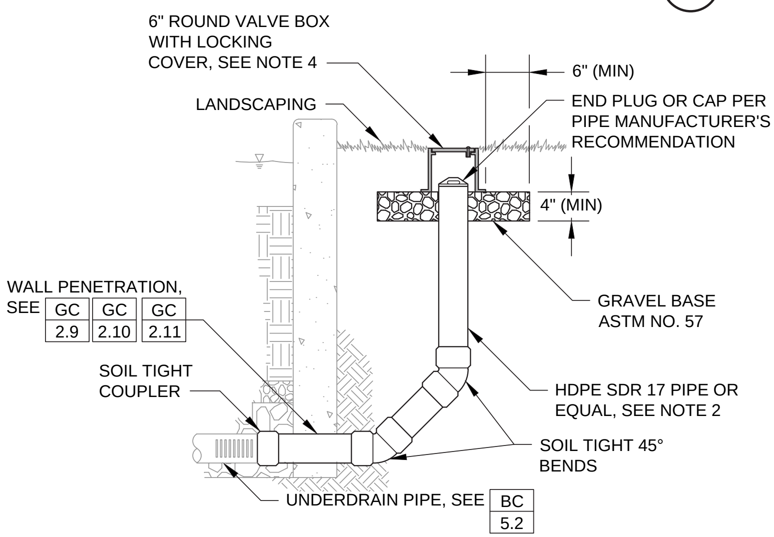
NOT FOR CONSTRUCTION - REFER TO USER GUIDE



CLEANOUT - ALTERNATIVE 1 (1)



CLEANOUT - ALTERNATIVE 2 (2)



CLEANOUT - ALTERNATIVE 3 (PARCEL ONLY) (3)

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CLEANOUTS SHALL CONFORM TO SAN FRANCISCO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER SAN FRANCISCO DBI AND PUBLIC WORKS.
2. CLEANOUT PIPE AND FITTINGS SHALL BE SAME SIZE AND MATERIAL AS SLOTTED UNDERDRAIN PIPE.
3. COVER SHALL BE TRAFFIC RATED WITH TAMPER RESISTANT LOCKING MECHANISM. COVER SHALL INCLUDE CASTING OF "CO" OR EQUAL.
4. CLEANOUT COVERS AND LIDS MUST COMPLY WITH SAN FRANCISCO PUBLIC WORKS STANDARD ACCESSIBILITY REQUIREMENTS.
5. CLEANOUT SHALL BE INSTALLED TO ALLOW FOR MAINTENANCE ACCESS TO ALL PIPES.
6. ALL FITTINGS SHALL BE SOIL TIGHT.

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

GENERAL COMPONENTS
CLEANOUTS

DWG NO. GC 5.1

PURPOSE:

END-OF-BLOCK MONITORING SYSTEMS ARE DESIGNED TO MONITOR FLOWS EXITING AN END-OF-BLOCK CATCH BASIN. THESE FLOWS ARE TYPICALLY VERY SMALL, REQUIRING THE USE OF SENSITIVE EQUIPMENT (STILLING WELLS AND HIGHLY SENSITIVE PRESSURE TRANSDUCERS) TO PRODUCE ACCURATE FLOW ESTIMATES. THESE GUIDELINES WILL HELP THE DESIGNER TO DESIGN A SYSTEM WHICH WILL BE CONDUCIVE TO FLOW MEASUREMENT USING THIS EQUIPMENT.

DESIGNER NOTES AND GUIDELINES:

1. THE DESIGNER MUST ADAPT THE SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST CONSULT WITH EQUIPMENT MANUFACTURER'S REPRESENTATIVE AND MONITORING PROFESSIONAL OR TECHNICIAN PRIOR TO COMPLETION OF DESIGN.
3. END-OF-BLOCK CATCH BASIN FLOWS SHOULD BE MEASURED WITH THE USE OF STILLING WELLS AND PRESSURE TRANSDUCERS.
4. PRESSURE TRANSDUCERS MAY BE VENTED OR UNVENTED. IF UNVENTED, A NEARBY BAROMETRIC TRANSDUCER OF THE SAME MAKE SHOULD BE INSTALLED FOR ATMOSPHERIC PRESSURE CORRECTION.
5. PVC STILLING WELLS MUST BE PERFORATED BELOW THE INVERT OF THE OUTLET PIPE. PERFORATIONS SHOULD ALWAYS BE ABOVE THE TOP OF THE PRESSURE TRANSDUCER HOUSING TO PROVIDE A PERMANENT WET POOL FOR THE TRANSDUCER.
6. THE STRUCTURE SHALL BE WATER TIGHT. CALIBRATION OF THE OUTLET PIPE WILL BE DIFFICULT IF LARGE VOLUMES OF WATER ARE NEEDED TO INCREASE THE WATER LEVEL IN THE STRUCTURE TO THE INVERT OF THE PIPE WEIR.
7. THE MONITORING STRUCTURE SHOULD BE LARGE ENOUGH TO PROVIDE ACCESS FOR INSTALLATION, MAINTENANCE, AND REMOVAL OF MONITORING EQUIPMENT.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ CATCH BASIN TYPE/MATERIAL, DIAMETER, AND DEPTH
- ☐ PRESSURE TRANSDUCER TYPE AND SPECIFICATIONS
- ☐ CONTROL ELEVATIONS FOR STILLING WELLS AND PRESSURE TRANSDUCERS
- ☐ MATERIAL TYPE AND SIZE FOR ALL PIPES AND TUBING
- ☐ DIAGRAM WITH ALL OUTLET MONITORING ASSEMBLY COMPONENTS IDENTIFIED OR REQUEST FOR CONTRACTOR SUBMITTAL OF MONITORING ASSEMBLY

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES	COMPONENTS
GC 6.1	GC 6.2

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016

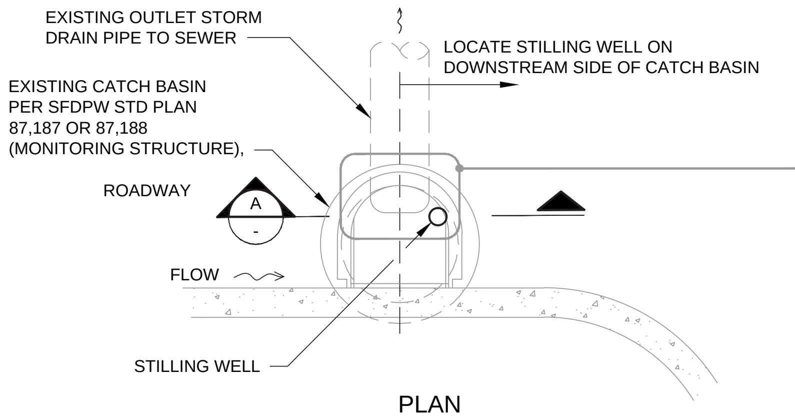
VERSION 2.0

REVISED

GENERAL COMPONENTS

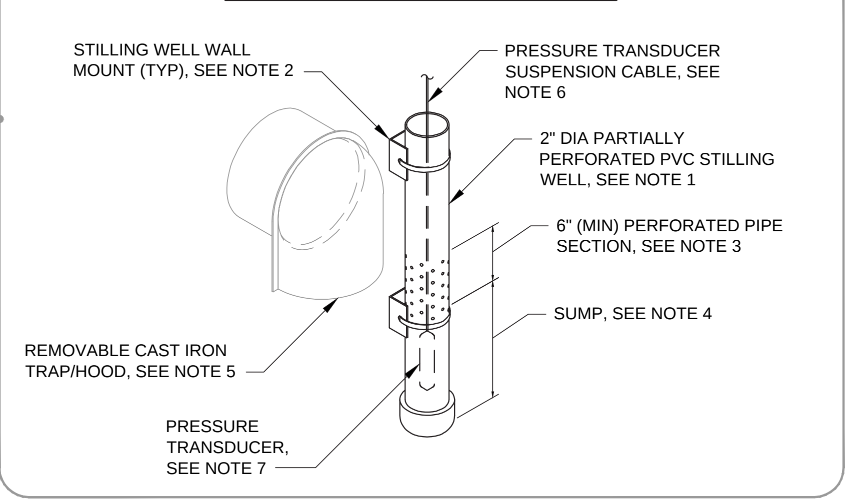
END-OF-BLOCK MONITORING DESIGNER NOTES

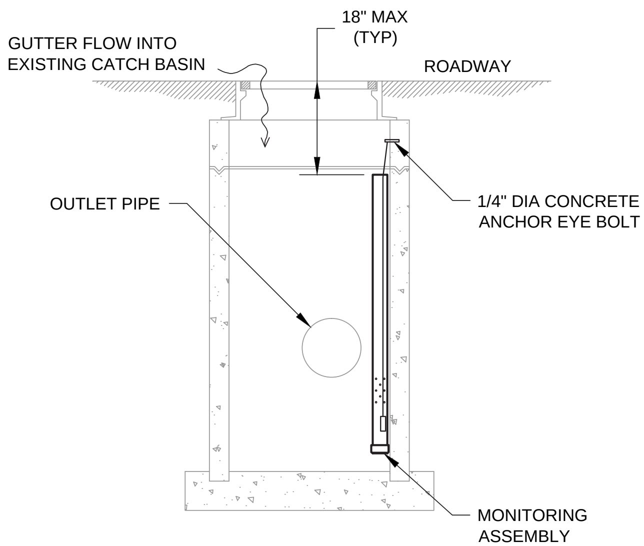
DWG NO. GC 6.1



PLAN

MONITORING ASSEMBLY DETAIL





SECTION A

CONSTRUCTION NOTES:

1. STILLING WELL SHALL BE MOUNTED VERTICALLY AND ALL FITTINGS SHALL BE WATERTIGHT.
2. ATTACH STILLING WELL WITH PREFABRICATED METAL STRUT CHANNEL AND PIPE CLAMPS (2 MINIMUM) PER MANUFACTURERS RECOMMENDATION.
3. PROVIDE PERFORATIONS ALONG CIRCUMFERENCE OF STILLING WELL BETWEEN OUTLET PIPE INVERT AND PRESSURE TRANSDUCER SUMP. PERFORATIONS SHALL MEASURE 1/4 INCH DIAMETER (MINIMUM) AT 1 INCH (MAXIMUM) ON-CENTER SPACING, ALL DIRECTIONS.
4. STILLING WELL SUMP SHALL BE NON-PERFORATED AND EXTEND 4 INCHES (MINIMUM) BELOW AND 2 INCHES (MINIMUM) ABOVE PRESSURE TRANSDUCER HOUSING TO ALLOW FOR SEDIMENT ACCUMULATION IN THE BOTTOM OF THE WELL AND PROVIDE A PERMANENT WET POOL FOR THE TRANSDUCER.
5. REMOVABLE CAST IRON TRAP/HOOD SHALL BE NEENAH R-3701 SERIES, NEENAH R-3711 SERIES OR EQUAL. INSTALL TRAP/HOOD PER MANUFACTURERS RECOMMENDATION.
6. PRESSURE TRANSDUCER SUSPENSION CABLE SHALL BE 1/16 INCH COATED STAINLESS STEEL CABLE WITH FERRULED CABLE LOOP AND COMPATIBLE OVAL CARABINER FOR CONNECTION TO CONCRETE ANCHOR EYE BOLT.
7. PRESSURE TRANSDUCER SHALL BE RATED FOR ZERO TO 21 PSI OF PRESSURE AND AN ACCURACY OF ±0.1 PERCENT FULL SCALE RANGE OR BETTER AT 25°C.

NOT FOR CONSTRUCTION - REFER TO USER GUIDE

NOTES	COMPONENTS
GC 6.1	GC 6.2

San Francisco Water Power Sewer

GREEN INFRASTRUCTURE TYPICAL DETAILS

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DATE SEPTEMBER 2016
VERSION 2.0
REVISED

GENERAL COMPONENTS

END-OF-BLOCK MONITORING

DWG NO. **GC 6.2**

(This Page Intentionally Left Blank)

A.4 Appendix 4
Sustainable Streets Specifications

BAY AREA PERVIOUS CONCRETE

Introduction

This section provides information and links to specifications specific to green infrastructure material elements with a focus on their application within the street right of way. It also provides considerations and references to other materials. **The User must verify that the correct specification version is being used as is required by each jurisdiction, and the most current version of each specification is being used for your project, as is required.** The San Mateo Countywide Program Green Infrastructure Committee (GI Committee) agreed to use the San Francisco Public Utility Commission's (SFPUC's) typical specifications as the base model documents for the Countywide Program. In addition, Bay Area Pervious Concrete (BAPC) specifications for pervious concrete are included based on discussions with SFPUC as recommended alternative materials and/or specifications. Countywide Program jurisdictions also have the ability to adopt other specifications if they so desire. **As new versions of the SFPUC or other specifications are released, each jurisdiction needs to review them and determine if they need to customize the specifications to meet their specific local requirements, and do so, as appropriate.** For courtesy, please credit SFPUC or BAPC in the specifications for allowing the public use of their documents.

Pervious Pavement Materials

A variety of pervious pavements are available; the following are the most likely to be placed in streets.

The SFPUC specifications are available in Microsoft Word and are set up to allow the User to modify the specifications to each particular project. **Each Countywide Program jurisdiction that uses these specifications shall revise references to San Francisco to their specific jurisdiction, and to their appropriate department or division, codes and regulations, etc. as appropriate.**

Courtesy copies of these specifications are provided for reference in the following pages.

A link to current versions (as of 2019) editable Word documents for these specifications is also provided here.

Permeable/Pervious Pavers

To locate this specification on the **SFPUC San Francisco Stormwater Management Requirements and Design Guidelines (SMR) document webpage,** linked here, see SMR Appendices, Appendix B: Green Infrastructure Typical Details & Specifications, Specifications available for download, Permeable Unit Paver Specification for the most current version. The SFPUC refers to pervious pavers as porous pavers.

Porous Asphalt

San Francisco Public Utility Commission – visit the website here. To locate this specification on the SFPUC San Francisco Stormwater Management Requirements and Design Guidelines (SMR) document webpage, see SMR Appendices, Appendix B: Green Infrastructure Typical Details & Specifications, Specifications available for download, Porous Asphalt Specification for the most current version.

Pervious Concrete

Either of the following specifications can be used:

Bay Area Pervious Concrete – visit the website here. See Pervious Concrete Specification and Design Details.

San Francisco Public Utility Commission – visit the website here. To locate this specification on the SFPUC San Francisco Stormwater Management Requirements and Design Guidelines (SMR) document webpage, see SMR Appendices, Appendix B: Green Infrastructure Typical Details & Specifications, Specifications available for download, Pervious Concrete Specification for the most current version.

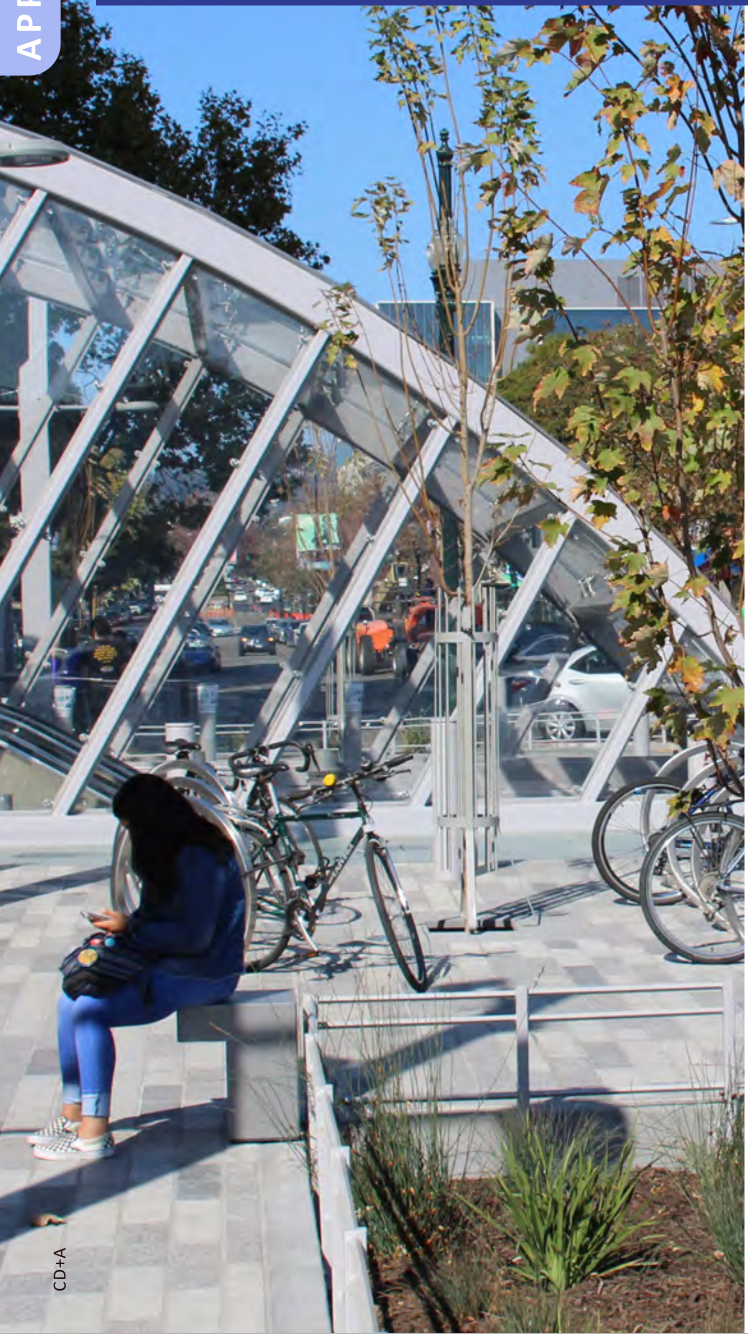
Biotreatment Soil Media[1]

There is ongoing debate about the quality of the biotreatment soil media for long term growth of plant materials, and particularly for trees. The high sand content, while allowing high percolation for runoff infiltration, does not retain water for plant use. This can be stressful to plants in general, but is especially stressful to plants in drought conditions or when they are not irrigated. In addition, a low soil content can limit long term growth and vitality of plants. BASMAA's Development Committee had a report prepared on this issue, looking at various research, strategies, and soil specifications from other cities using green infrastructure; however, no new biotreatment soil media specification was developed for the Bay Area.[2] In addition, BASMAA held a roundtable forum of arborists, compost and soil producers, designers, soil engineers, hydrologists and others to try and come up with a new and improved biotreatment soil media specification to address these concerns.

1 The term biotreatment soil media is used in the San Mateo C.3 Regulated Projects Guide whereas bioretention soil is used for San Francisco.
2 https://basmaa.org/frequently-requested-documents/. See the Biotreatment Soil Mix section.

BAY AREA PERVIOUS CONCRETE

A.4 Appendix 4
Sustainable Streets Specifications



Many strategies, issues, and considerations were gathered, but there was no consensus on how the bioretention soil media specification should be revised. In particular, soil producers were concerned about being able to consistently provide a product that met the specification, especially for infiltration rates.[3] It is unclear when this topic may be moved forward again at the regional level.

The SFPUC has made a first step to provide a better soil condition for trees and other plants in green infrastructure treatment measures. Under their agreement for standard C.3 regulated bioretention soil media, various soil amendments can be added in place of sand (up to 15%) to aid in the soil being able to retain water longer, while still providing a biotreatment or bioinfiltration function.

Other cities and agencies included a portion of soil into their standard biotreatment soil media. Typically these places have a lower requirement for infiltration (less than 5 inches/hour) than the Bay Area. Some agencies and cities in the Bay Area have experimented with adding soil to their biotreatment soil media with varying results, from good infiltration to waterlogging. It is unknown what "recipes" were used for these soil mixes, the level of knowledge and skill of contractors, what the conditions of installation were, the quality of installation, if underdrains and other components were used, and the existing project and soil conditions.

See the **C.3 Regulated Projects Guide**, Appendix K Soil Specifications (Biotreatment Soil Media Specifications), for the most current version of standard approved biotreatment soil media for San Mateo County. The June 2016 version is included at the end of this Appendix for reference only. Other biotreatment soil media are allowed if they are tested and meet the requirements set forth in Appendix K. This would permit the use of alternative biotreatment soil media and/or amendments that would better support tree and other plant health and long term vitality. This could include replacing a portion of the sand component with amendments or admixtures to increase its water holding capacity and improve nutrient value. Amendments, such as those used in the SFPUC specification, could include biochar, perlite, ground coconut coir, pumice, and vermiculite. Discussions with a few mulch producers and experts suggest that current thinking is that coconut coir may offer the best water retaining properties for an admixture.

3 https://basmaa.org/frequently-requested-documents/. See the Biotreatment Soil Mix section and BASMAA Biotreatment Soil and Tree Roundtable Summary: Improvements For the Health of Trees

The San Francisco Countywide C.3 Program, a different program, allows water retaining amendments to be added to the bioretention soil mix. For more information, refer to the **SFPUC's San Francisco Stormwater Management Requirements and Design Guidelines** (**SMR**) **document webpage**, linked here, see SMR Appendices, Appendix B: Green Infrastructure Typical Details & Specifications, Specifications available for download, Bioretention Soil Specification for the most current version of their standard approved bioretention soil.

A portion of the specification, pages 5 and 6, is excerpted below for reference. The full March 2016 version is included at the end of this Appendix for reference only.

1.01 BIORETENTION SOIL MIX (BSM)

A. General: BSM shall be a well-blended mixture of sand and compost, shall have sufficient moisture retention to support healthy plant growth, and shall meet the following criteria:

1. Mixture proportions: 30 to 40 percent Compost by volume and 60 to 70 percent Sand by volume

   DESIGNER NOTE: Up to 15 percent of the sand fraction may be replaced with other media or soil admixtures (e.g., scoria, coconut coir, perlite, expanded shale, gypsum, vermiculite, pumice, biochar, etc.) to enhance moisture retention capacity of soil, provided admixtures are low in fines (less than 5 percent passing the 200 sieve) and do not break down under normal handling and use. No topsoil, peat, silts, or clays are permitted to be used as admixtures. Admixtures shall be free of sediments and other materials deleterious to plant growth.

2. Organic matter content: 4 to 8 percent as determined by TMECC 05.07A, Loss on Ignition Method.

3. Extraneous materials: BSM shall be free of all roots, plants, weeds, sod, stones, clods, pockets of coarse sand, construction debris, or other extraneous materials harmful to plant growth.

CD+A

CD+A

A.4 Appendix 4
Sustainable Streets Specifications

4. Permeability/Saturated Hydraulic Conductivity: 10 inches per hour (minimum) tested in accordance with ASTM D2434 (Modified). See SFPUC Modified ASTM D2434 Procedures for required modifications to test.

   DESIGNER NOTE: 10-inch-per-hour minimum rate assumes a design rate of 5 inches per hour and a correction factor of 2 to account for reduction in performance from initially measured rates.

5. Acceptance of BSM quality and performance may be based on samples taken from stockpiles at supplier's yard, submitted test results, and/or onsite and laboratory testing of installed material at the discretion of the Engineer/Landscape Architect. The point of acceptance will be determined in the field by the Engineer/Landscape Architect.

   DESIGNER NOTE: Designer to consider non-compost based BSM specification if facility is serviced by an underdrain and if it is draining to phosphorus sensitive water body.

B. Sand: Sand in the BSM shall conform to the requirements for Sand, Type [specify type from table below] specified herein, unless otherwise approved by the Engineer/Landscape Architect.

DESIGNER NOTE: Designer to specify sand type based on project specific requirements. If bioretention facilities will be subjected to heavy sediment loads (e.g., arterial runoff), consider specifying Sand, Type B (low fines sand) in an effort to reduce clogging risk (pending local availability). Additionally, projects anticipating heavy sediment loads should incorporate pre-settling measures at the upstream end of the facility to allow for more efficient maintenance of facilities.

Composted Arbor Mulch [4]

The use of composted wood mulch is recommended in the C.3 Regulated Projects Guide. Composted wood mulch has been shown to float less and hold together better than other mulches[5]. Specifications for composted wood mulch have been developed and are posted on the Countywide Program website here: www.flowstobay.org/preventing-stormwater-pollution/with-new-redevelopment/c-3-regulated-projects/.

4 We would like to thank Ron Alexander, R. Alexander Associates, for his assistance in developing the Composted Wood Mulch specification.

5 https://www.stopwaste.org/sites/default/files/Mulch%20float%20test%20results.pdf

A.4 Appendix 4
Sustainable Streets Specifications

A. Composted Arbor Mulch (Based on Seattle Coarse Compost)

Mulch shall be non-floating or resist floating. A composted arbor mulch consisting of ground or shredded tree trimmings and vegetation that have been composted for at least the minimum requirement by CalRecycle for pathogen reduction [6]. It shall be dense and composed of various sizes that knit and hold together. Mulch shall be coarse ground wood (approximately ¼ inch to 3 inches along the longest dimension) derived from the mechanical grinding of the above-ground portions of trees. It may contain wood, wood fiber, and branches; but may not contain visible amounts of soil. It shall be free of dyes, recycled dimensional lumber, bark, weeds, seeds and invasive species including but not limited to horsetail, ivy, grass, knotweed, etc., and be free of diseases and other hazardous contaminants. Mulch must not contain more than 0.1% of deleterious materials such as rocks, glass, plastics, metals, clods, weeds, weed seeds, coarse objects, sticks larger than the specified particle size, salts, paint, petroleum products, pesticides or chemical residues harmful to plant or animal life. Mulch shall not contain eucalyptus.

Metal concentrations in compost must not exceed the maximum listed under 14 CA Code of Regs § 17868.2. Process compost materials under 14 CA Code of Regs § 17868.3. Compost producers must be participants in the United States Composting Council's seal of testing assurance program and the compost shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost producers must be permitted by the Department of Resources Recycling and Recovery, Local Enforcement Agencies, and any other State and local agencies that regulate solid waste plants. If exempt from State permitting provisions, the composting plant must certify it complies with the guidelines and procedures for production of compost under 14 CA Code of Regs § 17868.

Composted arbor mulch shall meet the following gradation by dry weight:

Percent Passing	Minimum	Maximum
3 inches	100%	100%
1 inch	90%	100%
¾ inch	70%	100%
¼ inch	40%	60%

[6] Note: As of October 2018, this means the material is over 131 degrees Fahrenheit for 15 days during which time the material is turned five times.

B. Composted Arbor Mulch (Based on 2015 Caltrans Medium Gradation Compost)[7]

Compost must be derived from green material consisting of shredded or ground vegetation. Compost must not be derived from mixed municipal solid waste and must not contain paint, petroleum products, pesticides, or other chemical residues harmful to plant or animal life.

Metal concentrations in compost must not exceed the maximum listed under 14 CA Code of Regs § 17868.2. Process compost materials under 14 CA Code of Regs § 17868.3. Compost producers must be participants in the United States Composting Council's seal of testing assurance program and the compost shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost producers must be permitted by the Department of Resources Recycling and Recovery, Local Enforcement Agencies, and any other State and local agencies that regulate solid waste plants. If exempt from State permitting provisions, the composting plant must certify it complies with the guidelines and procedures for production of compost under 14 CA Code of Regs § 17868.

The particle size must comply with the requirements shown in the following table:

Quality Characteristic Size Classification % Dry Weight Basis	**Test Method** [8]	**Requirement**	
		Min	**Max**
Pass 2-inch sieve	TMECC 02.02-B sample sieving for aggregate	90	-
Pass 3/8-inch sieve (minimum 25% retained)		40	75

[8] TMECC refers to Test Methods for the Examination of Composting and Compost, published by the United States Department of Agriculture and the United States Compost Council (USCC).

[7] See http://www.dot.ca.gov/hq/esc/oe/2015_SSPs.php for 21-2.02K_A04-20-18 for reference. Compost Gradation Table, page 2 of 2.

A.4 Appendix 4
Sustainable Streets Specifications

The quality characteristics of compost must have the values shown in this table:

Quality Characteristic	Test Method [9]	Requirement
pH	TMECC 04.11-A	6.2-8.2
Soluble salts (dS/m)	TMECC 04.10-A	0-6
Moisture content (% wet weight)	TMECC 03.09-A	25-60
Organic matter content (% dry weight)	TMECC 05.07-A	30-100
Maturity (seed emergence)(% relative to positive control)	TMECC 05.05-A	80 or above
Maturity (seedling vigor) (% relative to positive control)	TMECC 05.05-A	80 or above
Stability (mg CO2-C/g OM per day)	TMECC 05.08-B	8 or below
Pathogen Salmonella (most probable number per 4 grams dry weight basis)	TMECC 07.01-B	< 3 (or most current standard)
Pathogen Salmonella (most probable number per 4 grams dry weight basis)	TMECC 07.01-B	< 1,000 (or most current standard)
Physical contaminants (% dry weight) Plastic, glass, and metal	TMECC 02.02-C	combined total: < 0.5%
Film plastic (% dry weight)	TMECC 02.02-C	combined total: < 0.5%
Carbon and Nitrogen Ratio	-	C:N < 25:1 and C:N >15:1
Trace Contaminants (Lead, Mercury, Etc.)	-	Product must meet US EPA, 40 CFR 503 Regulations
Boron	-	total shall be <80ppm

[9] TMECC refers to Test Methods for the Examination of Composting and Compost, published by the United States Department of Agriculture and the United States Compost Council (USCC).

Green Infrastructure Plant List

The **C.3 Regulated Projects Guide**, Appendix A Plant List and Planting Guidance, provides recommended plant species for use in green infrastructure measures. Also see **Section 4.11 Choosing and Placing Appropriate Plant Material** in this guide for additional discussion regarding plant selection, use, and species. The use of other plant species is acceptable with the approval of the project's jurisdiction. Specified plants shall be appropriate to the climate, be drought tolerant, accept seasonal ponding (more an issue with native soil use), and not be invasive. Recent and on-going research is finding that due to the high sand component of the biotreatment soil media, and the resulting high water infiltration through it, and concern of maintenance personnel of seeing browning or declining plants due to a combination of high temperatures and soils that infiltrate quickly, that many plants are being irrigated at higher levels than anticipated per the project's established water budget, especially in the summer and early fall. Designers should strongly consider plants that are drought tolerant and are tolerant of the sand and compost soil mix.

The state of California requires agencies to adopt, implement, and enforce conformance with the Water Efficient Landscape Ordinance (WELO) model ordinance or with jurisdiction specific customized standards for certain new development and retrofitted projects. In addition, many Bay Area jurisdictions require or recommend the use of Bay-friendly Landscape standards, now called ReScape Landscape standards. Both codes/policies/guidance include specific criteria on plant species selection related to water usage, use of native and adapted plants, and other factors.

A WELO/irrigation professionals working group is currently (2018) assessing how to address the potential for "over" watering of plants used in green infrastructure measures than that determined in the WELO water budget and the use of plants preferring higher levels of irrigation. This is due to earlier thinking that plants needed to be more tolerant of water inundation in green infrastructure facilities which led to plant lists suggesting plants that could withstand standing water and which also meant the plants could also have a higher water demand in general. Many plant species commonly used for green infrastructure measures do fall within acceptability of both codes' irrigation level requirements at this time. Designers are reminded that plant and irrigation systems are to be designed as hydrozones. Plants in green infrastructure measures shall be on their own irrigation valve with the irrigation emitters/bubblers selected for and watering cycle length and volumes set to accommodate the sandy soils, e.g., lower irrigation volumes provided over a longer time period.

Studies have indicated that some plants are more likely to take up mercury, PCBs, and other contaminants from soil and groundwater through their roots and neutralize and store it in leaves and other parts of the plant, which aids in improving water quality. This process is called phytoremediation. Designers of green stormwater infrastructure treatment measures may wish to research and use such plants to help in removing and reducing contaminants.


CD+A

Section 32 14 43 – Permeable/Porous Unit Pavers

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints. The City uses the term "Permeable Unit Pavers" when infiltration achieved via aggregate filled joints and "Porous Unit Pavers" when infiltration is achieved through the paver material itself.

DESIGNER NOTE: Green text corresponds to notes to the designer.

PART 1 GENERAL

1.01 SUMMARY

A. This section Includes:

1. Permeable/Porous Unit Pavers
2. Joint Filter Aggregate
3. Pavement Base
4. Edge Restraints
5. Geotextile for Soil Separation

B. Related Sections

DESIGNER NOTE: The designer should list any additional specification sections which relate to the permeable/porous unit paver work (i.e., temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest version of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
ASTM C67	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C13	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Method for Sieve Analysis for Fine and Coarse Aggregate
ASTM C140	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM D448	Standard Classification for Sizes of Aggregate for Road and Bridge Construction

ASTM C936	Standard Specification for Solid Interlocking Concrete Pavers
ASTM C979	Specification for Pigments for Integrally Colored Concrete
ASTM C1781	Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems
ASTM E2835	Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

A. Interlocking Concrete Pavement Institute (ICPI)

1. Permeable Interlocking Concrete Pavement manual.

DESIGNER NOTE: The designer should consider the use of the ICPI Permeable Design Pro software for structural design and determination of adequate depth for the pavement section.

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. Paver Installation Subcontractor:

a. A copy of Subcontractor's current certificate from the Interlocking Concrete Pavement Institute's Concrete Paver Installer Certification program.

b. Job references from three (3) projects of a similar size and complexity. Provide Owner/Client/General Contractor names, postal address, phone number, and email address.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: The Contractor shall submit to the Engineer the following a minimum of 20 calendar days prior to the construction of the permeable/porous unit pavers:

1. Paver manufacturer's/installation subcontractor's drawings and details indicating perimeter conditions, junctions with other materials, expansion and control joints, paver layout/patterns, joint spacing and/or tabs, color arrangement, and installation [and setting] procedures. Drawings and details shall also indicate layout, pattern and relationship of paving joints to fixtures and project formed details.

2. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base, reservoir course, and joint filler materials performed within one (1) month of product delivery to site.

   DESIGNER NOTE: Consider revising acceptable age of sieve test depending on scale of project. On a larger project it may be appropriate to require testing by an independent lab with samples taken at the supplier's yard from the stockpile to be used for the project.

3. Product data sheets for unit pavers and geotextiles.

4. Laboratory test reports certifying compliance of the concrete pavers with ASTM C936.

5. Manufacturer's certification of concrete pavers by ICPI as having met applicable ASTM standards.

DESIGNER NOTE: Especially when using colored pavers, consider requiring submittal of full-size samples of each paver type, thickness, color, and finish. Require submittal of samples indicating the range of color expected in the finished installation. Accepted samples would become the standard of acceptance for the work of this Section.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect permeable/porous unit paver materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

   1. Paver Installation Subcontractor Qualifications:

   2. Installer shall provide documentation showing three (3) successful permeable/porous unit paver installations completed in the last three (3) years, collectively totaling more than 10,000 square feet. Documentation shall include name and address of project, and contact information for project owner.

   3. Installer shall utilize job foremen holding a record of completion from the Interlocking Concrete Pavement Institute PICP Installer Technician Course.

   DESIGNER NOTE: Consider changing these requirements to match scale and complexity of project including a minimum total amount of pavers placed.

B. Responsibilities of Contractor

   1. Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer, the Owner, general Contractor, and paver installer, to review the manufacturers' quality control plan, personnel qualifications, and the paver installers' Method Statement and Quality Control Plan.

2. Reference Panel: Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have a surface area of at least 100 square feet (sf), and a width and thickness as specified for the pavement in the Contract Documents. The Engineer shall observe and accept each element of the paver construction prior to the placement of additional pavement. Failure to install acceptable reference panels of permeable/porous unit pavers will indicate an unqualified installer. Construction and evaluation of the reference panel(s) will occur as follows:

   a. Notify the Engineer at least ten (10) Working Days before installing paver reference panel.

   b. Coordinate the location of the reference panel with the Engineer.

   c. Notify the Engineer when each element of the reference panel is ready for inspection.

   d. Remove, replace, and dispose of any unsatisfactory portions of reference panel as determined by the Engineer and at no additional cost to the Owner.

   e. Retain and maintain approved reference panel during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

   Approved reference panels may remain as final installations of the Work at the discretion of the Engineer. If not retained, the reference panel shall be removed and disposed at no additional cost to the Owner.

   DESIGNER NOTE: Mechanized installations may require a larger mock up area. Consult with the paver installation (Sub) Contractor on the size of the reference panel.

   DESIGNER NOTE: Use this panel to determine expected settlement (surcharge) of the leveling course, joint sizes, and lines, laying pattern, color and texture of the job.

   DESIGNER NOTE: The designer should consider requiring verification of subgrade infiltration rate and provision to increase reservoir course depth based on results.

3. Infiltration Testing: Perform surface infiltration tests per ASTM C1781 as described below.

   a. Three (3) test locations per 10,000 square feet of permeable/porous unit pavers, in place

   b. One (1) additional test location per 5,000 square feet of permeable/porous unit pavers, or fraction thereof, in place

DESIGNER NOTE: Designer to specify the number and location(s) of required post construction infiltration tests.

C. Acceptance

1. The surface elevation of pavers shall be 1/8 to 1/4 inch (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.

2. Lippage: No greater than 1/8 inch (3 mm) difference in height between adjacent pavers.

3. Bond lines for paver courses shall be within ½ inch (± 15 mm) over a 50-foot (15 m) string line.

4. The final surface tolerance of compacted pavers shall not deviate more than ± 3/8 inch (10 mm) under a 10-foot (3 m) long straightedge.

5. Infiltration Rate: The average of all tests shall be greater than 50 inches per hour with no single test less than 25 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

- For permeable/porous unit pavers that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 50 inches per hour
- For permeable pavement not subject to run-on OR vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 50 inches per hour with no single test less than 25 inches per hour

DESIGNER NOTE: The surface of the pavers may be 1/8 to 1/4 inch (3 to 6 mm) above the final designed elevations after compaction. This helps compensate for possible minor settling normal to pavements.

1.06 DELIVERY, STORAGE, AND HANDLING

A. General: Comply with Division 1 Product Requirement Section.

B. Comply with manufacturer's ordering instructions and lead-time requirements to avoid construction delays.

C. Delivery: Deliver materials in manufacturer's original, unopened, undamaged container packaging with identification tags intact on each paver bundle.

1. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.

2. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped cubes capable of transfer by forklift or clamp lift.

D. Unload pavers at job site in such a manner that no damage occurs to the product or existing construction.

E. Storage and Protection: Store materials in a protected area such that they are kept free from mud, dirt, and other foreign materials.

1.07 MAINTENANCE

DESIGNER NOTE: Consider requiring the provision of additional pavers to be retained and stored by the Owner for future maintenance.

- Extra materials: Provide [Specify area] [Specify percentage] additional material for use by Owner for maintenance and repair.
- Extra pavers shall be from the same production run as installed materials.

PART 2 PRODUCTS

DESIGNER NOTE: Some projects may include permeable/porous and solid unit pavers. Specify each product, as required.

2.01 PERMEABLE/POROUS UNIT PAVERS

A. Manufacturer: [Specify manufacturer name.].

1. Contact: [Specify ICPI member manufacturer contact information.].

B. Permeable/Porous Unit Paver Type: [Specify name of product group, family, series, etc.].

1. Material Standard: Comply with ASTM C 936.
2. Color [and finish]: [Specify color.] [Specify finish].
3. Color Pigment Material Standard: Comply with ASTM C979.
4. Size: [Specify.] inches [({Specify.}mm)] x [Specify.] inches [({Specify}mm)] x [Specify.] inches [({Specify.} mm)] thick.
5. Joint Gap Size: [Specify.] inches
6. Joint Gap Mechanism: [Specify if integral spacer, or other paver spacer.] type
7. Bevel Size: [Specify.] inches, [Specify.] type

DESIGNER NOTE: Concrete pavers with spacers integral to each unit are recommended for mechanically installed pavers and pavers subject to vehicular traffic. Verify with manufacturer that overall dimensions do not include spacers.

2.02 JOINT FILLER AGGREGATE

A. Crushed Particles: 90 percent (minimum) tested in accordance with California Test 205.

B. LA Abrasion: Less than 40 tested in accordance with ASTM C131.

C. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.

D. Rounded river gravel may not be used.

E. Permeable Unit Paver: The following aggregate shall be used to fill joints unless manufacturer recommends otherwise. Aggregate gradations shall be per Section 2.03.C.1. If manufacturer recommendation is different from the gradations shown below the Contractor shall be notified at least 48 hours prior to placement of the joint filler.

Gap Width	Aggregate Gradation
3/8” or ½”	ASTM No. 8 (modified)
¼”	ASTM No. 89 (modified)
1/8”	ASTM No. 10 (modified)

F. Porous Unit Pavers: Joint filler shall be per manufacturer’s recommendation.

2.03 PAVEMENT BASE

A. Pavement Base Material shall be consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials or rounded river gravel are not permitted. Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than ten (10) Working Days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to three (3) layers as specified on the Plans and included herein:

1. “Leveling Course” shall be ASTM No. 8 (modified) stone per Section 2.03.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide a smooth, level surface for placement of pavers.

2. "Base Course" shall be ASTM No. 57 (modified) stone per Section 2.03.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

3. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.03.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide water storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed rock to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: ASTM No. 2 stone is preferred.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying courser graded materials or reduction in permeability relative to the underlying material. Refer to SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

DESIGNER NOTE: If the designer chooses to specify materials per the procedure above, provide the required gradation the in the table below.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight					
	ASTM No. 10 (modified)	ASTM No. 89 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)	ASTM No. 3 (modified)	ASTM No. 2 (modified)
3 inch	–	–	–	–	–	100
2 1/2 inch	–	–	–	–	100	90 to 100
2 inch	–	–	–	–	90 to 100	35 to 70
1 1/2 inch	–	–	–	100	35 to 70	0 to 15
1 inch	–	–	–	95 to 100	0 to 15	–
3/4 inch	–	–	–	–	–	0 to 5
1/2 inch	–	100	100	25 to 60	0 to 5	–
3/8 inch	100	90 to 100	85 to 100	–	–	–
No. 4	85 to 100	20 to 55	10 to 30	0 to 10	–	–
No. 8	–	5 to 30	0 to 10	0 to 5	–	–

No. 16	–	0 to 10	0 to 5	–	–	–
No. 30	–	–	–	–	–	–
No. 50	–	0 to 5	–	–	–	–
No. 100[2]	10 to 30	–	0 to 2	0 to 2	0 to 2	0 to 2
No. 200[2]	0 to 2	0 to 2	–	–	–	–

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 and 200 sieve, as shown.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.
3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C131.
4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.04 ACCESSORIES

A. Provide accessory materials as follows: Edge Restraints

1. Manufacturer: [Specify manufacturer.].
2. Material(s): [Pre-cast concrete] [Cut stone] [steel].
3. Material Standard: [Specify material standard.].
4. Configuration: [Specify geometry, manufacturer’s model number, stakes or spikes, paver spacers, coatings, color, etc.]

DESIGNER NOTE: Curbs will typically be cast-in-place concrete or precast set in concrete haunches. Cast in place concrete curbs should be specified in another Section. Do not use plastic edging with steel spikes to restrain unit pavers for vehicular applications.

2.05 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: See ICPI publication, Permeable Interlocking Concrete Pavements for guidance on geotextile selection. Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%
Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer and shall be recompacted in accordance with Section 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade.

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

DESIGNER NOTE: Other subgrade verification methods may be required if site conditions limit proof rolling. Consult with geotechnical engineer for acceptable methods.

F. After compaction and proof roll, scarify subgrade ¼- to ½-inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct the over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor's expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor's expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer, at no additional cost to the Owner. Overlaps of the geotextile shall be a minimum of 1 foot or to the manufacturer's recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6)-inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10)-ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer's observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots, additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. Pavement base materials shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Do not subject placed and compacted gravel leveling course to any pedestrian or vehicular traffic before unit paver installation begins.

3. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any pavers.

DESIGNER NOTE: Consider developing a testing plan for the required testing and inspection of the pavement base. Verification of the in place density/compaction of the open graded base materials is typically not possible with the use of a nuclear densometer due to nature of these materials. Therefore other means to verify these materials are firm and unyielding (such as observation of the compaction process by a geotechnical engineer) are necessary.

DESIGNER NOTE: Consider requiring the Contractor to compact aggregates without crushing them.

3.03 PAVERS AND JOINT/OPENING FILL MATERIAL

A. Lay the unit pavers in the pattern(s) and joint widths shown on the Plans. Maintain straight pattern lines.

B. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.

C. Cut pavers and place along the edges with a double-bladed splitter or masonry saw.

D. Fill all openings and joints with joint filler aggregate conforming to Section 2.02.

E. Remove excess aggregate on the surface by sweeping pavers clean.

F. Compact and seat the pavers into the bedding material using a low-amplitude, 75 to 90 Hz plate compactor capable of at least 5,000 lbf (22 kN). This will require at least two passes with the plate compactor.

G. Do not compact within 6 feet (2 m) of the unrestrained edges of unit pavers.

H. Apply additional joint filler aggregate to the openings and joints if needed, filling them completely. Remove excess aggregate by sweeping, then compact the pavers. This will require at least two passes with the plate compactor.

I. All pavers within 6 feet (2 m) of the laying face must be left fully compacted and joints must be filled at the completion of each working day.

J. Compacted unit pavers shall meet the acceptance criteria set forth in Section 1.05.C.

3.04 PROTECTION OF PAVEMENT

A. Pavement surface shall be kept clean and free of clogging debris and soils from the Contractor’s operations and all upstream and adjacent debris. If debris or soils contaminate the pavers/joints, the pavement shall be cleaned at the Contractor’s expense and to the satisfaction of the Engineer. If pavement cannot be unclogged, it shall be removed and replaced at the Contractor’s expense and to the satisfaction of the Engineer.

B. Paver installation (Sub) Contractor shall return to the site after 6 months from the completion of the Work and provide the following as needed to fully meet the specifications described herein: fill paver joints with stones, replace broken or cracked pavers, and re-level settled pavers to initial elevations. Any additional work shall be considered part of the original bid price and with no additional compensation.

3.05 REJECTION

A. Pavers that do not meet the acceptance criteria set forth in Section 1.05.C will be rejected by the Engineer on a lot by lot basis. Permeable/porous unit pavers that have been rejected by the Engineer or the Contractor shall be removed and replaced at no additional cost to the Owner.

END OF SECTION

Section 32 12 43 – Porous Asphalt Concrete

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Green text corresponds to notes to the designer.

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Porous Asphalt Pavement
2. Pavement Base
3. Geotextile for Soil Separation

B. Related Sections:

DESIGNER NOTE: The designer should list any additional specification sections which relate to the porous asphalt work (i.e., traffic control, temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest revisions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications (published by State of California Business, Transportation, and Housing Agency, Department of Transportation)
San Francisco DPW	Engineering Standard Specifications
AASHTO	Standards of the American Association of State Highway and Transportation Officials, 1998 or latest edition
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.
NAPA IS 115	Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses
NAPA IS 131	Porous Asphalt Pavements for Stormwater Management, Design, Construction, and Maintenance.

1. Caltrans Standard Specifications: Any references to Caltrans Standard Specifications invoke technical specifications in Section 39 for material, construction, and quality control and quality assurance only. Caltrans contractual requirements, general specifications, and measurement and payment do not apply.

2. Caltrans Standard Specifications Term Equivalencies

Terms Equivalencies	
Term or Clause in Caltrans Standard Specifications	**Term or Clause in These Specifications**
The Department	The Owner
OGFC	Porous Asphalt

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. Project experience and personnel qualification examples as specified in Section 1.05.B for the contractor and personnel assigned to this project.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: Submittals shall conform to the requirements of Caltrans Standard Specifications including:

1. Proposed job mix formula per Section 1.05.B of this Specification.

2. Proposed QC plan per Section 39-1.04A (General Requirements for Contractor Quality Control) and Section 39-2.02A (Quality control plan requirements for the “Standard Construction Process”). The QC Plan shall satisfactorily test the porous asphalt for compliance with Section 39-2.02B (Quality Control for Standard Construction Process) of the Caltrans Standard Specifications, with the following modifications and additions:

a. Aggregate durability index shall be tested in accordance with Caltrans Test Method 229 at least one time per each 750 tons of porous asphalt.

b. Aggregate cleanliness value shall be tested in accordance with Caltrans Test Method 227 at least one time per each 750 tons of porous asphalt.

c. Air voids shall be tested for by determining the bulk specific gravity in accordance with ASTM D6752 or AASHTO T275, the maximum theoretical specific gravity with AASHTO T209, and the voids by test ASTM D3203.

d. Draindown shall be tested in accordance with ASTM D6390.

e. Retained tensile strength shall be tested in accordance with AASHTO 283.

f. Three (3) surface infiltration tests per ASTM C1701 shall be conducted per 10,000 square feet of porous asphalt, in place and one (1) additional test per 5,000 square feet of porous asphalt, or fraction thereof, in place. Document and record the results of each field infiltration test with a designated test number. Include infiltration rate, date pavement was placed, date test was taken, and location on the site (via stationing or other means) where test was performed in each test record. If minimum required field infiltration rate is not achieved at any location as defined in this Section, re-test for field infiltration rate at a new location for each failed field infiltration test. Coordinate location with Owner's Representative.

The QC plan shall be consistent with the Caltrans Quality Control Quality Assurance Manual for Asphalt Concrete Production and Placement (latest version).

In addition to the Caltrans submittal requirements, the Contractor shall submit the following:

3. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base and reservoir course materials performed within one (1) month of product delivery to site.

4. Product data sheets for geotextiles.

5. Testing agency qualifications as specified in Section 1.05.A.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect asphalt materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

DESIGNER NOTE: This specification does not include a test panel/mockup due to the difficulty of installation and because physical properties of the material are known from the plant test. Consider whether project design objectives warrant the cost of a test panel/mockup.

1. Contractor and Personnel Qualifications

DESIGNER NOTE: The designer should adjust the required qualifications for the contractor and personnel based on the availability of qualified bidders and project size, complexity, and risk.

a. Contractor qualification: The Contractor shall provide documentation showing one of the following for the general contractor or paving subcontractor:

1) One (1) example owner-accepted porous asphalt project, similar (or greater) in extent to the proposed project, completed in the last one (1) year with reference.

OR

2) Three (3) example owner-accepted open graded friction course projects completed in the last one (1) year with references.

Documentation shall include name and address of project, and contact information for project owner.

b. Personnel qualification: The Contractor or paving subcontractor shall provide a qualified foreman with experience installing porous asphalt and documentation showing with following:

1) One (1) example owner-accepted porous asphalt project, similar (or greater) in extent to the proposed project, completed in the last one (1) year with reference.

Documentation shall include name and address of project, and contact information for project owner.

The qualified foreman shall be onsite for the duration of asphalt work including preparation, placement, testing, and completion.

c. Testing agency qualification: Agencies that perform testing on porous asphalt materials shall meet the requirements of Caltrans Standard Specification Section 39-1.03A or be accredited by the AASHTO Accreditation Program (AAP) for the scope and standard being evaluated.

d. Plant qualification: Batch or continuous mixing plants used for porous asphalt shall meet the requirements of Caltrans Standard Specification Section 39-1.08A.

B. Authorized Job Mix Formula (JMF): The mix design process shall conform to Caltrans Specification Section 39-1.03 except as noted below.

1. The final paragraph under Section 39-1.03A is deleted and replaced with the following:

a. Submit a complete JMF submittal including identification of asphalt binder percentage in form CEM-3511 Contractor Job Mix Formula Proposal. Determine the optimum asphalt binder content using California Test 368 in a lab that meets the requirements of 1.05.A. of these specifications.

The products used in the JMF shall meet the requirements in Section 2.01 of this Specification.

The JMF shall meet the quality characteristics defined in Section 39-2.02B (Quality Control for Standard Construction Process) with the modified and additional quality characteristics listed in the table below.

Quality Characteristics	Test Method	Requirement
Aggregate Durability Index	CT 229	DI >= 35
Aggregate Cleanness Value	CT 227	CV >= 75
Air Void Content by Corelok (%)[1]	ASTM D6752 (with AASHTO T209 and ASTM D3203)	16–20%
Air Void Content by Paraffin Wax (%)[1]	AASHTO T275 (with AASHTO T209 and ASTM D3203)	18–22%
Draindown (% of total weight)	ASTM D6390	<= 3%
Retained Tensile Strength (%)	AASHTO 283	>= 80%
Infiltration Rate (Average Inches per Hour)	ASTM C1701	See Note 2.

[1] Either method of determining air void content is acceptable.

[2] The finish surface shall yield an infiltration rate that is consistent with the following: The average infiltration rate from three (3) infiltration tests conducted per ASTM C1701 shall be greater than 100 inches per hour with no single test less than 50 inches per hour. Water shall infiltrate rapidly and uniformly through the surface without formation of large puddles when applied at a rate of 5 gallons per minute (gpm).

2. Once verified and accepted by the Engineer, the JMF meeting the criteria above shall become the Authorized JMF. Acceptance of the JMF shall be per Caltrans Standard Specification Section 39-1.03G, except that verification of the JMF by the City of San Francisco shall be considered equivalent to verification of the JMF by Caltrans. Any adjustments or renewals of the JMF shall be per Caltrans Standard Specifications Section 39-1.03 (Hot Mix Asphalt Mix Design Requirements). Submit a letter from the asphalt supplier with the recommended temperature ranges for mixing, laying, breakdown rolling, and finished rolling, as well as the recommended maximum temperature of the finished mat before placement of subsequent lifts.

C. Responsibilities of Contractor

1. General: Conform to the requirements set forth in Section 39-1.04 (Contractor Quality Control) and Section 39-2.02 (Standard Construction Process Contractor Quality Control) of the Caltrans Standard Specifications.

2. Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer, the Owner, the general Contractor, and paving subcontractor, to review preparation, placement, testing procedures, and responsibilities.

3. Quality Control: Contractor quality control inspection and testing of porous asphalt shall be conducted in accordance with the approved QC plan.

4. Load Slip: Provide a load slip certified by a licensed weightmaster showing combined mixture weight for each load of porous asphalt transported to the location.

5. Infiltration Rate Testing: Perform surface infiltration tests per ASTM C1701 as described below.

a. Three (3) test locations per 10,000 square feet of porous asphalt in place.

b. One (1) additional test location per 5,000 square feet of porous asphalt, or fraction thereof, in place.

DESIGNER NOTE: Designer to specify the number and location(s) of required post-construction infiltration tests.

6. Required Inspections: Notify the Engineer at least 5 business days prior placement of porous asphalt.

7. Failed Tests: Each test shall meet the acceptance criteria as defined in this section. For any single quality characteristic except smoothness, if two consecutive quality control test results do not comply with the action limits or specifications:

a. Stop production.

b. Notify the Engineer.

c. Take corrective action.

d. Demonstrate compliance with the specifications before resuming production and placement.

DESIGNER NOTE: The following table is a Sample Contractor Quality Control Sampling and Testing Plan; it is provided to illustrate the type and frequency of testing that may be required The Contractor will need to develop a similar table as part of their QC plan. Frequency and standard for all tests should be project specific.

Sample Contractor Quality Control Sampling and Testing Plan						
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**	
Plant Operations						
Aggregate Gradation	CT 202	1/750 tons	Plant	Plant Inspector	1/2"	TV ± 6
					3/8"	TV ± 6
					No. 4	TV ± 7
					No. 8	TV ± 5
					No. 30	TV ± 4
					No. 200	TV ± 2
Asphalt Binder Content	CT 382	Daily	Plant	Plant Inspector	Design ± 0.5%	
Percent of crushed particles coarse aggregate (%, min)	CT 205	1/project	Plant	Plant Inspector		
One fractured face					90	
Two fractured faces					75	
Fine aggregate (%, min) (Passing no. 4 sieve and retained on no. 8 sieve.)						
One fractured face					90	
Los Angeles Rattler (%, max)	CT 211	1/project	Plant	Plant Inspector		
Loss at 100 rev.					12	
Loss at 500 rev.					40	
Aggregate Durability Index	CT 229	1/750 tons	Plant	Plant Inspector	DI > 35	
Aggregate Cleanness Value	CT 227	1/750 tons	Plant	Plant Inspector	CV > 75	
Asphalt Temp.	Recorded	Continuous	Plant	Plant Inspector	120–190	
Plant Mix Temperature	Recorded	Continuous	Plant	Plant Inspector	165 Maximum	
Aggregate moisture content	CT 226	2/day	Plant	Plant Inspector	For adjusting the plant controller at the HMA plant	
Flat and elongated particles (%, max by weight @ 5:1)	CT 235	1/project	Plant	Plant Inspector	Report Only	

Sample Contractor Quality Control Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**
Street Operations					
Subgrade Preparation	Visual	Daily	Jobsite	Field Inspector	Smooth and Clean
Asphalt Paver & Hopper	Visual and Measure	Daily	Jobsite	Field Inspector	Manufacturer Standards
Compaction Equipment	Visual and Measure	Daily	Jobsite	Field Inspector	Manufacturer Standards
Compaction Process	Visual	Continuous	Jobsite	Field Inspector	Per Specifications
Pavement Temp. at Breakdown	Temperature Equipment	Hourly	Mat Behind Paver	Field Inspector	Per Specifications
Asphalt Binder Content	CT 382	Daily	Mat Behind Paver	Field Inspector/Tester	Design ± 0.5%
HMA Moisture Content (%, max)	CT 226	Daily	Mat Behind Paver	Field Inspector/Tester	1.0
Lift Thickness	Measured	Hourly	Mat Behind Paver	Field Inspector	Per Specifications
Pavement Temp. at Finish	Temperature Equipment	Daily	At Finish Roller	Field Inspector	Per Specifications
Air Void Content by Paraffin Wax (%)	AASHTO T275 (with AASHTO T209 and ASTM D3203)	Daily	Cores of Finished Surface	Field Inspector	16–20%
Tensile Strength	AASHTO 283	Daily	Cores of Finished Surface	Engineer	>= 80%
Long./Transverse Joints	Visual	Continuous	Pavement Joints	Field Inspector	Industry Standards
Smoothness	10 ft straightedge	Hourly	Finished Surface	Field Inspector	Per Specifications

Sample Contractor Quality Control Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**
Street Operations (continued)					
Infiltration Rate (average Inches per hour)	ASTM C1701	Three (3) test locations per 10,000 square feet of pervious asphalt, in place One (1) additional test location per 5,000 square feet of pervious asphalt, or fraction thereof, in place	Finished Surface	Field Inspector	Each Test: 50"/hr min Daily Avg.: 100"/hr min
Pavement Transitions	Visual	Daily	AC Transitions	Field Inspector	Per Specifications

D. Acceptance: Acceptance of porous asphalt shall be determined based on the criteria defined in Section 39-2.03A (Acceptance) of the Caltrans Standard Specifications, with the following modifications and additions:

1. Source aggregate will not be subject to acceptance testing once is has been approved as part of the JMF, unless samples are requested by the Engineer.

2. Air Voids: Air voids shall be tested for by determining the bulk specific gravity in accordance with ASTM D6752 or AASHTO T275, the maximum theoretical specific gravity with AASHTO T209, and the voids by test ASTM D3203.

3. Retained Tensile Strength: Retained tensile strength shall be tested in accordance with AASHTO 283.

Test results for air voids, draindown, and retained tensile strength shall be consistent with the characteristics of the approved JMF.

4. Infiltration Testing

a. Infiltration Rate Testing: The average of all surface infiltration tests shall be greater than 200 inches per hour with no single test less than 100 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

- For porous asphalt that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 200 inches per hour with no single test less than 100 inches per hour
- For porous asphalt not subject to run-on OR vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 50 inches per hour

b. Infiltration Visual Testing: Visual flood testing of the surface shall be conducted by application of clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution devise. Water used for the test shall be clean, free of suspended solids and deleterious liquids and will be provided at no extra cost to the Owner. All applied water shall infiltrate directly without large puddle formation or surface runoff, and shall be observed by the Engineer. The Engineer shall mark areas where large puddles form in the field. Areas with slow infiltration shall not exceed 10 percent of the total surface.

DESIGNER NOTE: Smoothness specification should be revised as needed to reflect project design objectives (e.g., smoothness specifications from Section 212 of the City Streets and Highways specifications).

5. Smoothness: Porous asphalt smoothness shall be checked with a 10-foot straightedge. Vertical measurement shall be taken between the pavement's determined plane and straight edge in a direction perpendicular and parallel to the centerline. The finished pavement shall be uniform to a degree such that no variations greater than 3/8-inch are present between the straightedge and pavement surface.

6. Grade: Porous asphalt shall be true to designed spot elevations plus or minus ½ inch and shall not deviate from designed slope more than ¼ inch in ten (10) feet. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the porous asphalt shall be flush.

7. Line: Porous asphalt margins shall be true to designed lines plus or minus ½ inch at any point.

8. Slope: Porous asphalt shall be sloped as shown on the Plans. Slope shall be consistent to within 1/4 inch in ten (10) feet.

9. Thickness: Each core sample shall be equal to the minimum section depth or more as specified on the Plans.

DESIGNER NOTE: Revise the load slip specification as needed to align with the measurement and payment specifications.

10. Load Slip: Each load of porous asphalt transported to the location of placement shall have a load slip delivered with the load that is certified by a licensed weightmaster and includes the combined mixture weight.

DESIGNER NOTE: Designer should specify consequences of any failed acceptance tests (e.g., reduced payment for lower infiltration rate and lower percent voids, reduced payment for failed smoothness tests) or if consequences are full replacement.

11. Reduced Payment Factors: The reduced payment factors in Caltrans Standard Specification 39-2.03A (Testing) do not apply.

DESIGNER NOTE: The following table is a Sample Owner Quality Assurance Sampling and Testing Plan is provided to illustrate the type and frequency of testing that may be required. Frequency and standard for all tests should be project specific.

Sample Owner Quality Assurance Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Responsibility**	**Attribute or Tolerance**
Plant Operations					
Street Operations					
Asphalt Binder Content	CT 382	Daily	Hopper	Engineer	Design ± 0.5%
HMA Moisture Content (%, max)	CT 226	Daily	Hopper	Engineer	1.0
Lift Thickness	Measured	Hourly	Cores of Finished Surface	Engineer	Per Specifications
Air Void Content by Paraffin Wax (%)	AASHTO T275 (with AASHTO T209 and ASTM D3203)	Daily	Cores of Finished Surface	Engineer	16–20%
Tensile Strength	AASHTO 283	Daily	Cores of Finished Surface	Engineer	>= 80%
Long./Transverse Joints	Visual	Continuous	Pavement Joints	Engineer	Per Specifications
Smoothness	10 ft straightedge	Hourly	Finished Surface	Engineer	Per Specifications
Infiltration Rate (average inches per hour)	ASTM C1701	3/day	Finished Surface	Engineer	Each Test: 50"/hr min Daily Avg.: 100"/hr min
Pavement Transitions	Visual	Daily	AC Transitions	Engineer	Per Specifications

PART 2 PRODUCTS

DESIGNER NOTE: If a product is not available, the designer needs to ensure that the desired voids and surface texture will meet the desired pavement characteristics for surface smoothness, voids, and bonding.

2.01 POROUS ASPHALT

Porous Asphalt mixture must comply with the approved Job Mix Formula (See Section 1.05 of this Specification). The components of the asphalt mixture must comply with the specifications below.

A. Asphalt Binder: Asphalt binder must comply with Caltrans Specification Section 92 except as noted below.

1. Performance Graded (PG) Asphalt Binder: PG asphalt binder must be PG 70-10 per Caltrans Specification Section 92-1.02B.

2. PG Polymer Modified Asphalt Binder:

PG polymer modified asphalt binder must be PG 76-22 PM per Caltrans Specification Section 92-1.02B for use in vehicular applications.

PG polymer modified asphalt binder must be either PG 64-28 PM or PG 76-22 PM per Caltrans Specification Section 92-1.02B for use in pedestrian applications.

B. Aggregates: Aggregates shall conform to Caltrans Specification Section 39-1.02E for Open Graded Friction Course (OGFC) with the following additions and modifications:

1. Durability Index: 35 (minimum) tested in accordance with California Test 229 at least once per 750 tons of porous asphalt.

2. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 750 tons of porous asphalt.

3. Aggregate for porous asphalt shall meet the following gradation:

Porous Asphalt Aggregate Gradation	
Sieve[1]	**Percent Passing by Weight**
3/4 inch	100
1/2 inch	85 to 100
3/8 inch	55 to 75
No. 4	10 to 25
No. 8	5 to 12
No. 30	0 to 10
No. 200	0 to 3

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

C. Materials Not to Be Used: The following materials shall not be used unless approved in advance by the Engineer.

1. Geosynthetic pavement interlayer

2. Tack Coat (except on vertical faces of curbs, edges of PCC structures, or when paving over areas with impermeable bases).

3. Asphalt Rubber Binder.

4. Crumb Rubber Modifier.

5. Reclaimed Asphalt Pavement.

6. Paint Binder per Section 212.06 of the DPW Standard Specifications

D. Job Mix Formula (JMF): The JMF shall comply with the requirements of Section 1.05.C of this Specification.

2.02 PAVEMENT BASE

A. Pavement Base Material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials are not permitted. The Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than 10 Working Days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to two (2) layers as specified on the Plans and included herein:

1. "Base Course" shall be ASTM No. 3 (modified) or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

2. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed gravel to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying coarser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
3 inch	100	–	–	–
2 1/2 inch	90 to 100	100	–	–
2 inch	35 to 70	90 to 100	–	–
1 1/2 inch	0 to 15	35 to 70	–	100
1 inch	–	0 to 15	–	95 to 100
3/4 inch	0 to 5	–	–	–
1/2 inch	–	0 to 5	100	25 to 60
3/8 inch	–	–	85 to 100	–
No. 4	–	–	10 to 30	0 to 10
No. 8	–	–	0 to 10	0 to 5
No. 16	–	–	0 to 5	–
No. 100[2]	0 to 2	0 to 2	0 to 2	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 sieve.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.
3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C 131.
4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.03 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%
Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer, and shall be recompacted in accordance with 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

F. After compaction and proof roll, scarify subgrade ¼ to ½ inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct the over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor’s expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor’s expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer, at the Contractor’s expense. Overlaps of the geotextile shall be a minimum of 1 foot or to the manufacturer’s recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6)-inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10)-ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer’s observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf

(60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. The pavement base shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any porous asphalt.

3.03 POROUS ASPHALT PREPARATION

DESIGNER NOTE: Designer should specify where a tack coat should be applied, if at all. See 3.03.A.2 for list of potential locations.

A. Preparation for placement of porous asphalt pavement shall comply with Section 39-1.09 of the Caltrans Standard Specifications, except as noted below.

1. Pavement Base: Confirm that the completed pavement base conforms to these specifications.

2. Tack Coat: Shall not be used except on vertical faces of curbs, edges of PCC structures, or when paving over areas with impermeable bases.

3. Geosynthetic Pavement Interlay: Shall not be used.

4. Environmental Conditions: Do not place porous asphalt when the ambient temperature is less than 60 degrees Fahrenheit, on any wet surface, or when the average ground surface temperature is less than 45 degrees Fahrenheit.

5. Qualified Personnel: The qualified foreman as defined in 1.05.B.2 shall be onsite for the duration of porous asphalt preparation.

3.04 POROUS ASPHALT PLACEMENT

DESIGNER NOTE: Designer should specify where a tack coat should be applied (e.g., face of curb, structures,) if at all.

A. Porous asphalt equipment, transportation, spreading, and compacting shall comply with the Caltrans Specification applicable to Open Graded Friction Course (OGFC), except as noted below or as specified in the approved mix design.

B. Qualified Personnel: The qualified foreman as defined in 1.05.B.2 shall be onsite for the duration of porous asphalt placement.

C. Spreading and Compacting Equipment: shall conform to Section 39-1.10 of the Caltrans Standard Specifications except that pneumatic tire rollers shall not be used.

DESIGNER NOTE: The compaction could be established by the contractor rather than prescribed below depending on whether the contracting agency prefers to take a prescriptive approach or performance based approach. Prescriptive is used here because full depth porous asphalt is an emerging technology and there are limited density specifications for open graded (porous) asphalt mixtures. But care must be taken to ensure this prescriptive specification is compatible with the acceptance criteria.

D. Spreading and Compacting:

The type of rollers to be used and their relative position in the compaction sequence shall be dictated by the contractor provided the requirements below are met and the completed porous asphalt meets the required quality characteristics specified in Section 1.05. Deviation from the requirements below must be approved in advance by the Engineer.

1. The porous asphalt shall be laid in lifts of up to 4 inches in thickness using approved equipment to achieve the total thickness indicated in the Plans.

DESIGNER NOTE: Designer should consider using thinner lifts to the extent practical to ensure better compaction.

2. The temperature of the Porous HMA mix during laying, breakdown rolling, and finished rolling, shall be within the supplier-recommended temperature range.

3. Breakdown rolling shall be performed with one or two passes of a 7.5- to 10-ton vibratory roller operated in low amplitude mode when the mix temperature is within the supplier-recommended temperature range.

4. Finished rolling shall be performed with a double-drum finish roller operated in static mode when the mix temperature is within the supplier-recommended temperature range.

5. Finished paving shall be even, without pockets, and graded to elevations shown on the Plans. Finished porous asphalt shall meet the acceptance criteria for Smoothness set forth in Section 1.05.D.

DESIGNER NOTE: Designer should specify details of the straightedge test and tolerance if different than specified in Section 1.05E.

6. The Contractor shall take care to insure that the porous asphalt lifts join completely to previous lifts. The Contractor shall keep the time between lift placements to a minimum, keeping the surface of the previous lift clear from dust and moisture between lifts, and restrict traffic from initial lifts until the full depth of asphalt pavement has been placed.

7. Sufficient time shall be allowed between lifts to allow the asphalt to set and cool to at or below the supplier recommended maximum temperature for placement of subsequent lifts.

3.05 OPENING TO TRAFFIC

A. After final rolling, no vehicular traffic of any kind shall be permitted on the pavement surface until cooling and hardening has taken place, and in no case within the first six (6) hours. Provide traffic control measures as necessary to prevent vehicular use and remove when no longer required.

3.06 PROTECTION OF PAVEMENT

A. Hardened porous asphalt pavement surface shall be kept clean and free of clogging debris and soils from the Contractor's operations and all upstream and adjacent debris. If debris or soils contaminate the porous pavement voids, the pavement shall be cleaned at the Contractor's expense and to the satisfaction of the Engineer. If porous asphalt pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

3.07 REJECTION

A. Porous asphalt that does not meet the acceptance criteria set forth in Section 1.05.E will be rejected by the Engineer. Porous asphalt that has been rejected by the Engineer shall be removed and replaced at the Contractor's expense.

END OF SECTION

Option A: SFPUC Pervious Concrete Specifications

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Green text corresponds to notes to the designer. Blue text corresponds to requirements taken directly from ACI 522.1.

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Pervious Concrete
2. Pavement Base
3. Geotextile for Soil Separation

B. Related Sections:

DESIGNER NOTE: The designer should list any additional specification sections which relate to the pervious concrete work (i.e., temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards This section incorporates by reference the latest versions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
AASHTO	Standards of the American Association of State Highway and Transportation Officials, 1998 or latest edition
ACI 522.1	Specifications for Pervious Concrete Pavement
ACI 301	Specifications for Structural Concrete
ACI 305.1	Standard Specifications for Hot Weather Concreting
ACI 306.1	Standard Specifications for Cold Weather Concreting
ACI 308.1	Standard Specifications for Curing Concrete
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. National Ready Mix Concrete Association (NRMCA) Pervious Concrete Contractor Certifications and project experience as specified in Section 1.05.A for the crew assigned to this project.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: The Contractor shall submit to the Engineer the following a minimum of 20 calendar days prior to the construction of the pervious cement concrete pavement:

1. NRMCA Certifications for the batch plant to be used in the production of pervious concrete for this project.

2. Proposed mix design including the following:

a. Batch weights of all constituents.

b. Portland cement type and brand.

c. Non-Portland cement pozzolan type and source.

d. Microfiber brand and type.

e. Admixture type and brand.

f. Aggregate source(s), gradation(s), LA abrasion, and cleanness value(s).

g. Fresh density of the pervious concrete per ASTM C1688.

No concrete shall be placed until the Engineer has provided written acceptance of the mix design per Section 1.05.B.

3. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base and reservoir course materials performed within one (1) month of product delivery to site.

DESIGNER NOTE: Consider revising acceptable age of sieve test depending on scale of project. On a larger project it may be appropriate to require testing by an independent lab with samples taken at the supplier's yard from the stockpile to be used for the project.

4. Product data sheets for all proposed admixtures and geotextiles.

5. A detailed plan of the proposed paving pattern showing the location and type (saw cut or rolled in plastic concrete) of all planned joints. No deviation from the jointing pattern shown on the Plans will be allowed without written approval of the Engineer.

6. A detailed procedure for the production, transportation, placement, protection, curing, and temperature monitoring of concrete for hot and/or cold weather, unless written approval of the Engineer waiving the requirement is received.

7. Field technician qualifications as specified in Section 1.05.A.

8. Testing agency qualifications as specified in Section 1.05.A.

9. Density of fresh pervious concrete, length of cores, and density of cores for one (1) reference panel. Reference panel shall be placed, jointed, cured, and tested as specified in Section 1.05.D.1 and be within tolerance of the required thickness defined by the Contract Documents.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect concrete materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

1. Contractor and Personnel Qualifications

a. Contractor qualification: Unless otherwise approved by Engineer, Contractor shall provide evidence of employment for one (1) NRMCA certified Pervious Concrete Installer and four (4) NRMCA certified Pervious Concrete Technicians who must be on site, working as members of each placement crew, during all concrete placement.

For all projects where the total pervious concrete pavement area exceeds 20,000 square feet (sf), the Contractor shall provide evidence of employment for at least one (1) NRMCA certified Pervious Concrete Craftsman who must be onsite, working as part of the placement crew, during all concrete placement. Additionally, for every 10,000 sf of pavement area over 20,000 sf, one (1) additional NRMCA certified Pervious Concrete Installer is required on site, working as part of the placement crew.

The Contractor shall provide documentation showing three (3) successful pervious concrete projects completed in the last three (3) years collectively totaling more than 20,000 square feet. Documentation shall include name and address of project, and contact information for project owner.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified bidders and the size of the project.

b. Field technician qualification: Field tests of concrete required in the responsibilities of the testing agency shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete

Technician, or equivalent, and an ACI Concrete Field Testing Technician – Grade I, or equivalent.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified personnel and the size of the project.

c. Testing agency qualification: Agencies that perform testing on concrete materials shall meet the requirements of ASTM C1077 and provide evidence of employment for at least one (1) NRMCA Certified Pervious Concrete Technician, responsible for testing, or providing direct oversight of testing, of all concrete materials. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by the Engineer before performing any Work.

d. Batch plant qualification: Batch plant used for pervious concrete shall be a semi-automatic or automatic batching plant with a current NRMCA certification.

DESIGNER NOTE: Volumetric (truck mounted) Site Mixed Mobile Mixers may be used at the designers discretion. Mixing operations should be per manufactures directions. Designer should specify certification and calibration requirements for Volumetric Mobile Mixers including, but not limited to:

- Proof of Volumetric Mixer Manufacturer Bureau (VMMB) certification, compliance with VMMB 100-01 Volumetric Mixer Standards, and associated VMMB rating plate, or equal
- Provisions for calibration of Volumetric Mobile Mixers performed with aggregate manufactured for the project and recalibrated with each restocked stock pile

Additionally, the designer should specify required quality control measures to ensure aggregates, cementitious material, and admixtures are free from contamination from deleterious material or other stockpiles/storage containers, protected from damage by equipment, vehicles, or weather, and properly batched in lieu of batch ticket (e.g., labeling of aggregate bins to ensure correct aggregate is fed into appropriate mixer material compartment.

B. Approved Mix Design: Once accepted by the Engineer, the mix design meeting the criteria specified in Section 2.01.F shall become the Approved Mix Design and shall not be modified in any way. The Approved Mix Design shall be determined from information submitted under Section 1.04 and from results of reference panel testing as described in Section 1.05.D.1.

Modifications to the Approved Mix Design will not be allowed and any modified mix placed in the Work will be rejected. Proposed modifications to the Approved

Mix Design shall be submitted as a new mix design and shall require a new reference panel to validate the proposed mix design and determine the new Approved Mix Design. If accepted by the Engineer, the new mix design shall become the Approved Mix Design. The requirement for a new reference panel may be waived at the discretion of the Engineer. Only one (1) Approved Mix Design shall be valid at any time. Admixture and water dosages may be modified as needed to maintain mix properties.

C. Responsibilities of Contractor

1. Pre-Placement Conference: A mandatory pre-placement conference will take place including at a minimum the Engineer, the Owner, general contractor, pervious concrete installer, concrete supplier, and field testing agency representative. The document Checklist for the Concrete Pre-Construction Conference (available from the National Ready Mix Concrete Association) will be used to review all materials, personnel qualifications, concrete production, delivery, maintaining moisture retention of fresh mixture, preparation, placing, curing (including timing, placement, and securing of curing cover), jointing, testing procedures, and responsibilities. Meeting emphasis will be on how pervious concrete differs from conventional concrete.

2. Reference Panel: Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have a surface area of at least 225 square feet, and a width and thickness as specified for the pavement in the Contract Documents. The Engineer shall observe and accept each element of the pervious concrete construction. Construction and evaluation of the reference panel(s) will occur as follows:

   a. Notify the Engineer at least ten (10) Working Days before installing pervious concrete reference panel.

   b. Coordinate the location of the reference panel with the Engineer.

   c. Notify the Engineer when each element of the reference panel is ready for inspection.

   d. Remove, replace, and dispose of any unsatisfactory portions of reference panel as determined by the Engineer and at no additional cost to the Owner.

   e. Retain and maintain approved reference panels during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

   Approved reference panels may remain as final installations of the Work at the discretion of the Engineer. If not retained, the reference panel shall be removed and disposed of at no additional cost to the Owner.

3. Testing facilitation: Owner's use of testing services will not relieve Contractor of the responsibility to furnish materials and construction in full compliance with the Contract Documents. Unless otherwise specified in the Contract Documents, Contractor shall assume the following duties and responsibilities:

    a. Furnish the materials to be tested, including concrete cores.

    b. Furnish any necessary labor to assist Owner's testing agency in obtaining and handling samples, including concrete cores, at the project site or at the source of materials.

    c. Provide measures to collect slurry and debris during coring operation in order to avoid sealing adjacent pavement.

    d. Fill core holes in accordance with Section 1.05.D.2.

    e. Advise Owner's testing agency at least 24 hours in advance of operations to allow for completion of quality tests and for assignment of personnel.

4. Pressure wash testing: Before final acceptance by the Engineer, the Contractor shall pressure wash the pervious concrete. Pressure washing shall be provided and completed by using portable washer equipment working at a minimum of 3,000 psi at 2.0 to 2.5 gpm. The nozzle shall be a zero degree nozzle and be held a maximum of three (3) inches off the concrete surface. The Contractor shall pressure test three (3) locations per lot or as determined by the Engineer. Any sections of pervious concrete that breaks up, ravels, or does not infiltrate shall be removed and replaced with acceptable pervious concrete to the nearest joints. The Engineer will reject the concrete if the pressure washing dislodges aggregate particles from more than two (2) percent of the pervious concrete in a single panel (joint to joint) or dislodges aggregates from a contiguous area of the pavement surface exceeding five times the nominal maximum aggregate size in any direction.

    The Contractor shall decide, after placing the pervious concrete, when to perform the quality assurance pressure wash testing for the acceptance.

DESIGNER NOTE: The designer should consider requiring verification of subgrade infiltration rate and provision to increase reservoir course depth based on results.

D. Testing

1. Reference Panel: Testing for the reference panel shall adhere to the requirements for testing of Pavement per Section 1.05.D.2 for approval by the Engineer. Each test shall meet the acceptance criteria for Reference Panel as defined in Section 1.05.E.1.

The Engineer shall inspect and approve the reference panel prior to the placement of additional pervious concrete.

Failure to install acceptable reference panels of pervious concrete will indicate an unqualified installer.

Production sections of this Work shall not be placed until achieving a complete reference panel that fully complies with the Plans and Specifications and has written acceptance issued by the Engineer.

The completed and accepted reference panels shall be maintained and protected throughout the duration of the Work and may not be demolished and disposed of without written permission from the Engineer. If a reference panel is incorporated into the Work, it shall remain in place and be accepted as a single lot.

Unless otherwise determined by the Engineer, density testing of fresh concrete and hardened cores will be used to validate the mix design per the design criteria set forth in Section 1.04.B and the acceptance criteria in Section 1.05.E.1.

The average fresh density and average hardened density of the cores shall be the densities used for the Approved Mix Design.

2. Pavement: The following testing shall be conducted for approval by the Engineer for each reference panel and each lot of pervious concrete placed, where a lot is defined as the lesser of one (1) day's production or 5,000 square feet of pervious concrete, in place, unless otherwise specified below:

   a. Density testing of at least one (1) cubic foot of fresh concrete in accordance with ASTM C1688.

   b. Thickness testing of three (3), four- (4)-inch hardened concrete cores in accordance with ASTM C174 and adhering to the following requirements:

      1) Removed not less than seven (7) days after placement of pervious concrete.

      2) Location selected in accordance with ASTM D3665.

      3) Cut in accordance with ASTM C42.

   c. Density and void content testing of the three (3) hardened concrete cores extracted for thickness testing and trimmed to produce flat core ends per ASTM C42 paragraph 7.4.1 and 7.4.2. Samples shall be tested in accordance with ASTM C1754.

   d. Surface infiltration tests per ASTM C1701 and at the frequency described below.

1) Three (3) test locations per 10,000 square feet of pervious concrete, in place

2) One (1) additional test location per 5,000 square feet of pervious concrete, or fraction thereof, in place

DESIGNER NOTE: Designer to specify the number and location(s) of required post construction infiltration tests.

Core holes shall be filled with solid concrete, pre-blended grout, or pervious concrete and shall match adjacent pavement color, and grade. At the Engineer's discretion, a sacrificial panel for cores may be required or allowed.

Each test shall meet the acceptance criteria for Pavement as defined in Section 1.05.E.2.

E. Acceptance

1. Reference Panel: Acceptance of the reference panel will be based on the criteria for acceptance of Pavement per Section 1.05.E.2 with the following deviations:

a. Hardened Density: The density of each core shall be within five (5) pounds per cubic foot of the average hardened density of the three (3) cores.

b. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the average fresh density of the three (3) samples.

2. Pavement: Acceptance of a lot of pervious concrete will be based on the following criteria:

a. Smoothness: Pervious concrete pavement smoothness shall be checked with a 10-foot straightedge. Vertical measurement should be taken between the pavement's determined plane and straight edge, discounting surface void and roughness irregularities, in a direction perpendicular and parallel to the centerline. The finished pavement shall be uniform to a degree such that no variations greater than 3/8-inch are present between the straight edge and pavement surface over a distance of at least 6 inches.

b. Grade: Pervious concrete shall be true to designed spot elevations plus or minus ½ inch and shall not deviate from designed slope more than ¼ inch in ten (10) feet. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the pervious concrete shall be flush.

c. Line: Pervious concrete margins shall be true to designed lines plus or minus ½ inch at any point.

d. Slope: Pervious concrete shall be sloped as shown on the Plans. Slope shall be consistent to within 1/4 inch in ten (10) feet.

e. Thickness: Each core sample shall be equal to the minimum section depth or more as specified on the Plans.

f. Hardened Density: The density of the core samples for each lot shall be within five (5) pounds per cubic foot of the density as accepted in the reference panel.

g. Void Content: The total void content of the core samples for each reference panel and lot shall be twenty (20) percent, plus or minus five (5) percent, in place, as constructed.

h. Infiltration Rate: The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

- For permeable pavement that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
    - The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour
- For permeable pavement not subject to run-on OR vehicular traffic:
    - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 75 inches per hour

i. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the fresh density indicated by the Approved Mix Design.

j. Batch Ticket: Each load of pervious concrete transported to the location of placement shall have a Batch Ticket delivered with the load. Batch Tickets shall be provided upon request for each load and shall be in accordance with ASTM C94, with the following additions:

1) Batch weights of all constituents in the mix, including cement, aggregate, admixtures, water, and fibers

2) Signature of responsible representative of the concrete producer, affirming the accuracy of the information provided

k. Appearance: Each lot of finished pervious concrete will be inspected for appearance by the Engineer after completion of pressure wash testing per Section 1.05.C.4. The pervious concrete shall have a consistent surface texture, shall have no more than five (5) percent of the surface area within each panel (joint to joint) filled with paste, shall be free of ridges or other surface imperfections, shall have joints that are in the specified location and are constructed per specification, shall be free of cracks and shall not be raveled.

A panel will be considered raveled if aggregate is dislodged from a contiguous area of the pavement surface or longitudinally along a joint exceeding five times the nominal maximum aggregate size in any direction OR if aggregate particles are dislodged from more than two (2) percent of the pervious concrete within each panel (joint to joint).Raveling occurring during the first three (3) months after installation is subject to complete removal and replacement of affected panels with acceptable pervious concrete at the Owner's discretion and Contractor's expense. Requirement to replace affected panels shall continue until three (3) months after the date of replacement. Written notification of defects is the sole responsibility of the Owner.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

l. Conformance to Approved Mix Design: The pervious concrete used shall conform to the Approved Mix Design within the limits set forth in ASTM C94.

3. Required Inspections: Notify the Engineer at least 48 hours prior to required inspections specified in Sections 3.01, 3.02, and 3.03.B.

PART 2 PRODUCTS

DESIGNER NOTE: Designers should maximize the use of regionally available materials.

2.01 PERVIOUS CONCRETE

DESIGNER NOTE: No reinforcing bars or tie bars will be used in the installation of pervious concrete.

Pervious Concrete shall comply with ASTM C94, except sections 4.2, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 7, 8, 16, 17, 18, 19, 20 and the requirements specified herein. The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the design density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in ASTM C94 Paragraph 9.3.

A. Cement: Cement in the mix design shall conform to the requirements for Portland Cement or Blended Hydraulic Cement as specified herein:

1. Portland Cement: Portland Cement shall meet the requirements of ASTM C150 Type I, II, or V Portland cement.

2. Blended Hydraulic Cement: Blended Hydraulic Cement shall be Type IP or IS Cement conforming to ASTM C595. Type IP(X), Portland Pozzolan Cement, and IS(X) where (X) dictates pozzolan and slag percentage, respectively, shall be Portland Cement and Pozzolan. The pozzolan shall be limited to fly ash or ground granulated blast furnace slag.

   The fly ash or ground granulated blast furnace slag constituent content in the finished cement shall not vary more than plus or minus 5 percent by weight of the finished cement from the certified value.

3. Supplementary cementitious material shall be as specified herein:

   a. Fly Ash: Fly ash shall conform to the requirements of ASTM C618, Class F or C.

   b. Slag Cement: Slag cement shall meet the requirements of ASTM C989, Grade 100 or Grade 120.

   c. Silica Fume: Silica fume shall meet the requirements of ASTM C1240.

B. Aggregates: Aggregates shall conform to ASTM C33 except as specified herein, unless otherwise approved by the Engineer.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 300 cubic yards of concrete.

Sieve[1]	Percent Passing by Weight				
	Coarse Aggregate				Fine Aggregate
	ASTM No. 7	ASTM No. 8	ASTM No. 89	ASTM No. 9	
2 inch	–	–	–	–	–
1 1/2 inch	–	–	–	–	–
1 inch	–	–	–	–	–
3/4 inch	100	–	–	–	–
1/2 inch	90 to 100	100	100	–	–
3/8 inch	40 to 70	85 to 100	90 to 100	100	100
No. 4	0 to 15	10 to 30	22 to 55	85 to 100	95 to 100
No. 8	0 to 5	0 to 10	5 to 30	10 to 40	80 to 100
No. 16	–	0 to 5	0 to 10	0 to 10	50 to 85
No. 30	–	–	0 to 5	0 to 5	25 to 60

No. 50	–	–	–	–	5 to 30
No. 100	–	–	–	–	0 to 10
No. 200	–	–	–	–	0 to 3

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

In individual tests, a variation of 4 percent under the minimum percentages or over the maximum percentages will be allowed. The average of three successive tests shall be within the percentages stated above. Aggregate shall contain no pieces larger than two times the maximum sieve size for the specified grading measured along the line of greatest dimension.

2. Coarse Aggregate

   a. LA Abrasion: 35 percent (maximum) tested in accordance with ASTM C131 at least once per 300 cubic yards of concrete.

   b. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 300 cubic yard of concrete.

3. Acceptance of grading and quality of the aggregate may be based on samples taken from stockpiles at the concrete plant or a submitted gradation report at the discretion of the Engineer. The point of acceptance will be determined in the field by the Engineer.

C. Admixtures

1. Air Entraining Admixtures: Air entraining admixtures shall meet the requirements of ASTM C260.

2. Water Reducing Admixtures: Water reducing admixtures shall meet the requirements of ASTM C494, Type A.

3. Hydration Stabilizing Admixtures: Hydration stabilizing admixtures shall meet the requirements of ASTM C494, Type B or Type D.

4. Superplasticizers: Superplasticizers and retarders shall meet the requirements of ASTM C494, Type F or Type G and ASTM C1017, Type 1.

5. Viscosity Modifying Admixtures: Viscosity modifying admixtures may be used if approved by the Engineer.

6. Color Pigment: Color pigment shall meet the requirements of ASTM C979 for integrally colored concrete. Pigments shall be color stable, non-fading, and resistant to lime and other alkalis.

   DESIGNER NOTE: Designer to specify color, as indicated by manufacturer's designation, architect's sample, etc. with provision for approved equal color.

D. Water: Clean potable water or water conforming to ASTM C1602 shall be used in the mix design and on the jobsite. The use of hot water is not permitted.

E. Microfibers: Microfibers shall conform to the requirements of ASTM C1116, Type III and shall be monofilament and ½ inch in length.

F. Mix Design:

1. General: The Contractor shall propose a mix design for pervious concrete and shall submit the mix design to the Engineer for acceptance prior to constructing the reference panels. Pervious concrete shall not be placed in the reference panels without a mix design that has been reviewed and accepted by the Engineer.

2. Mix Design Criteria: The Contractor shall include the following elements and results of the described procedures in the proposed mix design:

a. The cementitious content, including pozzolans if used, shall be a minimum of 480 and a maximum of 600 pounds per cubic yard.

b. The mix may incorporate up to 5 percent fine aggregate, by weight.

c. The mix shall incorporate a hydration stabilizing admixture.

d. The mix may incorporate microfibers or fibers per Manufacturer's recommendations.

e. The mix shall be designed to meet the acceptance criteria for Void Content per Section 1.05.F.2 as determined by the testing methods specified in Section 1.05.E.2.

f. The water/cement ratio shall be between 0.27 and 0.35.

g. Up to 50 percent of cementitious material in the mix, by weight, may be fly ash, slag cement, or a combination of silica fume and either or both of the above, with silica fume not exceeding 10 percent.

Deviations from this mix design, such as the use of internal curing admixtures, cementitious content outside of the range specified, or finer aggregate gradations may be permitted at the sole discretion of the Engineer provided the Contractor can demonstrate the viability of the mix design through past successful installations or sound science.

2.02 PAVEMENT BASE

A. Pavement Base Material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials or round river gravel are not permitted. Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than Working 10 days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to two (2) layers as specified on the Plans and included herein:

1. "Base Course" shall be ASTM No. 3 (modified) or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

2. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed rock to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying courser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
3 inch	100	–	–	–
2 1/2 inch	90 to 100	100	–	–
2 inch	35 to 70	90 to 100	–	–
1 1/2 inch	0 to 15	35 to 70	–	100
1 inch	–	0 to 15	–	95 to 100
3/4 inch	0 to 5	–	–	–
1/2 inch	–	0 to 5	100	25 to 60

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
3/8 inch	–	–	85 to 100	–
No. 4	–	–	10 to 30	0 to 10
No. 8	–	–	0 to 10	0 to 5
No. 16	–	–	0 to 5	–
No. 100[2]	0 to 2	0 to 2	0 to 2	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 sieve.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.
3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C131.
4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.03 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%

Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer and shall be recompacted in accordance with Section 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade.

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

DESIGNER NOTE: Other subgrade verification methods may be required if site conditions limit proof rolling. Consult with geotechnical engineer for acceptable methods.

F. After compaction and proof roll, scarify subgrade ¼- to ½-inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor's expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor's expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer at no additional cost to the Owner. Overlaps of the geotextile shall be a minimum of one (1) foot or to the manufacturer's recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6) inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10) ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer's observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots, additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. The pavement base shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor’s expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any pervious concrete.

DESIGNER NOTE: Consider developing a testing plan for the required testing and inspection of the pavement base. Verification of the in place density/compaction of the open graded base materials is typically not possible with the use of a nuclear densometer due to nature of these materials. Therefore other means to verify these materials are firm and unyielding (such as observation of the compaction process by a geotechnical engineer) are necessary.

DESIGNER NOTE: Consider requiring the Contractor to compact aggregates without crushing them.

3.03 MIXING, PLACEMENT & CURING OF PERVIOUS CONCRETE

A. Pervious concrete formwork

1. Forms shall be made of steel or wood and shall be in good condition, clean, and capable of being anchored in place so as to ensure pavement placement true to the grades, lines and slopes as specified on the Plans.

2. Forms that are bent, warped, unclean, or otherwise deemed inadequate by the Engineer shall not be used.

3. Existing curbs, structures, or the vertical face of previously placed pervious concrete may be used as a form.

4. Set, align, and brace forms to satisfy the lines, grades, and slopes on the Plans.

5. Apply form-release agent to the form face immediately before placing concrete.

6. No pervious concrete shall be placed until the forms are inspected and accepted by the Engineer.

7. Slip forming is an acceptable method for placement of pervious concrete.

B. Batching, mixing, and delivery

1. Pervious concrete shall be batched and centrally mixed at a batching plant meeting the requirements set forth in Section 1.06.A.4. Pervious concrete shall not be shrink mixed or transit mixed.

2. Begin mixing immediately after cement has been added to aggregates. Batch and mix concrete in compliance with ASTM C94, with the following exceptions:

   a. Placement of concrete shall occur no more than 60 minutes from the time water or aggregate is added to the cement.

   b. If a hydration-stabilizing admixture is used, up to 60 minutes may be added to the placement time, resulting in a maximum placement time of 120 minutes.

Additional water may be added on site, but the fresh density must still meet the requirements of Section 2.01.F.2 after water addition.

C. Placing and consolidation

1. Pervious concrete shall not be placed on standing water or frozen pavement base.

2. Wet the pavement base with water before concrete placement such that the material is saturated but without any standing water on the prepared base immediately before concrete placement.

3. Place pervious concrete on the prepared pavement base as close to its final position as possible, either directly from the transporting equipment or by conveyor, unless otherwise specified. Spread the concrete using mechanized equipment or hand tools, without segregation.

4. Strike off concrete between forms using a form riding paving machine or roller screed at the appropriate height, as determined by the Contractor, to allow for compaction to finished grade. Equipment used for striking off the pervious concrete shall leave a smooth surface, free of ridges or other imperfections, without drawing excessive paste to the surface. Vibratory screeds are not permitted. Other strike-off devices may be used when accepted by the Engineer.

5. Compact pervious concrete with a purpose built pervious concrete cross roller or alternate method approved by the Engineer. Rollers shall be of sufficient weight and width to compact the fresh pervious concrete to grade, leaving a smooth surface, free of ridges or other imperfections, without

drawing excessive paste to the surface. Compacted pervious concrete shall meet the acceptance criteria for Smoothness set forth in Section 1.05.E.2.

6. Contractor’s personnel shall take care to avoid foot traffic in the pervious concrete to prevent non-uniform compaction and to keep contaminated material from entering the pavement mix. Foot traffic on the fresh concrete shall not be allowed after it has been struck off.

7. Place pervious concrete continuously. Where placement has been halted for a period of 15 minutes, a header shall be placed between the forms and a construction joint formed. The construction joint shall be located at a contraction joint location, unless otherwise approved by the Engineer. The pervious concrete shall be compacted and finished to the header before placement may continue. Upon resuming placement, the header may be carefully removed and a construction joint formed at that location. Any sloughing or sagging of the previously placed pervious concrete at the header location shall be corrected prior to placing new pervious concrete against the joint.

D. Edging: Edging of the top surface shall be completed in plastic concrete to a radius of not less than 1/4 inch. Defects shall be repaired immediately.

E. Jointing: Joints shall be of three (3) types: construction, contraction, and isolation. Wherever possible, the angle between intersecting joints shall be between 80 and 100 degrees. Construct joints at the locations and to the horizontal dimensions indicated on the Plans.

1. Construction Joints: Construction joints shall be formed at the end of a day’s work or when necessary to stop production for any reason.

a. Construction joints shall be located as near as possible to the location of a planned contraction or isolation joint.

b. Construction joints are to be formed by placing a header between the forms, at right angles, to the full depth of the finished pervious concrete, and set to the height of the forms. Pervious concrete shall be placed against the header and compacted and finished as normal, including edging.

c. Upon resuming paving, the header shall be carefully removed and new pervious concrete placed directly against the existing pervious concrete. The new pervious concrete shall be compacted and finished against the hardened pervious concrete as if it were a form.

d. If an isolation joint is planned at this location, then the premolded joint filler shall be placed against the existing pervious concrete and the new pervious concrete shall be placed against the premolded joint filler. The joint shall be tooled on both sides of the premolded joint filler.

2. Contraction Joints: Contraction joints shall be used to control random cracking.

a. Contraction joints shall be placed every 15 feet unless otherwise shown on the Plans.

DESIGNER NOTE: Designer should consider size and aspect ratio of panels when locating joints.

b. Plastic Formed Joints: Contraction joints may be formed in the plastic concrete using a roller designed for this purpose or by other methods accepted by the Engineer.

1) Rollers shall have sufficient weight to produce the joint and shall not otherwise damage or mar the surface.

2) Plastic formed joints shall be a minimum depth of 1 and 3/4 inches and have a width of no more than 1/8 inch.

3) Joints shall be tooled on both sides of the joint with a radius not less than 1/4 inch.

c. Saw Cut Joints: At the option of the Contractor, contraction joints may be saw cut provided joints are early-entry dry-cut type.

1) Joints shall be cut using purpose built early-entry saw cutting equipment.

2) Saw cut joints shall be a minimum depth of 1/4 of the pervious concrete thickness, up to a maximum required depth of 1 and 1/4 inches, and have a joint width of no more than 1/8 inch.

3) Saw cutting shall occur as soon as the concrete is sufficiently cured so that it may be cut without raveling or dislodging aggregate from the finished surface, no longer than four (4) hours after placement of pavement.

4) Remove cuttings from surface immediately after saw cutting of joints.

5) To minimize drying, curing materials shall be removed only as needed to make cuts and shall be replaced immediately after cutting. The exposed pervious concrete shall be kept moist for the entire duration of exposure.

3. Isolation Joints: Isolation joints shall be used where the pervious concrete abuts existing facilities or where shown on the Plans.

a. Isolation joints shall continue through the depth of the pervious concrete using a 3/8 inch premolded joint filler.

b. Isolation joints may be formed by inserting the premolded joint filler into the plastic concrete or by forming a construction joint and affixing the premolded joint filler against one side of the joint and placing fresh pervious concrete against it.

c. Isolation joints and filler shall be flush with the surrounding pervious concrete and shall not deviate from the acceptance criteria for Grade as specified in Section 1.05.E.2.

d. The edges of the pervious concrete on either side of the premolded joint filler shall be hand tooled to a radius not less than 1/4 inch.

F. Curing

1. Begin curing within 20 minutes of concrete discharge from the truck, unless otherwise specified or approved by the Engineer.

2. Completely cover the pavement surface and all exposed edges with a minimum six- (6)-mil-thick white polyethylene sheet, unless otherwise specified or approved by the Engineer. No wetted burlap or cloth shall be used.

3. Thoroughly secure a polyethylene sheet at all exterior edges and interior laps without using soil. The method of securing the cover material shall prevent wind from removing the sheet and from blowing under the sheet across the surface of the concrete.

4. Curing compound shall not be used on any pervious cement concrete surface.

5. Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified or approved by the Engineer.

6. With the exception of saw cutting equipment, all traffic shall be kept off of the pervious concrete during the curing period.

7. Any testing for acceptance shall not occur until the end of the curing period.

G. Cold-weather construction

1. Protect concrete from freezing and record concrete temperature no less than twice per 24-hour period in accordance with ACI 306.1.

3.04 OPENING TO TRAFFIC

A. No traffic shall be allowed on the pervious cement concrete pavement for 10 days.

3.05 PROTECTION OF PAVEMENT

A. Cured and exposed pervious cement concrete pavement surface shall be kept clean and free of clogging debris and soils from the Contractor's operations and all upstream and adjacent debris. If debris or soils contaminate the pervious pavement voids, the pavement shall be cleaned at the Contractor's expense and to the satisfaction of the Engineer. If pervious cement concrete pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

3.06 REJECTION

A. Pervious concrete that does not meet the acceptance criteria set forth in Section 1.05.E.2 will be rejected by the Engineer on a lot-by-lot basis. Pervious concrete that has been rejected by the Engineer or the Contractor shall be removed and replaced at no additional cost to the Owner.

END OF SECTION

1. General information

1.1 Summary

This work includes specifications for Pervious concrete at the location and to the dimensions shown on the plans, in accordance with the project manual. Intended for use with very specific pervious concrete aggregates and mix designs, and applications.

1.2 Scope

This specification provides requirements for the construction of Pervious Concrete.

1.3 Referenced standards

1.3.1 Annual Book of ASTM Standards, American Society for Testing and Materials (ASTM) Standards, Material References.

1.3.1.1 ASTM C 29 “Test for Unit Weight and Voids in Aggregate”

1.3.1.2 ASTM C 150 “Specifications for Portland Cement” (Types I or II only).

1.3.1.3 ASTM C 172 “Sampling fresh concrete”

1.3.1.4 ASTM C 494 “Specification for Chemical Admixtures for Concrete”

1.3.1.5 ASTM C 595“Specifications for Blended Hydraulic Cements” (Types IP or IS only).

1.3.1.6 ASTM C 1688 “Standard Test for Density and Voids Content of Freshly Mixed Pervious Concrete”

1.3.1.7 ASTM C-1701 “Standard Test Method for Infiltration Rate of In Place Pervious Concrete”

1.3.1.8 ASTM C 1028 - 07 “Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like- Surfaces by the Horizontal Dynamometer Pull-Meter Method”

1.3.1.9 ASTM C 1692 “Clean Potable Water”

1.3.2 Maintenance and cleaning which meet the standards found in the BAPC Pervious Concrete Maintenance Manuel, dated 2013 or newer.

1.3.3 ACI 306R “Cold Weather Concreting”

1.3.4 ACI 305 “Hot Weather Concreting”

1.4 Definition

1.4.1. Pervious Concrete

1.4.1.1 Pervious concrete contains little or no fines, creating an open matrix allowing water to pass through it. Properly installed and cured, pervious concrete is a strong and durable pavement or hardscape that can be used in any application in place of standard impervious concrete or asphalt.

1.5 Submittals

1.5.1 Bid Submittals— The following items must be submitted with the bid proposal. Proposals without the following submittals shall be rejected.

1.5.1.1 Certificates of Qualifications for Pervious Concrete Craftsman or Installers as discussed in Quality Control Section 1.6.1.1.A.

1.5.1.2 Print out of NRMCA Certified Professional website database showing the Craftsman certificate holder as an employee of the qualifying company as discussed in Quality Control Section 1.6.1.1.A/B

1.5.1.3 List of 5 reference jobs as discussed in Quality Control Section 1.6.1.1.C

1.5.2 Pre-Installation Submittals**—**The following items must be submitted no less than four (4) weeks before scheduled installation date.

1.5.2.1 Mix Design

1. Batch weights of all constituents.
2. Portland cement type and brand.
3. Non-Portland cement pozzolan type and source.
4. Macro-fiber brand and type, if used.
5. Admixture type and brand.
6. Aggregate source(s) and gradation(s).
7. Fresh density of the pervious concrete.

1.6 Quality Control

1.6.1 General—Test and inspect concrete materials and operations as work progresses as described in 1.6.2.1 Failure to detect defective work or material early will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

1.6.1.1 Contractor qualification—

A. The Contractor shall employ no less than one National Ready Mixed Concrete Association (NRMCA) certified pervious concrete craftsman, who must be listed on the NRMCA pervious concrete database as an employee of the Contractor, who shall oversee concrete placement, ***or*** the Contractor shall employ no less than four NRMCA certified Pervious Concrete Installers, who shall be on site working as members of each placement crew during all concrete placement. Craftsman consultants "for hire" are not permitted as qualifiers.

B. For all projects where the total pervious concrete pavement area exceeds 20,000 square feet, at least one (1) NRMCA certified Pervious Concrete Craftsman who is a full-time employee of the installing company is required.

C. Contractor must provide documentation showing five or more successful pervious concrete projects in the last two years totaling more than 50,000 sq. ft. Documentation shall include name and address of project, photographs and contact information for project owner, architect or engineer.

1.6.2 Testing as required by project engineer

1.6.2.1 Fresh Density Test

Obtain a minimum 1 ft3 sample for acceptance tests in accordance with ASTM C172. Perform a minimum of one density test in accordance with ASTM C1688 during each day's placement or when visual inspection indicates a change in the concrete. Fresh density shall be between +/-5 lb/ft3 of the specified fresh density.

1.6.2.2 Permeability Test

Permeability shall be tested using ASTM C 1701. One test for every 10,000 sq ft, minimum 3 tests, results should be averaged. Test locations should be at least 25' from each other.

A. Must be tested on clean, level pervious pavement upon completion of the curing period but before acceptance and opening the pavement to traffic.

B. Permeability shall be at least 350 inches per hour on average as tested after curing period has ended.

1.6.2.3 Hardened density (optional)

If specifically required by the project engineer, after seven days curing, a minimum 3 cores should be taken from the test panels, in accordance with ASTM C 42, and measured for thickness and density in accordance with *ASTM C 1754*. These test results should be recorded as a reference for subsequent quality assurance and acceptance testing. Cores taken from subsequent placements should also be tested in accordance with ASTM C 1754. The resulting measured density should be within plus or minus 5% of the average density of cores from the test panel.

1.6.2.4 If less than four (4) inches of open graded base rock is used under the pavement the permeability rate will not be valid and the permeability rate shall not be used for criteria for acceptance of rejection of the pavement.

1.6.2.5 Compressive strength testing is not used for pervious concrete.

1.6.3 Testing agencies—Agencies that perform testing services on concrete materials shall meet the requirements of ASTM C1077. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by Architect/Engineer before performing any Work.

1.6.3.1 Field tests of concrete required in 1.6.2 shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete Technician and an ACI Concrete Field Testing Technician—Grade 1 or equivalent.

1.6.4 Approved Mix Design - Once accepted by the Engineer, the mix design meeting the criteria specified in Section 1.5.2.1 shall become the approved mix design and shall not be modified in any way unless re-submitted and approved by the engineer. Modifications to the approved mix design not approved prior to being placed may be rejected. Admixture and water dosages may be modified as needed to maintain mix properties.

1.7 Field conditions

1.7.1 Protection of Existing Improvements

1.7.1.1 General contractor is responsible for preparing site for work – clearing area, protecting adjacent finished surfaces, materials and previously installed objects or furniture. General contractor shall provide suitable protection where required before work commences and maintain protection throughout the course of the work.

1.7.1.2 To whatever extent possible, do not damage or disturb existing adjacent vegetation. Installer shall not be responsible for damaged vegetation within the work area. Remove all concrete stains from adjacent exposed surfaces of paving, structures, and grounds. Remove all waste and spillage.

1.7.2 Safety and Traffic Control:

1.7.2.1 General contractor shall notify and cooperate with local authorities and other organizations having jurisdiction when construction work will interfere with existing roads and traffic.

1.7.2.2 General contractor shall provide temporary barriers, signs, warning lights, flagmen, and other protections as required to assure the safety of persons and vehicles around the construction area and to organize the smooth flow of traffic.

1.7.3 Weather Limitations:

1.7.3.1 Do not place pervious concrete pavement when the ambient temperature is below 45°F, is expected to fall below 32°F within 48 hours of placement, or is above 90°F, unless otherwise permitted in writing by the design professional of record. In the case of cold weather installation, surface efflorescence, as well as streaking, or tiger striping, which is a result of the curing membrane, may be significant.

1.7.3.2 Do not place pervious concrete pavement when the wind, heat or humidity does not allow enough time to place, properly joint, compact, edge, finish and cure before the surface dries to the point where it will result in raveling, i.e. loss of wet metallic sheen.

1.8 Acceptance

1.8.1 Reference Panel: Acceptance of the reference panel will be based on the criteria for acceptance of pavement per Section 1.8.2

1.8.2 Acceptance of pervious concrete pavement will be based on the following criteria:

a. Appearance: Each lot of finished pervious concrete will be inspected for appearance by the Engineer. The pervious concrete shall have a consistent surface texture, shall have no more than three (3) percent of the surface area within each panel (joint to joint) clogged/sealed with cement paste or raveled, shall be free of ridges or other surface imperfections, shall have joints that are in the specified location and are constructed per specification, and shall be free of cracks. Raveling is defined as*:* the contiguous dislodging of the surface layer(s) of aggregate.

b. Smoothness: Pervious concrete pavement smoothness shall be checked with a 10-foot straight edge. Vertical measurement should be taken between the pavement's determined plane and straight edge discounting surface void and roughness irregularities. The surface of the finished pavement shall be uniform to a degree such that no variations greater than 1/2-inch over ten (10) feet are present when tested with a 10-foot straight edge and checked in a direction perpendicular or parallel to the centerline and the pavement's planed surface.

c. Grade: Pervious concrete shall be true to designed grades plus or minus ½ inch. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the pervious concrete shall be within ¼ inch of that surface.

d. Line: Pervious concrete margins shall be true to designed lines plus or minus ½ inch at any point.

e. Infiltration Rate: The average of all three (3) infiltration tests shall be greater than 350 inches per hour with no single test less than 100 inches per hour.

f. Pressure wash testing: Before final acceptance the Engineer, may require a pressure wash test of the pervious concrete. Pressure washing shall be provided and completed by using portable washer equipment working at a minimum of 3000 psi at 2.4 gpm. The nozzle shall be a zero degree nozzle and be held a maximum of three (3) inches off the concrete surface and moved at a slow but steady rate. The Contractor shall pressure test a min three (3) locations per lot or as determined by the Engineer. Any sections of pervious concrete that breaks up, ravels, or does not infiltrate shall be removed and replaced with acceptable pervious concrete to the nearest joints. The Engineer may reject the concrete if the pressure washing dislodges more than a few individual aggregate particles in each panel. The Contractor shall decide, after placing the pervious concrete, when to perform the quality assurance pressure wash testing for the acceptance.

2. Products

2.1 Fabric

2.1.1 Non-woven geotech fabric, if required for separation shall be Mirafi 140n or approved equal. If the designer determines geotech fabric is required for strength use Mirafi HP 370 or approved equal.

2.2 Base

2.2.1 Base shall be composed of an open graded washed crushed rock maintaining a minimum of 35% void space.

2.2.2 For installations of more than 6” the section beyond 6” may be a larger size provide it meets 2.2-2.2.1.

2.3 Forms

2.3.1 Form materials must be durable enough to resist deformation during edge compaction and maintain grade.

2.3.2 Forms shall be clean and free of debris of any kind, rust, and hardened concrete.

2.4 Pervious Concrete

Comply with ASTM C94/C94M and the following requirements:

2.4.1 Aggregates

2.4.1.1. Aggregate shall have a minimum specific gravity of 2.60, a minimum rodded void content of 36% per ASTM C29, and a maximum absorption rate of 3%. Crushed aggregate or gravel shall be permitted.

2.4.1.2. Size of aggregate to be determined by engineer or owner based on locally available materials but in no case shall be larger than 1/2” nominal.

2.4.2 Admixtures

2.4.2.1 Hydration stabilizers are required for use to extended set time. Additional working time provided by Hydration stabilizers can be several hours and is determined by dosage rate as recommended by manufacturer.

2.4.2.2 Super absorbent polymers (SAP) are required to improve workability and curing and eliminate need for water reducers and viscosity modifiers. Use Pervious Enhancer Pro or approved equal.

2.4.2.3 Other admixtures may be used and must comply with ASTM C 494 and approved by the design professional of record.

2.4.3 Supplementary Cementitious Materials

2.4.3.1 SCMs such as fly ash, slag and silica fume are approved for use in pervious concrete. SCM mix proportions shall be included in the mix design.

2.4.3.2 Supplementary cementitious material shall be as specified herein:

a. Fly Ash: Fly ash shall conform to the requirements of ASTM C618, Class F or C.

b. Slag Cement: Slag cement shall meet the requirements of ASTM C989, Grade 100 or Grade 120.

c. Silica Fume: Silica fume shall meet the requirements of ASTM C1240.

2.4.4 Reinforcing Materials

2.4.4.1 The use of Macro-fibers in pervious concrete mixtures increases durability and is permitted when required. Micro-fibers have minimal effect.

2.4.4.2 No reinforcing bars, tie bars or dowels will be used in the installation of pervious concrete.

2.4.5 Pigments

Use pigments or color complying with ASTM C979 if specified in Contract Documents.

2.4.6 Water

Clean potable water shall be used per ASTM C 1692.

2.5 Cure Materials

2.5.1 Moisture-Retaining Cover:

A minimum of six mil Polyethylene film ASTM C 171 shall be used to cover the fresh pervious concrete.

2.5.2 Evaporation Control

Surface stabilizers and ASTM C309 compliant curing agents are allowed prior to polyethylene cover as long as they are applied in mist form and do not dilute the surface paste.

---

3. Execution

3.1 Reference Panel

3.1.1 Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Test panel requirement may be waived based on contractor experience, if approved by project engineer or owner. Notify the Engineer at least two (2) Working Days before installing pervious concrete reference panel.

3.1.2 At a location, as approved by the contracting agency, the proposed contractor shall construct a sample reference panel on-site, using the same design requirements required for the substantial portion of the project. The sample reference panel should be a minimum of 150 sqft at the same thickness as specified for the application, and should be installed using the same required tools and qualified personnel required for project installation as found in Section 1.6.1.1. The fresh concrete used in the reference panel shall be tested unit weight as per ASTM-C 1688.

3.1.3 The design professional of record shall approve a site cast sample of the specified pavement before paving begins. The following criteria for the sample shall be used:

3.1.3.1 The surface appearance of the sample must be approved for texture, finish and should have minimal surface sealing or raveling as described in Acceptance section 1.8.2. The finished product must a reasonable facsimile of the approved sample.

3.1.3.2 Permeability shall be tested using ASTM C 1701 or approved equal.

A) Permeability shall be at least 350 inches per hour on average, as tested after the initial curing period.

B) If less than 4 inches of specified base rock is installed the ASTM C 1701 permeability test shall not be criteria for acceptance.

3.1.4 Accepted reference panels, in like new condition, may be used in the contract work. Retain and maintain approved reference panels during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

3.1.5 Rejected panels shall be removed at contractor’s expense.

3.2 Pre-installation meeting

3.2.1 If required, a pre-paving meeting shall be scheduled at prior to the installation. The following individuals are required to attend:

3.2.1.1 General contractor representative

3.2.1.2 Pervious concrete installation representative

3.2.1.3 Site work contractor representative

3.2.1.4 Engineer

3.3 Subgrade prep

3.3.1 General contractor shall ensure the subgrade is prepared in accordance with Contract Documents.

3.3.2 General contractor shall ensure that the required pavement thickness is obtained in all locations by verifying subgrade elevation.

3.3.3 General contractor shall ensure that subgrade is not over-compacted before installing the base rock material.

3.3.4 General contractor shall keep all traffic off the subgrade during construction to the maximum extent practical. Re-grade and re-compact subgrade disturbed or over-compacted by construction traffic, as needed. Compact the material added to obtain final subgrade elevation.

3.4 Base Installation

3.4.1 Placement of all other elements of the design (i.e. conduits, drainage pipe(s), utilities, irrigation sleeves, etc.) are to be to reviewed by the General contractor and site contractor prior to placing base.

3.4.2 Geotech fabric (if required) must extend at least three inches outside of base, or per the design documents, whichever is greater unless otherwise specified by the design professional.

3.4.3 General contractor shall inspect the in-place open graded base aggregate:

3.4.3.1 Ensure compliance to the plans and specifications.

3.4.3.2 Verify the base rock is free-draining. If not, do not proceed.

3.4.3.3 General contractor shall ensure that the required pavement thickness is obtained in all locations by verifying base elevation.

3.4.3.4 Base must extend at least three inches beyond edge of slab.

3.5 Setting formwork

3.5.1 Set, align, and brace forms so that the hardened pavement meets the tolerances specified in 3.6. Install forms to allow continuous progress of work and so that forms can remain in place at least 72 hours after concrete placement. Assemble formwork to permit easy stripping and dismantling without damage to concrete.

3.5.2 The vertical face of previously placed concrete may be used as a form ensuring that the pavement is protected from damage.

3.5.3 Forms may be wood or metal.

3.6 Tolerances

3.6.1 Top of Forms: Not more than 3/8" inch variance in 5 feet.

3.6.2 Vertical Face on Longitudinal Axis: Not more than 3/8" inch in 5 feet.

3.7 Batching & Mixing

3.7.1 Mix Proportions

3.7.1.1 Total cementitious material should be sufficient to result in a design void content of 17-23%.

3.7.1.2 The volume of aggregate, cement, water, and admixture per cubic yard calculated as a function of the unit weight as determined by ASTM C1688 Standard Test for Density and Voids Content of Freshly Mixed Pervious Concrete and must result in a yield of 27 cubic feet per cubic yard.

3.7.1.3 The measured unit weight per CY of the concrete per ASTM C1688 shall be +5/-5 lbs. of the design unit weight.

3.7.2 Batch and mix in compliance with ASTM C94/C94M

3.7.3 Discharge shall be completed as long as the mix is workable.

3.7.4 Hydration stabilizer can significantly increase working time. Installer should be well versed in the use of hydration stabilizer.

3.7.5 Water addition to maintain wet metallic sheen on the paste is permitted at the point of discharge. Water addition at site does not extend working time.

3.8 Delivery

3.8.1 Delivery of materials must be carefully scheduled to avoid trucks waiting for excessive periods of time on job. Pervious concrete that has been in the truck for excessive periods of time and is no longer workable should be rejected.

3.8.2 Standard Ready Mix Concrete trucks

3.8.2.1 Standard Ready Mix Concrete trucks can be used for pervious concrete mixes.

3.8.3 Volumetric trucks also known as ‘Truck Mounted Mobile Mixers’

3.8.3.1 Volumetric trucks can be used for delivery and mixing of pervious concrete as well.

3.9 Pervious Concrete Placement

3.9.1 Inspection

3.9.1.1 Before placing concrete, inspect and complete formwork installation.

3.9.2 Prior to placement

3.9.2.1 Prior to placement of pervious concrete, moisten sub-base aggregate to provide a uniform dampened condition at the time concrete is placed. If initial application of water is quickly absorbed apply a second application of water just before installing pervious concrete.

3.9.3 Placement

3.9.3.1 Deposit concrete either directly from the transporting equipment onto the subgrade or sub-base, unless otherwise specified.

3.9.3.2 Do not place concrete on frozen subgrade or sub-base.

3.9.3.3 Finish the pavement to the elevations and thickness specified in Contract Documents and meet the requirements of 3.6.

3.9.4 Edging

3.9.4.1 Edge top surface to a radius of not less than 1.5x the nominal size of the aggregate.

3.9.5 Finishing

3.9.5.1 Compact fresh concrete to stay within the requirement tolerances.

3.9.5.2 Compact pervious concrete to a dense, pervious surface.

3.9.5.3 Tools

A. Spinning “Roller” screed – A spinning/motorized roller screed is the preferable method of strike off and initial compaction.

B. Hand Operated Straight Edge -- A hand operated straight edge may be used to place the pervious concrete where the spinning roller screed is not feasible.

C. Cross roller or motorized float pan should be used to provide secondary compaction and improve surface flatness and texture.

D. Finishing Tools – Hand floats and other tools typical to concrete finishing may be used but only if they do not seal the surface.
E. Asphalt rollers, truss screeds or plate compactors – shall not be used.

3.10 Jointing

3.10.1 Joint placement in pervious concrete is more restrictive than traditional concrete. Joint placement is at the discretion of the installer unless noted in the design documents in which case the designer or engineer shall consult with installer on joint location.

3.10.2 When joint placement is not indicated on the Project Drawings, installer shall submit drawings describing proposed jointing. Do not proceed with Work until the joint placement is accepted by the Architect/ Engineer.

3.10.3 Spacing between contraction joints shall not exceed 20 feet. The larger horizontal dimension of the slab panel, shall not exceed 150% of the smaller dimension.

3.10.4 Tool contraction joints to the specified depth and width in fresh concrete immediately after the concrete is compacted.

3.10.4.1 Contraction joint depth shall be a minimum of one fifth the pavement thickness.

3.10.5 Saw cut concrete joints may be placed after concrete has hardened sufficiently to prevent aggregate from being dislodged. If saw cuts are performed before the curing period has ended, the slabs must be kept sufficiently wet when it is uncovered and immediately recovered.

3.11 Concrete curing

3.11.1 Proper moisture level is indicated by cement paste with a wet metallic sheen. Loss of surface moisture, as indicated by a loss of wet metallic sheen, results in raveling. Begin the curing as soon as possible after discharge of material and before excessive loss of surface moisture occurs.

3.11.1.1 Polyethylene Moisture-Retaining Cover:

A. Completely cover the pavement surface with a minimum 6 mil thick polyethylene sheet. Cut sheeting to a minimum of a full placement width plus 12” on both sides.
B. Cover all exposed edges of pavement with polyethylene sheet. Overlap sheet edges by at least 12”.
C. Secure curing cover material in such a manner as to ensure curing sheet will remain securely in place throughout the duration of the curing period.
D. Evaporation Control: Water, surface stabilizers and ASTM C309 compliant curing agents are allowed as long as they are applied in mist form and do not excessively dilute the surface paste.

3.11.2 Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified. Mixes with 20% or more SEMs shall be cured a minimum of 10 days.

1. General information

1.1 Summary

This work includes specifications for Pervious concrete at the location and to the dimensions shown on the plans, in accordance with the project manual. Intended for use with very specific pervious concrete aggregates and mix designs, and applications.

1.2 Scope

This specification provides requirements for the construction of Pervious Concrete.

1.3 Referenced standards

1.3.1 Annual Book of ASTM Standards, American Society for Testing and Materials (ASTM) Standards, Material References.

1.3.1.1 ASTM C 29 “Test for Unit Weight and Voids in Aggregate”

1.3.1.2 ASTM C 150 “Specifications for Portland Cement” (Types I or II only).

1.3.1.3 ASTM C 172 “Sampling fresh concrete”

1.3.1.4 ASTM C 494 “Specification for Chemical Admixtures for Concrete”

1.3.1.5 ASTM C 595“Specifications for Blended Hydraulic Cements” (Types IP or IS only).

1.3.1.6 ASTM C 1688 “Standard Test for Density and Voids Content of Freshly Mixed Pervious Concrete”

1.3.1.7 ASTM C-1701 “Standard Test Method for Infiltration Rate of In Place Pervious Concrete”

1.3.1.8 ASTM C 1028 - 07 “Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like- Surfaces by the Horizontal Dynamometer Pull-Meter Method”

1.3.1.9 ASTM C 1692 “Clean Potable Water”

1.3.2 Maintenance and cleaning which meet the standards found in the BAPC Pervious Concrete Maintenance Manuel, dated 2013 or newer.

1.3.3 ACI 306R “Cold Weather Concreting”

1.3.4 ACI 305 “Hot Weather Concreting”

1.4 Definition

1.4.1. Pervious Concrete

1.4.1.1 Pervious concrete contains little or no fines, creating an open matrix allowing water to pass through it. Properly installed and cured, pervious concrete is a strong and durable pavement or hardscape that can be used in any application in place of standard impervious concrete or asphalt.

1.5 Submittals

1.5.1 Bid Submittals— The following items must be submitted with the bid proposal. Proposals without the following submittals shall be rejected.

1.5.1.1 Certificates of Qualifications for Pervious Concrete Craftsman or Installers as discussed in Quality Control Section 1.6.1.1.A.

1.5.1.2 Print out of NRMCA Certified Professional website database showing the Craftsman certificate holder as an employee of the qualifying company as discussed in Quality Control Section 1.6.1.1.A/B

1.5.1.3 List of 5 reference jobs as discussed in Quality Control Section 1.6.1.1.C

1.5.2 Pre-Installation Submittals**—**The following items must be submitted no less than four (4) weeks before scheduled installation date.

1.5.2.1 Mix Design

1. Batch weights of all constituents.
2. Portland cement type and brand.
3. Non-Portland cement pozzolan type and source.
4. Macro-fiber brand and type, if used.
5. Admixture type and brand.
6. Aggregate source(s) and gradation(s).
7. Fresh density of the pervious concrete.

1.6 Quality Control

1.6.1 General—Test and inspect concrete materials and operations as work progresses as described in 1.6.2.1 Failure to detect defective work or material early will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

1.6.1.1 Contractor qualification—

A. The Contractor shall employ no less than one National Ready Mixed Concrete Association (NRMCA) certified pervious concrete craftsman, who must be listed on the NRMCA pervious concrete database as an employee of the Contractor, who shall oversee concrete placement, ***or*** the Contractor shall employ no less than four NRMCA certified Pervious Concrete Installers, who shall be on site working as members of each placement crew during all concrete placement. Craftsman consultants “for hire” are not permitted as qualifiers.

B. For all projects where the total pervious concrete pavement area exceeds 20,000 square feet, at least one (1) NRMCA certified Pervious Concrete Craftsman who is a full-time employee of the installing company is required.

C. Contractor must provide documentation showing five or more successful pervious concrete projects in the last two years totaling more than 50,000 sq. ft. Documentation shall include name and address of project, photographs and contact information for project owner, architect or engineer.

1.6.2 Testing as required by project engineer

1.6.2.1 Fresh Density Test

Obtain a minimum 1 ft3 sample for acceptance tests in accordance with ASTM C172. Perform a minimum of one density test in accordance with ASTM C1688 during each day's placement or when visual inspection indicates a change in the concrete. Fresh density shall be between +/-5 lb/ft3 of the specified fresh density.

1.6.2.2 Permeability Test

Permeability shall be tested using ASTM C 1701. One test for every 10,000 sq ft, minimum 3 tests, results should be averaged. Test locations should be at least 25' from each other.

A. Must be tested on clean, level pervious pavement upon completion of the curing period but before acceptance and opening the pavement to traffic.

B. Permeability shall be at least 350 inches per hour on average as tested after curing period has ended.

1.6.2.3 Hardened density (optional)

If specifically required by the project engineer, after seven days curing, a minimum 3 cores should be taken from the test panels, in accordance with ASTM C 42, and measured for thickness and density in accordance with *ASTM C 1754*. These test results should be recorded as a reference for subsequent quality assurance and acceptance testing. Cores taken from subsequent placements should also be tested in accordance with ASTM C 1754. The resulting measured density should be within plus or minus 5% of the average density of cores from the test panel.

1.6.2.4 If less than four (4) inches of open graded base rock is used under the pavement the permeability rate will not be valid and the permeability rate shall not be used for criteria for acceptance of rejection of the pavement.

1.6.2.5 Compressive strength testing is not used for pervious concrete.

1.6.3 Testing agencies—Agencies that perform testing services on concrete materials shall meet the requirements of ASTM C1077. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by Architect/Engineer before performing any Work.

1.6.3.1 Field tests of concrete required in 1.6.2 shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete Technician and an ACI Concrete Field Testing Technician—Grade 1 or equivalent.

1.6.4 Approved Mix Design - Once accepted by the Engineer, the mix design meeting the criteria specified in Section 1.5.2.1 shall become the approved mix design and shall not be modified in any way unless re-submitted and approved by the engineer. Modifications to the approved mix design not approved prior to being placed may be rejected. Admixture and water dosages may be modified as needed to maintain mix properties.

1.7 Field conditions

1.7.1 Protection of Existing Improvements

1.7.1.1 General contractor is responsible for preparing site for work – clearing area, protecting adjacent finished surfaces, materials and previously installed objects or furniture. General contractor shall provide suitable protection where required before work commences and maintain protection throughout the course of the work.

1.7.1.2 To whatever extent possible, do not damage or disturb existing adjacent vegetation. Installer shall not be responsible for damaged vegetation within the work area. Remove all concrete stains from adjacent exposed surfaces of paving, structures, and grounds. Remove all waste and spillage.

1.7.2 Safety and Traffic Control:

1.7.2.1 General contractor shall notify and cooperate with local authorities and other organizations having jurisdiction when construction work will interfere with existing roads and traffic.

1.7.2.2 General contractor shall provide temporary barriers, signs, warning lights, flagmen, and other protections as required to assure the safety of persons and vehicles around the construction area and to organize the smooth flow of traffic.

1.7.3 Weather Limitations:

1.7.3.1 Do not place pervious concrete pavement when the ambient temperature is below 45°F, is expected to fall below 32°F within 48 hours of placement, or is above 90°F, unless otherwise permitted in writing by the design professional of record. In the case of cold weather installation, surface efflorescence, as well as streaking, or tiger striping, which is a result of the curing membrane, may be significant.

1.7.3.2 Do not place pervious concrete pavement when the wind, heat or humidity does not allow enough time to place, properly joint, compact, edge, finish and cure before the surface dries to the point where it will result in raveling, i.e. loss of wet metallic sheen.

1.8 Acceptance

1.8.1 Reference Panel: Acceptance of the reference panel will be based on the criteria for acceptance of pavement per Section 1.8.2

1.8.2 Acceptance of pervious concrete pavement will be based on the following criteria:

a. <u>Appearance</u>: Each lot of finished pervious concrete will be inspected for appearance by the Engineer. The pervious concrete shall have a consistent surface texture, shall have no more than three (3) percent of the surface area within each panel (joint to joint) clogged/sealed with cement paste or raveled, shall be free of ridges or other surface imperfections, shall have joints that are in the specified location and are constructed per specification, and shall be free of cracks. Raveling is defined as*:* the contiguous dislodging of the surface layer(s) of aggregate.

b. Smoothness: Pervious concrete pavement smoothness shall be checked with a 10-foot straight edge. Vertical measurement should be taken between the pavement's determined plane and straight edge discounting surface void and roughness irregularities. The surface of the finished pavement shall be uniform to a degree such that no variations greater than 1/2-inch over ten (10) feet are present when tested with a 10-foot straight edge and checked in a direction perpendicular or parallel to the centerline and the pavement's planed surface.

c. Grade: Pervious concrete shall be true to designed grades plus or minus ½ inch. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the pervious concrete shall be within ¼ inch of that surface.

d. Line: Pervious concrete margins shall be true to designed lines plus or minus ½ inch at any point.

e. Infiltration Rate: The average of all three (3) infiltration tests shall be greater than 350 inches per hour with no single test less than 100 inches per hour.

f. Pressure wash testing: Before final acceptance the Engineer, may require a pressure wash test of the pervious concrete. Pressure washing shall be provided and completed by using portable washer equipment working at a minimum of 3000 psi at 2.4 gpm. The nozzle shall be a zero degree nozzle and be held a maximum of three (3) inches off the concrete surface and moved at a slow but steady rate. The Contractor shall pressure test a min three (3) locations per lot or as determined by the Engineer. Any sections of pervious concrete that breaks up, ravels, or does not infiltrate shall be removed and replaced with acceptable pervious concrete to the nearest joints. The Engineer may reject the concrete if the pressure washing dislodges more than a few individual aggregate particles in each panel. The Contractor shall decide, after placing the pervious concrete, when to perform the quality assurance pressure wash testing for the acceptance.

2. Products

2.1 Fabric

2.1.1 Non-woven geotech fabric, if required for separation shall be Mirafi 140n or approved equal. If the designer determines geotech fabric is required for strength use Mirafi HP 370 or approved equal.

2.2 Base

2.2.1 Base shall be composed of an open graded washed crushed rock maintaining a minimum of 35% void space.
2.2.2 For installations of more than 6" the section beyond 6" may be a larger size provide it meets 2.2-2.2.1.

2.3 Forms

2.3.1 Form materials must be durable enough to resist deformation during edge compaction and maintain grade.
2.3.2 Forms shall be clean and free of debris of any kind, rust, and hardened concrete.

2.4 Pervious Concrete

Comply with ASTM C94/C94M and the following requirements:

2.4.1 Aggregates

2.4.1.1. Aggregate shall have a minimum specific gravity of 2.60, a minimum rodded void content of 36% per ASTM C29, and a maximum absorption rate of 3%. Crushed aggregate or gravel shall be permitted.
2.4.1.2. Size of aggregate to be determined by engineer or owner based on locally available materials but in no case shall be larger than 1/2" nominal.

2.4.2 Admixtures

2.4.2.1 Hydration stabilizers are required for use to extended set time. Additional working time provided by Hydration stabilizers can be several hours and is determined by dosage rate as recommended by manufacturer.
2.4.2.2 Super absorbent polymers (SAP) are required to improve workability and curing and eliminate need for water reducers and viscosity modifiers. Use Pervious Enhancer Pro or approved equal.
2.4.2.3 Other admixtures may be used and must comply with ASTM C 494 and approved by the design professional of record.

2.4.3 Supplementary Cementitious Materials

2.4.3.1 SCMs such as fly ash, slag and silica fume are approved for use in pervious concrete. SCM mix proportions shall be included in the mix design.
2.4.3.2 Supplementary cementitious material shall be as specified herein:

a. Fly Ash: Fly ash shall conform to the requirements of ASTM C618, Class F or C.
b. Slag Cement: Slag cement shall meet the requirements of ASTM C989, Grade 100 or Grade 120.
c. Silica Fume: Silica fume shall meet the requirements of ASTM C1240.

2.4.4 Reinforcing Materials

2.4.4.1 The use of Macro-fibers in pervious concrete mixtures increases durability and is permitted when required. Micro-fibers have minimal effect.
2.4.4.2 No reinforcing bars, tie bars or dowels will be used in the installation of pervious concrete.

2.4.5 Pigments

Use pigments or color complying with ASTM C979 if specified in Contract Documents.

2.4.6 Water

Clean potable water shall be used per ASTM C 1692.

2.5 Cure Materials

2.5.1 Moisture-Retaining Cover:

A minimum of six mil Polyethylene film ASTM C 171 shall be used to cover the fresh pervious concrete.

2.5.2 Evaporation Control

Surface stabilizers and ASTM C309 compliant curing agents are allowed prior to polyethylene cover as long as they are applied in mist form and do not dilute the surface paste.

3. Execution

3.1 Reference Panel

3.1.1 Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Test panel requirement may be waived based on contractor experience, if approved by project engineer or owner. Notify the Engineer at least two (2) Working Days before installing pervious concrete reference panel.

3.1.2 At a location, as approved by the contracting agency, the proposed contractor shall construct a sample reference panel on-site, using the same design requirements required for the substantial portion of the project. The sample reference panel should be a minimum of 150 sqft at the same thickness as specified for the application, and should be installed using the same required tools and qualified personnel required for project installation as found in Section 1.6.1.1. The fresh concrete used in the reference panel shall be tested unit weight as per ASTM-C 1688.

3.1.3 The design professional of record shall approve a site cast sample of the specified pavement before paving begins. The following criteria for the sample shall be used:

3.1.3.1 The surface appearance of the sample must be approved for texture, finish and should have minimal surface sealing or raveling as described in Acceptance section 1.8.2. The finished product must a reasonable facsimile of the approved sample.

3.1.3.2 Permeability shall be tested using ASTM C 1701 or approved equal.

A) Permeability shall be at least 350 inches per hour on average, as tested after the initial curing period.

B) If less than 4 inches of specified base rock is installed the ASTM C 1701 permeability test shall not be criteria for acceptance.

3.1.4 Accepted reference panels, in like new condition, may be used in the contract work. Retain and maintain approved reference panels during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

3.1.5 Rejected panels shall be removed at contractor’s expense.

3.2 Pre-installation meeting

3.2.1 If required, a pre-paving meeting shall be scheduled at prior to the installation. The following individuals are required to attend:

3.2.1.1 General contractor representative

3.2.1.2 Pervious concrete installation representative

3.2.1.3 Site work contractor representative

3.2.1.4 Engineer

3.3 Subgrade prep

3.3.1 General contractor shall ensure the subgrade is prepared in accordance with Contract Documents.

3.3.2 General contractor shall ensure that the required pavement thickness is obtained in all locations by verifying subgrade elevation.

3.3.3 General contractor shall ensure that subgrade is not over-compacted before installing the base rock material.

3.3.4 General contractor shall keep all traffic off the subgrade during construction to the maximum extent practical. Re-grade and re-compact subgrade disturbed or over-compacted by construction traffic, as needed. Compact the material added to obtain final subgrade elevation.

3.4 Base Installation

3.4.1 Placement of all other elements of the design (i.e. conduits, drainage pipe(s), utilities, irrigation sleeves, etc.) are to be to reviewed by the General contractor and site contractor prior to placing base.

3.4.2 Geotech fabric (if required) must extend at least three inches outside of base, or per the design documents, whichever is greater unless otherwise specified by the design professional.

3.4.3 General contractor shall inspect the in-place open graded base aggregate:

3.4.3.1 Ensure compliance to the plans and specifications.

3.4.3.2 Verify the base rock is free-draining. If not, do not proceed.

3.4.3.3 General contractor shall ensure that the required pavement thickness is obtained in all locations by verifying base elevation.

3.4.3.4 Base must extend at least three inches beyond edge of slab.

3.5 Setting formwork

3.5.1 Set, align, and brace forms so that the hardened pavement meets the tolerances specified in 3.6. Install forms to allow continuous progress of work and so that forms can remain in place at least 72 hours after concrete placement. Assemble formwork to permit easy stripping and dismantling without damage to concrete.

3.5.2 The vertical face of previously placed concrete may be used as a form ensuring that the pavement is protected from damage.

3.5.3 Forms may be wood or metal.

3.6 Tolerances

3.6.1 Top of Forms: Not more than 3/8" inch variance in 5 feet.

3.6.2 Vertical Face on Longitudinal Axis: Not more than 3/8" inch in 5 feet.

3.7 Batching & Mixing

3.7.1 Mix Proportions

3.7.1.1 Total cementitious material should be sufficient to result in a design void content of 17-23%.

3.7.1.2 The volume of aggregate, cement, water, and admixture per cubic yard calculated as a function of the unit weight as determined by ASTM C1688 Standard Test for Density and Voids Content of Freshly Mixed Pervious Concrete and must result in a yield of 27 cubic feet per cubic yard.

3.7.1.3 The measured unit weight per CY of the concrete per ASTM C1688 shall be +5/-5 lbs. of the design unit weight.

3.7.2 Batch and mix in compliance with ASTM C94/C94M

3.7.3 Discharge shall be completed as long as the mix is workable.

3.7.4 Hydration stabilizer can significantly increase working time. Installer should be well versed in the use of hydration stabilizer.

3.7.5 Water addition to maintain wet metallic sheen on the paste is permitted at the point of discharge. Water addition at site does not extend working time.

3.8 Delivery

3.8.1 Delivery of materials must be carefully scheduled to avoid trucks waiting for excessive periods of time on job. Pervious concrete that has been in the truck for excessive periods of time and is no longer workable should be rejected.

3.8.2 Standard Ready Mix Concrete trucks

3.8.2.1 Standard Ready Mix Concrete trucks can be used for pervious concrete mixes.

3.8.3 Volumetric trucks also known as 'Truck Mounted Mobile Mixers'

3.8.3.1 Volumetric trucks can be used for delivery and mixing of pervious concrete as well.

3.9 Pervious Concrete Placement

3.9.1 Inspection

3.9.1.1 Before placing concrete, inspect and complete formwork installation.

3.9.2 Prior to placement

3.9.2.1 Prior to placement of pervious concrete, moisten sub-base aggregate to provide a uniform dampened condition at the time concrete is placed. If initial application of water is quickly absorbed apply a second application of water just before installing pervious concrete.

3.9.3 Placement

3.9.3.1 Deposit concrete either directly from the transporting equipment onto the subgrade or sub-base, unless otherwise specified.

3.9.3.2 Do not place concrete on frozen subgrade or sub-base.

3.9.3.3 Finish the pavement to the elevations and thickness specified in Contract Documents and meet the requirements of 3.6.

3.9.4 Edging

3.9.4.1 Edge top surface to a radius of not less than 1.5x the nominal size of the aggregate.

3.9.5 Finishing

3.9.5.1 Compact fresh concrete to stay within the requirement tolerances.

3.9.5.2 Compact pervious concrete to a dense, pervious surface.

3.9.5.3 Tools

A. Spinning "Roller" screed – A spinning/motorized roller screed is the preferable method of strike off and initial compaction.

B. Hand Operated Straight Edge -- A hand operated straight edge may be used to place the pervious concrete where the spinning roller screed is not feasible.

C. Cross roller or motorized float pan should be used to provide secondary compaction and improve surface flatness and texture.

D. Finishing Tools – Hand floats and other tools typical to concrete finishing may be used but only if they do not seal the surface.

E. Asphalt rollers, truss screeds or plate compactors – shall not be used.

3.10 Jointing

3.10.1 Joint placement in pervious concrete is more restrictive than traditional concrete. Joint placement is at the discretion of the installer unless noted in the design documents in which case the designer or engineer shall consult with installer on joint location.

3.10.2 When joint placement is not indicated on the Project Drawings, installer shall submit drawings describing proposed jointing. Do not proceed with Work until the joint placement is accepted by the Architect/ Engineer.

3.10.3 Spacing between contraction joints shall not exceed 20 feet. The larger horizontal dimension of the slab panel, shall not exceed 150% of the smaller dimension.

3.10.4 Tool contraction joints to the specified depth and width in fresh concrete immediately after the concrete is compacted.

3.10.4.1 Contraction joint depth shall be a minimum of one fifth the pavement thickness.

3.10.5 Saw cut concrete joints may be placed after concrete has hardened sufficiently to prevent aggregate from being dislodged. If saw cuts are performed before the curing period has ended, the slabs must be kept sufficiently wet when it is uncovered and immediately recovered.

3.11 Concrete curing

3.11.1 Proper moisture level is indicated by cement paste with a wet metallic sheen. Loss of surface moisture, as indicated by a loss of wet metallic sheen, results in raveling. Begin the curing as soon as possible after discharge of material and before excessive loss of surface moisture occurs.

3.11.1.1 Polyethylene Moisture-Retaining Cover:

A. Completely cover the pavement surface with a minimum 6 mil thick polyethylene sheet. Cut sheeting to a minimum of a full placement width plus 12” on both sides.

B. Cover all exposed edges of pavement with polyethylene sheet. Overlap sheet edges by at least 12”.

C. Secure curing cover material in such a manner as to ensure curing sheet will remain securely in place throughout the duration of the curing period.

D. Evaporation Control: Water, surface stabilizers and ASTM C309 compliant curing agents are allowed as long as they are applied in mist form and do not excessively dilute the surface paste.

3.11.2 Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified. Mixes with 20% or more SEMs shall be cured a minimum of 10 days.

3.11.3 All curing times are based on temperatures at or above 55°F during the curing time. Each day temperatures are lower than 55°F does not count as a curing day. The added time required is to be determined by the design professional of record.

3.12 Concrete protection

3.12.1 Pavement Protection during Construction

3.12.1.1 General contractor must inform all trades who use the pavement for staging, storage or other reasons; especially landscapers, not to place materials such as dirt, debris, or bark directly on the pervious concrete.

3.12.1.2 General contractor shall protect the pavement surface from abrasion, discoloration, or sediments until completion of any construction or landscaping activity that may expose the pavement to hazards.

3.12.1.3 General contractor shall be responsible to clean, repair and touch-up, or replace when directed, pavement which has been soiled, discolored, or damaged by other trades outside the installer's control prior to substantial completion.

3.13 Cleaning

3.13.1 Pressure washing or vacuuming or a combination of both may be used as required. Pressure washers are approved for use after 14 days.

3.14 Maintenance/Cleaning

3.14.1 After completion of installation General Contractor is responsible for protecting and cleaning.

3.14.2 Owner is responsible for all maintenance after project work acceptance.

3.14.3 The contractor must supply the owner with a copy of a Pervious Concrete Maintenance Manual.

3.15 Opening to traffic

3.15.1 The pavement must have cured for at minimum 7 uninterrupted days before light vehicle traffic is permitted, 28 days cure for heavy vehicles. The Architect/Engineer must accept the pavement before being opened up to traffic.

Section 33 47 27 – Bioretention

DESIGNER NOTE: Green text corresponds to notes to the designer. Remove prior to use.

DESIGNER NOTE: Replace "Engineer/Landscape Architect" with person in responsible charge for the project (e.g., Owner, Engineer, Landscape Architect).

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Bioretention Soil Mix
2. Aggregate Storage
3. Mulch [To be completed by designer.]
4. Streambed Gravel [To be completed by designer.]

B. Related Sections:

1. Section 01 57 29 – Temporary Protection of Green Infrastructure Facilities

DESIGNER NOTE: The designer should list any additional specification sections which relate to the bioretention work (i.e., clean outs and underdrains, overflow structures, planting, temporary erosion control, utilities, irrigation, earthwork, other appurtenances, etc.).

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest versions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.

1.03 DEFINITIONS

A. Bioretention Soil Mix (BSM): A soil mix that has been specially blended and tested for use in bioretention facilities with the intent to meet the following objectives:

1. Infiltrate runoff at a minimum rate of 5 inches per hour throughout the life of the facility, and
2. By nature of its components be capable of the removal of certain suspended and dissolved stormwater pollutants, and
3. Have sufficient moisture retention and other agronomic properties to support healthy vegetation.

1.04 REFERENCES

DESIGNER NOTE: Designer to provide references to all project specific documents (e.g., geotechnical report).

1.05 SUBMITTALS

A. Pre-Installation Submittals: The Contractor shall submit to the Engineer/Landscape Architect the following a minimum of 20 calendar days (or as directed by the Engineer/Landscape Architect) prior to the construction of bioretention facilities:

1. BSM Submittals

a. Two one (1) gallon samples of the BSM.

b. Source certificates for all BSM materials.

c. Sieve analysis of BSM per ASTM D422 performed within two (2) months of product delivery to site

d. Certification from the soil supplier or an accredited testing agency that the BSM, including sand and compost components, conforms to all industry or technical society reference standards specified in Sections 2.01.A, 2.01.B, and 2.01C.

e. A description of the equipment and methods used to mix the sand and compost to produce BSM.

f. Organic content test results of the BSM, performed in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method."

g. Permeability test results for BSM per ASTM D2434 (Modified). See SFPUC Modified ASTM D2434 Procedures for required modifications to test.

DESIGNER NOTE: On larger projects, it may be appropriate to require that the above testing be performed on samples taken at the supplier's yard from the stockpile to be used for the project; see designer note in Section 1.06.C.2.

2. Sand Submittals

a. Sieve analysis of sand per ASTM D422 performed within two (2) months of product delivery to site.

DESIGNER NOTE: Consider revising acceptable age of sieve tests depending on scale of project. On a larger project it may be appropriate to require testing on samples taken at the supplier's yard from the stockpile to be used for the project.

3. Compost Submittals

a. Quality analysis results for compost performed in accordance with Seal of Testing Assurance (STA) standards, as specified in Section 2.01.C, and performed within two (2) months of product delivery to site.

b. Sieve analysis of compost per TMECC 02.02-B performed within two (2) months of product delivery to site.

4. Other Submittals

a. Cut sheets of any media or soil admixes to enhance moisture retention properties, if used.

b. Testing agency qualifications as specified in Section 1.06.B.

DESIGNER NOTE: Designer should include relevant submittal requirements for mulch and streambed gravel (e.g., sieve analysis), to ensure quality of delivered products.

1.06 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect bioretention materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered after installation, nor shall it constitute final acceptance.

B. Testing Agency Qualification:

1. General: Agencies that perform testing on bioretention materials, including permeability testing, shall be accredited by STA, ASTM, AASHTO, or other designated recognized standards organization. All certifications shall be current. Testing agency shall be capable of performing all tests to the designated and recognized standards specified and shall provide test results with an accompanying Manufacturer's Certificate of Compliance. The following information shall be provided for all testing laboratories used:

a. Name of lab(s) and contact person(s)

b. Address(es) and phone number(s)

c. Email address(es)

d. Qualifications of laboratory and personnel including the date of current certification by STA, ASTM, AASHTO, or approved equal.

2. Compost: Laboratory that performs testing shall be independent, enrolled in the US Composting Council's (USCC) Compost Analysis Proficiency (CAP) program, and perform testing in accordance with USCC Test Method for The Examination of Composting and Compost (TMECC). The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans

Memorial Highway, Suite 275, Holbrook, NY 11741, 631-737-4931, www.compostingcouncil.org.

C. Responsibilities of Contractor

1. Submittals: Some of the tests required for this specification are unique, and BSM shall be considered a long-lead-time item. Under no circumstance shall failure to comply with all specification requirements be an excuse for a delay or for expedient substitution of unacceptable material(s). The requirements of Division 0 apply in their entirety.

   Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer/Landscape Architect, the Resident Engineer, the Owner/Client Representative, Installer, and general Contractor, to review schedule, products, soil testing, permeability testing, and installation. The Contractor shall notify the Engineer/Landscape Architect a minimum of 2 working days prior to conference.

   DESIGNER NOTE: Pre-placement conference is mandatory for all projects within the public right-of-way, or on other public property, and is strongly recommended for privately-owned parcel projects.

2. Testing: All testing specified herein is the responsibility of the Contractor and shall be conducted by an independent testing agency, retained by the Contractor. The Owner reserves the right to conduct additional testing on all materials submitted, delivered, or in-place to ensure compliance with Specifications.

   DESIGNER NOTE: Batch-specific test results and certifications shall be required for projects installing more than 500 cubic yards of BSM.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Protect the BSM and mulch from contamination and all sources of additional moisture at supplier site, during transport, and at the project site, until incorporated into the Work.

B. The Contractor is required to coordinate delivery of BSM and aggregates with bioretention facility excavation and soil installation. A written schedule shall be submitted for review as part of the submittal package. BSM should not be stockpiled onsite for any length of time. In no case shall BSM be stockpiled onsite for more than 24 hours without prior written approval by the Engineer/Landscape Architect. If stockpiling onsite for any length of time, BSM stockpiles shall meet the following requirements:

1. Locate stockpiles away from drainage courses, inlets, sewer cleanout vents, and concentrated stormwater flows

2. Place stockpiles on geotextile fabric

3. Cover stockpiles with plastic or comparable material

4. Contain stockpiles (and prevent contamination from adjacent stockpiles) with temporary perimeter barrier (e.g., sand bags, wattles, silt fence)

PART 2 PRODUCTS

2.01 BIORETENTION SOIL MIX (BSM)

A. General: BSM shall be a well-blended mixture of sand and compost, shall have sufficient moisture retention to support healthy plant growth, and shall meet the following criteria:

1. Mixture proportions: 30 to 40 percent Compost by volume and 60 to 70 percent Sand by volume

   DESIGNER NOTE: Up to 15 percent of the sand fraction may be replaced with other media or soil admixtures (e.g., scoria, coconut coir, perlite, expanded shale, gypsum, vermiculite, pumice, biochar, etc.) to enhance moisture retention capacity of soil, provided admixtures are low in fines (less than 5 percent passing the 200 sieve) and do not break down under normal handling and use. No topsoil, peat, silts, or clays are permitted to be used as admixtures. Admixtures shall be free of sediments and other materials deleterious to plant growth.

2. Organic matter content: 4 to 8 percent as determined by TMECC 05.07-A, Loss on Ignition Method.

3. Extraneous materials: BSM shall be free of all roots, plants, weeds, sod, stones, clods, pockets of coarse sand, construction debris, or other extraneous materials harmful to plant growth.

4. Permeability/Saturated Hydraulic Conductivity: 10 inches per hour (minimum) tested in accordance with ASTM D2434 (Modified). See SFPUC Modified ASTM D2434 Procedures for required modifications to test.

   DESIGNER NOTE: 10-inch-per-hour minimum rate assumes a design rate of 5 inches per hour and a correction factor of 2 to account for reduction in performance from initially measured rates.

5. Acceptance of BSM quality and performance may be based on samples taken from stockpiles at supplier’s yard, submitted test results, and/or onsite and laboratory testing of installed material at the discretion of the Engineer/Landscape Architect. The point of acceptance will be determined in the field by the Engineer/Landscape Architect.

DESIGNER NOTE: Designer to consider non-compost based BSM specification if facility is serviced by an underdrain and if it is draining to phosphorus sensitive water body.

B. Sand: Sand in the BSM shall conform to the requirements for Sand, Type [specify type from table below] specified herein, unless otherwise approved by the Engineer/Landscape Architect.

DESIGNER NOTE: Designer to specify sand type based on project specific requirements. If bioretention facilities will be subjected to heavy sediment loads (e.g., arterial runoff), consider specifying Sand, Type B (low fines sand) in an effort to reduce clogging risk (pending local availability). Additionally, projects anticipating heavy sediment loads should incorporate pre-settling measures at the upstream end of the facility to allow for more efficient maintenance of facilities.

1. Sand shall be free of wood, waste, coating, or any other deleterious material.

2. Sand material shall meet the following specifications for gradation.

Sieve Size[1]	Percent Passing by Weight	
	Type A[2]	Type B (low fines)[3]
3/8 inch	100	100
No. 4	90 to 100	90 to 100
No. 8	70 to 100	70 to 100
No. 16	40 to 95	40 to 85
No. 30	15 to 70	15 to 60
No. 50	5 to 55	8 to 15
No. 100	0 to 15	0 to 4
No. 200	0 to 5	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Sand conforming to ASTM C33 for Fine Aggregate satisfies the requirements of this specification for Sand, Type A.

[3] Type B (low fines) sand gradation pending local availability.

3. Coefficient of Uniformity: $C_u = \frac{D_{60}}{D_{10}}$: 4 or less for Sand, Type B.

4. Effective Particle Size (D_{10}): 0.3 to 0.5 mm for Sand, Type B.

5. All aggregate passing the No. 200 sieve shall be non-plastic.

6. Acceptance of grading and quality of the sand may be based on samples taken from stockpiles at supplier’s yard or a submitted gradation report at the discretion of the Engineer/Landscape Architect. The point of acceptance will be determined in the field by the Engineer/Landscape Architect.

C. Compost: Compost in the BSM shall be well decomposed, stable, weed free organic matter sourced from waste materials including yard debris, wood wastes or other organic materials, not including biosolids or manure feedstock. Compost shall conform to California Code of Regulations Title 14, Division 7, Chapter 3.1

requirements, be certified through the USCC Seal of Testing Assurance (STA) Program, and meeting the criteria specified herein.

1. Feedstock: Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues. Feedstock shall not include biosolids or manure.

2. Organic Matter Content: 35 to 75 percent by dry weight tested in accordance with TMECC 05.07-A (Loss on Ignition Organic Matter Method).

3. Carbon to Nitrogen Ratio: C:N between 15:1 and 25:1 when tested in accordance with TMECC 05.02-A.

4. Maturity/Stability: shall have a dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120°F) upon delivery or rewetting is not acceptable. In addition any one of the following is required to indicate stability:

   a. Specific Oxygen Uptake Rate (SOUR): 1.5 milligrams O_2 per gram biodegradable volatile solids per hour (maximum) per TMECC 05.08-A.

   b. Carbon Dioxide Evolution Rate: 8 milligrams CO_2 per gram volatile solids per day per TMECC 05.08-B.

   c. Dewar Self Heating Test: 20°C temperature rise (maximum) per TMECC 05.08-D (Class IV or V).

   d. Solvita®: Index value greater than 6 per TMECC 05.08-E.

5. Toxicity: Seed Germination: greater than 80 percent of control AND Vigor: greater than 80 percent of control per TMECC 05.05-A.

6. Nutrient Content: provide analysis detailing nutrient content including N-P-K, Ca, Na, Mg, S, and B.

   a. Total Nitrogen: 0.9 percent (minimum).

   b. Boron: Total shall be < 80 ppm

7. Salinity/Electrical Conductivity: less than 6.0 deciSiemen per meter (dS/m or mmhos/cm) per TMECC 04.10-A (1:5 Slurry Method, Mass Basis).

8. pH: 6.5 to 8 per TMECC 04.11-A (1:5 Slurry pH).

9. Gradation: Compost for BSM shall meet the following size gradation per TMECC 02.02-B (test shall be run on dry compost sample):

Sieve Size	Percent Passing by Weight	
	Min	*Max*
1 inch	99	100
1/2 inch	90	100
1/4 inch	40	90

No. 200	1	10

10. Bulk density: 500 to 1,100 dry pounds per cubic yard.
11. Moisture content: 30 to 55 percent of dry solids.
12. Inerts: compost shall be relatively free of inert ingredients, including glass, plastic and paper, less than 1 percent by weight or volume per TMECC 03.08A.
13. Weed seed/pathogen destruction: provide proof of process to further reduce pathogens (PFRP). For example, turned windrows must reach minimum 55°C for 15 days with at least 5 turnings during that period.
14. Select Pathogens
    a. Salmonella: less than 3 Most Probable Number per 4 grams of total solids, dry weight per TMECC 07.02.
    b. Coliform Bacteria: fecal coliform less than 1,000 Most Probable Number per gram of total solids, dry weight per TMECC 07.01.
15. Trace Contaminants Metals (lead, mercury, etc.): Product must meet US EPA, 40 CFR 503 regulations.

D. Soil Admixtures: [Specify admixtures, if used]

2.02 AGGREGATE STORAGE

DESIGNER NOTE: Aggregate storage layer requirements are dependent on location of project (i.e., MS4 areas vs. combined sewer areas), site specific conditions (e.g., native soil infiltration rates, storage volume needs of project). The designer should update this specification based on the aggregate storage materials required for the project.

DESIGNER NOTE: Aggregate storage is optional in combined sewer areas for facilities without underdrains. BSM depth may also be increased for additional storage capacity (in lieu of an aggregate storage layer), provided the facility is within a combined sewer area and not serviced by an underdrain.

A. Aggregate Storage shall consist of hard, durable, and clean, sand, gravel, or mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove fines, organic matter, extraneous debris, or objectionable materials. Recycled materials are not permitted. The material shall be obtained only from a source(s) approved by the Engineer/Landscape Architect. Written requests for source approval shall be submitted to the Engineer/Landscape Architect not less than ten (10) working days prior to the intended use of the Material. Should the proposed source be one that the Engineer/Landscape Architect has no history of Material performance with, the Engineer/Landscape Architect reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet

Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract.

B. Aggregate storage shall meet the following specifications for grading and quality.

1. Aggregate gradation testing in accordance with ASTM C136 at least once per 500 cubic yards.

Sieve[1]	Percent Passing by Weight		
	Choking Course ASTM No. 9 (Modified)[3]	**Reservoir Course ASTM No. 7 (Modified)[4]**	**Caltrans Class 2 Permeable Aggregate (MS4 Areas Only)**
1 inch	–	–	100
3/4 inch	–	100	90 to 100
1/2 inch	100	90 to 100	–
3/8 inch	100	40 to 70	40 to 100
No. 4	85 to 100	0 to 15	25 to 40
No. 8	10 to 40	0 to 5	18 to 33
No. 16	0 to 10	–	–
No. 30	–	–	5 to 15
No. 50	–	–	0 to 7
No. 200[2]	0 to 2	0 to 2	0 to 3

1 Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

2 Gradation modified from ASTM for portion passing the No. 200 sieve.

3 Materials likely to meet this specification are available locally as Graniterock 1/4” premium screenings (Wilson 1/4" x #10 Premium Screenings).

4 Materials likely to meet this specification are available locally as Graniterock 1/2” premium screenings (Wilson 1/2" x #4 Roofing Aggregate).

2. Crushed Particles: 90 percent (minimum) fractured faces tested in accordance with California Test 205. Do not use rounded river gravel.

3. L.A. Abrasion: 40 percent (maximum) tested in accordance with ASTM C 131.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying coarser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC Aggregate Filter Criteria Guidance document for information on selecting appropriate alternate materials.

DESIGNER NOTE: Designer should verify that underdrain slot dimensions for project are compatible with aggregate gradation specified. Refer to the SFPUC Aggregate Filter Criteria Guidance document for information on selecting appropriate underdrain materials.

2.03 MULCH

DESIGNER NOTE: This section intentionally left blank. Designer to specify mulch requirements for bioretention facilities. Mulch may be wood, compost, or rock mulch. Mulch shall be free of dyes, recycled dimensional lumber, and bark. Materials selected shall be sufficiently permeable to allow water to pass through at a rate equal to or greater than the underlying BSM. Typical mulch recommended for this application includes tree trimming mulch per Caltrans Standard Specification Section 20-7.02D(6)(a) and (e), or other comparable material (e.g., arbor mulch).

2.04 STREAMBED GRAVEL

DESIGNER NOTE: This section intentionally left blank. Designer to specify gravel requirements, including gradation, for bioretention facilities. Streambed Gravel shall be sized to provide energy dissipation and to minimize erosion at facility inlets and outlets. The following text is a sample/template specification for cobbles within a bioretention facility:

Streambed Cobbles shall be clean, naturally occurring water rounded gravel material. Streambed Cobbles shall have a well-graded distribution of cobble sizes and conform to the following gradation [Designer to specify]:

Streambed Cobbles	
Approximate Size[1]	**Percent Passing by Weight**

[1] Approximate size can be determined by taking the average dimension of the three axes of the rock, Length, Width, and Thickness, by use of the following calculation: (Length + Width + Thickness)/3 = Approximate Size Length is the longest axis, width is the second longest axis, and thickness is the shortest axis.

The grading of the cobbles shall be determined by the Engineer/Landscape Architect by visual inspection of the load before it is dumped into place, or, if so ordered by the Engineer/Landscape Architect, by dumping individual loads on a flat surface and sorting and measuring the individual rocks contained in the load. Cobbles must be washed before placement.

PART 3 EXECUTION

3.01 GENERAL

A. Prevent runoff from adjacent pervious and impervious surfaces from entering the bioretention facility (e.g., sand bag inlet curb cuts, stabilize adjacent areas, flow diversion) until authorization is given by the Engineer/Landscape Architect. Refer to SFPUC Specification Section 01 57 29 Temporary Protection of Green Infrastructure Facilities.

B. Exclude equipment from bioretention facilities. No equipment shall operate within the facility once bioretention facility excavation has begun, including during and after excavation, backfilling, mulching, or planting.

C. Prevent foreign materials and substances, such as silt laden run-off, construction debris, paint, paint washout, concrete slurry, concrete layers or chunks, cement, plaster, oils, gasoline, diesel fuel, paint thinner, turpentine, tar, roofing compound, or acid from entering or being stored in the facility at any point during construction.

3.02 GRADING

A. The Contractor shall not start bioretention facility grading until all areas draining to the facility are stabilized and authorization has been given by the Engineer/Landscape Architect.

B. Construct bioretention facility subgrade to +/- 3/4 inch of the grades and slopes specified on the Plans.

C. Excavation within 6 inches of final native soil grade shall not be permitted if facility soils have standing water, or have been subjected to more than 1/2 inch of precipitation within the previous 48 hours.

3.03 SUBGRADE PREPARATION AND PROTECTION

A. Protect the bioretention excavation from over compaction and/or contamination.

1. Areas which have been over compacted by equipment or vehicle traffic or by other means and which need to be ripped, over excavated, receive additional scarification, or other restorative means shall be done at the Contractor's expense and at the direction of the Engineer/Landscape Architect.

2. Excavated areas contaminated by sediment laden runoff prior to placement of BSM or Aggregate Storage material shall be remediated at the Contractor's expense by removing the contaminated soil (top 3 inches minimum) and replacing with a suitable material, as determined by the Engineer/Landscape Architect.

B. Remove all trash, debris, construction waste, cement dust and/or slurry, or any other materials that may impede infiltration into prepared subgrade.

C. The subgrade shall be inspected and accepted by the Engineer/Landscape Architect prior to placement of any materials or final subgrade scarification.

D. Scarify the surface of the subgrade to a minimum depth of 3 inches immediately prior to placement of BSM or aggregate storage material. Acceptable methods of scarification include use of excavator bucket teeth or a rototiller to loosen the surface of the subgrade.

E. Place aggregate storage material, where shown on drawings with conveyor belt or with an excavator or loader from a height no higher than 6 feet unless otherwise approved by the Engineer/Landscape Architect (i.e., do not dump material directly from truck into cell).

F. Aggregate Storage areas contaminated by sediment-laden runoff prior to placement of BSM shall be remediated at the Contractor's expense by removing the contaminated aggregate storage material (top 3 inches minimum or as directed by the Engineer/Landscape Architect) and replacing with clean aggregate storage material per Section 2.03, to the lines and grades on the Plans.

G. Aggregate Storage material shall be inspected and accepted for placement and finish grade by the Engineer/Landscape Architect prior to the installation of BSM. Any material that does not conform to this Specification shall be removed and replaced with acceptable material or remediated to the satisfaction of the Engineer/Landscape Architect, at the Contractor's expense.

3.04 BIORETENTION SOIL MIX PLACEMENT

A. The Contractor shall not place BSM until the Engineer/Landscape Architect has reviewed and confirmed the following:

1. BSM delivery ticket(s): Delivery tickets shall show that the full delivered amount of BSM matches the product type, volume and manufacturer named in the submittals. Each delivered batch of BSM shall be accompanied by a certification letter from the supplier verifying that the material meets specifications and is supplied from the approved BSM stockpile.

2. Visual match with submitted samples: Delivered product will be compared to the submitted 1-gallon sample, to verify that it matches the submitted sample. The Engineer/Landscape Architect may inspect any loads of BSM on delivery and stop placement if the soil does not appear to match the submittals; and require sampling and testing of the delivered soil to determine if the soil meets the requirements of Section 2.01 before authorizing soil placement.

3. Inspection of the aggregate storage layer, underdrain, cleanout, and overflow structure installation, where included on the plans.

DESIGNER NOTE: On larger projects, it may be appropriate to require that the testing specified in Section 2.01 be performed on samples taken at the supplier's yard from the stockpile to be used for the project; see designer note in Section 1.06.C.2.

B. BSM placement, grading and consolidation shall not occur when the BSM is excessively wet, or has been subjected to more than 1/2 inch of precipitation within 48 hours prior to placement. Excessively wet is defined as being at or above 22 percent soil moisture by a General Tools & Instruments DSMM500 Precision Digital Soil Moisture Meter with Probe (or equivalent). A minimum of three readings with the soil moisture probe will be used to determine the average percent soil moisture reading per each truck load. There should be no visible free water in the material.

C. The Contractor shall place BSM loosely with a conveyor belt or with an excavator or loader from a height no higher than 6 feet, unless otherwise approved by the Engineer/Landscape Architect (i.e., do not dump material directly from truck into cell). Soil shall be placed upon a prepared subgrade in accordance with these Specifications and in conformity with the lines, grades, depth, and typical cross-section shown in the Drawings or as established by the Engineer/Landscape Architect.

D. Excessively dry BSM may be lightly and uniformly moistened, as necessary, to facilitate placement and workability.

E. Compact BSM using non-mechanical compaction methods (e.g., boot packing, hand tamping, or water consolidation) to 83 percent (+/- 2 percent) of the maximum dry density per modified Proctor test (ASTM D1557), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6938. Moisture content determination shall be conducted on a soil sample taken at the location of the nuclear gage reading per ASTM D2216.

DESIGNER NOTE: BSM compaction target density will be updated as more data from installed projects becomes available on the optimal compaction to minimize settlement while maintaining the infiltration capacity of the media. Designers are encouraged to report field density measurements, observed infiltration rates (if available), and anecdotal field observations (e.g., soil appears well draining, settlement observed minimal).

F. Grade BSM to a smooth, uniform surface plane with loose, uniformly fine texture. Rake, remove ridges, and fill depressions to meet finish grades.

G. Final soil depth shall be measured and verified only after the soil has been compacted. If after consolidation, the soil is not within +/- 3/4 inch of the grades and slopes specified on the Plans, add material to bring it up to final grade and raked.

H. The BSM shall be inspected and accepted for placement and finish grade by the Engineer/Landscape Architect prior to the installation of planting and mulch. Any BSM that does not conform to this Specification shall be remediated to the satisfaction of the Engineer/Landscape Architect, or removed and replaced with acceptable BSM, at the Contractor's expense.

3.05 PLANTING AND MULCHING

A. Bioretention facilities shall be planted and mulched as shown on the Plans.

B. Bioretention facilities shall not be planted or mulched when soils are excessively wet as defined in Section 3.04.

C. Bioretention facility areas contaminated by sediment laden runoff prior to planting or placement of mulch shall be remediated at the Contractor's expense by removing the contaminated BSM (top 3 inches minimum) and replacing with BSM per Section 2.01, to the lines and grades on the Plans.

D. All mulch shall be inspected and accepted by the Engineer/Landscape Architect to ensure appropriate depth and material prior to facility commissioning (e.g., unblocking of inlets).

DESIGNER NOTE: Planting and mulching requirements shall be determined by the designer and included or referenced herein.

3.06 FLOOD TESTING

A. Inlets shall be constructed per the Plans and free from all obstructions prior to commencing flow testing.

B. Testing shall be conducted at the conclusion of the 90-day plant grow-in period. Protection and flow diversion measures installed to comply with Section 01 57 29 Temp Protection of GI Facilities shall be removed in their entirety prior to commencing flow testing.

C. Underdrains shall be plugged at the outlet structure to minimize water consumption during testing.

D. Prior to testing, broom sweep gutter and other impervious surfaces within the test area to remove sediments and other objectionable materials.

E. The Engineer/Landscape Architect shall be present during the demonstration. The Contractor shall notify the Engineer/Landscape Architect a minimum of 2 working days prior to testing.

F. The Contractor shall water test each facility to demonstrate that all inlet curb openings are capturing and diverting all water in the gutter to the facility, outlet structures are engaging at the elevation specified, and the designed ponding depth is achieved. Testing shall include application of water from a hydrant or water truck per Section 00 73 73, Article 3.04 (Requirements for Using Water For Construction), at a minimum rate of 10 gallons per minute, into the gutter a minimum of 15 feet upstream of the inlet curb opening being tested. Each inlet shall be tested individually. If erosion occurs during testing, restore soils, plants, and other affected materials.

DESIGNER NOTE: Designer should update test flow rate for inlets to reflect project-specific design, as needed.

G. Engineer/Landscape Architect will identify deficiencies and required corrections, including but not limited to relocating misplaced plants, adjusting streambed gravel, adjusting mulch, adjusting inlets, splash aprons, and forebays, removing and replacing inlets, and removing debris.

H. Once adjustments are made, the Contractor shall re-test to confirm all test water flows into the facility from the gutter and correct any remaining deficiencies identified by Engineer/Landscape Architect.

I. Inlets, outlets, and other bioretention facility appurtenances shall not be accepted until testing and any required correction and retesting is complete and accepted by the Engineer/Landscape Architect.

DESIGNER NOTE: The Owner may, at any time, conduct additional testing on all materials submitted, delivered, or in-place, to ensure compliance with the Specifications. Testing may include permeability testing per ASTM D2434 (Modified), density testing per ASTM D6938, etc., if the Engineer/Landscape Architect suspects the facility does not conform to these specifications (e.g., as evidenced by lower than anticipated infiltration capacity).

DESIGNER NOTE: Designer should consider adding a similar requirement to the Concrete Paving and Sanitary Sewerage Utilities sections of the Specifications, as needed.

END OF SECTION

(This Page Intentionally Left Blank)

A.5 Appendix 5
Sample Maintenance Forms

Landscaped Stormwater Facility Maintenance Checklist

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
Clean Water. Healthy Community.

Property Owner

Property Owner Phone:

Project Address

Treatment Measure No.

Supervisor Name:

Supervisor Phone:

Maintenance Date:

Maintenance Duration:

Maintenance Personnel Type:

- ☐ City Crew
- ☐ Contractor
- ☐ Property Owner
- ☐ Site Manager
- ☐ Volunteer
- ☐ Other ____________

Facility Type:

- ☐ Rain Garden/Bioretention Area
- ☐ Stormwater Planter
- ☐ Stormwater Curb Extension
- ☐ Green Gutter
- ☐ Vegetated Swale
- ☐ Other ____________

Type of Inspection:

- ☐ Monthly
- ☐ Pre-Wet Season
- ☐ After Storm Event
- ☐ End of Wet Season
- ☐ Other ____________

Critical Maintenance Observations:

	Yes	No
Is there standing water in the facility for more than 5 days after a rainfall event?	☐	☐
Is runoff allowed to freely enter and exit the landscape facility?	☐	☐
Is there significant sediment build up at stormwater entry points or throughout the facility's landscape?	☐	☐
Is there any structural damage to hardscape elements?	☐	☐
Are plants in a healthy condition?	☐	☐
Are plants overgrown and/or posing a safety hazard?	☐	☐
Are there visible signs of soil erosion along stormwater entry points or side slopes of facilities?	☐	☐
Are there any leaks, damage, improper coverage, exposed piping, or overwatering from the irrigation system?	☐	☐
Does the facility have at least 70% plant coverage?	☐	☐
Is there any evidence of contamination or hazardous waste in the facility?	☐	☐

Comments:

Landscaped Stormwater Facility Maintenance Checklist

1. POOR DRAINAGE ACTIONS:

- Remove sediment build-up in facility or exit point blockages ☐
- Inspected the underdrain system for blockages or root intrusion ☐
- Adjust overflow inlets to limit ponding depth of water ☐
- Additional actions needed ☐

Expected Positive Results:

There should be no areas of standing water once inflow has ceased after 5 days.

Comments:

Issue Remedied?

Yes ☐ No ☐

2. TRASH REMOVAL ACTIONS:

- Remove any trash inside and around the landscape facility ☐
- Once removed, recycle or safe dispose of applicable trash items ☐
- Remove any hazardous/animal waste safely ☐
- Additional actions needed ☐

Expected Positive Results:

There should be no trash within or around the facility after the maintenance period.

Comments:

Issue Remedied?

Yes ☐ No ☐

3. SEDIMENT REMOVAL ACTIONS:

- Remove sediment build-up in facility and at runoff entry points ☐
- Determine source of sediment load and take corrective action ☐
- May need to also replace plant material and mulch/soil layers ☐
- Additional actions needed ☐

Expected Positive Results:

Sediment material is removed so that there is no clogging or blockage. Material is disposed of properly.

Comments:

Issue Remedied?

Yes ☐ No ☐

A.5 Appendix 5
Sample Maintenance Forms

Landscaped Stormwater Facility Maintenance Checklist

4. ENTRY POINT EROSION ACTIONS:		Expected Positive Results:	Issue Remedied? Yes	No
Provide additional hardscape at curb cuts/splash pads to dissipate water energy	☐	Entry points of stormwater are properly graded and armored for erosion control.	☐	☐
Repair or replace curb cuts to control soil/mulch erosion	☐	Comments:		
Adjust overflow inlets to limit ponding depth of water	☐			
May need to also replace or repair mulch/soil layers	☐			
Additional actions needed	☐			

5. MULCH APPLICATION ACTIONS:		Expected Positive Results:	Issue Remedied? Yes	No
Determine if appropriate mulch material used is working	☐	All bare earth is covered in an even appearance, to a depth of 3 inches.	☐	☐
Add or redistribute mulch where it has been reduced to less than 3 inches deep	☐	Comments:		
Place mulch that has been knocked or washed out of landscape back into place	☐			
Additional actions needed	☐			

6. PLANT COVERAGE ACTIONS:		Expected Positive Results:	Issue Remedied? Yes	No
Determine if there is at least 70% plant coverage on the ground plane	☐	There should be at least 70% coverage of plant material on the ground plane.	☐	☐
If not, schedule the installation of additional plants	☐	Comments:		
Refer to as-built drawings for plant species and size	☐			
Replace ill-adapted plants with a species better adapted site conditions.	☐			
Additional actions needed	☐			

Landscaped Stormwater Facility Maintenance Checklist

7. PLANT HEALTH ACTIONS:		Expected Positive Results:	Issue Remedied?
Determine if any plants are dead, damaged, diseased, stressed or missing	☐	All plants are healthy, disease-free and suited to the environmental conditions.	Yes ☐ No ☐
Determine the cause of poor plant health conditions	☐	Comments:	
Remove struggling plants unlikely to recover or plants likely to infect surrounding plants	☐		
May need to also replace plant material	☐		
Additional actions needed	☐		

8. TRIMMING GRASS-LIKE PLANT ACTIONS:		Expected Positive Results:	Issue Remedied?
Determine if grasses and/or grass like plants are overgrown	☐	Plants appear natural in appearance and are lightly trimmed to maintain at least 12 inches of height.	Yes ☐ No ☐
Trim grasses and/or grass like plants no less than 12” high	☐	Comments:	
If plants are suffering from past aggressive trimming techniques, replace with new plant material and trim plants appropriately	☐		
Additional actions needed	☐		

9. VISUAL SAFETY & PUBLIC SAFETY ACTIONS:		Expected Positive Results:	Issue Remedied?
Determine if plant material obstructs visibility or if safety is compromised	☐	Visibility is maintained throughout the site including proper clearances and site triangles.	Yes ☐ No ☐
Trim any tree branches or shrubs that interfere with public safety, including visibility clearances	☐	Comments:	
May need to also replace plant material with species better suited for the site’s safety conditions	☐		
Additional actions needed	☐		

A.5 Appendix 5
Sample Maintenance Forms

Landscaped Stormwater Facility Maintenance Checklist

10. PLANT HEALTH ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Determine if any plants are dead, damaged, diseased, stressed or missing	☐	All plants are healthy, disease-free and suited to the environmental conditions.	☐	☐
Determine the cause of poor plant health conditions	☐	Comments:		
Remove struggling plants unlikely to recover or plants likely to infect surrounding plants	☐			
May need to also replace plant material	☐			
Additional actions needed	☐			

11. TREE HEALTH ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Determine if trees are struggling, have trunk damage,weak branches, or have suckers growing from trunk	☐	Trees of all ages are healthy, free from damage and disease. Branches are strong and are pruned as necessary to reduce weight.	☐	☐
Remove dead, damaged or diseased branches of trees	☐	Comments:		
Adjust tree grates openings at trunk base, if applicable	☐			
Cut out suckers at trunk base	☐			
Remove trees unlikely to recover	☐			
Replace removed or missing trees with a healthy tree.	☐			
Additional actions needed	☐			

12. YOUNG TREE STRUCTURE ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Determine if branch structure can be corrected without compromising tree health	☐	Young trees are structurally pruned annually. Branch structure is strong.	☐	☐
Instate annual pruning during young tree development	☐	Comments:		
Additional actions needed	☐			

Landscaped Stormwater Facility Maintenance Checklist

13. HAND WEEDING ACTIONS:		Expected Positive Results:	Issue Remedied?
Remove all visible weeds located in planted areas, sidewalks, gutters and pavement.	☐	Little to no weeds visible within the planting area, sidewalks, gutters and pavement. Weeds are removed by hand only.	Yes ☐ No ☐
Remove as much of the root system as possible	☐	Comments:	
Dispose of weeds off-site	☐		
If absolutely necessary, use only the least toxic herbicides	☐		
Additional actions needed	☐		

14. TRIMMING PLANTS AT SIDEWALKS ACTIONS:		Expected Positive Results:	Issue Remedied?
Determine if plants are overgrown over the sidewalk and are impeding accessible pedestrian travel	☐	Plants are in scale with their surroundings and do not impede pedestrian circulation.	Yes ☐ No ☐
Trim shrub branches and groundcovers back from all sidewalks, curbs and paved areas.	☐	Comments:	
Cut the edges of groundcovers at an angle for a more natural appearance	☐		
May need to replace plant material with less vigorous species	☐		
Additional actions needed	☐		

15. IRRIGATION SCHEDULE ACTIONS:		Expected Positive Results:	Issue Remedied?
Determine if irrigation schedule severely mismatched to current watering needs. Plants are dying or dead	☐	Irrigation schedule matches the seasonal water needs of planting.	Yes ☐ No ☐
Adjust irrigation controller for current water needs of plants	☐		
May need to replace dead or dying plant material	☐	Comments:	
Additional actions needed	☐		

A.5 Appendix 5
Sample Maintenance Forms

Landscaped Stormwater Facility Maintenance Checklist

16. IRRIGATION COMPONENTS ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Determine if any Irrigation system components are damaged/ compromised due to exposure, vandalism, or general wear	☐	All irrigation system components are in working order and adequately protected.	☐	☐
Correct/repair any minor breaks in irrigation components	☐	Comments:		
Replace irrigation components for proper irrigation function	☐			
Test irrigation system after repair or component replacement	☐			
Additional actions needed	☐			

Additional Comments:

____

____

____

____

____

Supervisor Name: **Supervisor Signature:** **Date:**

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
Clean Water. Healthy Community.

(This Page Intentionally Left Blank)

A.5 Appendix 5
Sample Maintenance Forms

Pervious Pavement Maintenance Checklist

SAN MATEO COUNTYWIDE Water Pollution Prevention Program
Clean Water. Healthy Community.

Property Owner

Property Owner Phone:

Project Address

Treatment Measure No.

Supervisor Name:

Supervisor Phone:

Maintenance Date:

Maintenance Duration:

Maintenance Personnel Type:

- ☐ City Crew
- ☐ Contractor
- ☐ Property Owner
- ☐ Site Manager
- ☐ Volunteer
- ☐ Other ________________

Pervious Pavement Type:

- ☐ Pervious Pavers
- ☐ Pervious Concrete
- ☐ Porous Asphalt
- ☐ Reinforced Paving
- ☐ Boardwalk/Suspended Deck
- ☐ Other ________________

Type of Inspection:

- ☐ Monthly
- ☐ Pre-Wet Season
- ☐ After Storm Event
- ☐ End of Wet Season
- ☐ Other ________________

Critical Maintenance Observations:

	Yes	No
Is there standing water on the surface of the pervious pavement after a rainfall event?	☐	☐
Is there significant sediment build-up within the pervious pavement system prohibiting runoff to soak into the pervious pavement?	☐	☐
Are there areas of unexpected settlement/sinking within the pervious pavement system?	☐	☐
Is there any structural damage to pervious pavement elements, including any adjacent elements that contains the pervious pavement?	☐	☐
If using reinforced grass paving, are plants in a healthy condition?	☐	☐
Is the pervious pavement condition creating a safety hazard?	☐	☐
Is there any evidence of contamination or hazardous waste entering the pervious pavement system?	☐	☐

Comments:

Pervious Pavement Maintenance Checklist

1. POOR DRAINAGE ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Identify any sediment build-up within the pervious pavement pores or between paving joints	☐	There should be no areas of standing water once inflow has ceased after 6 hours.	☐	☐
Vacuum sweep sediment build-up within the pervious pavement pores or between paving joints	☐	Comments:		
Perform an infiltration test during dry conditions	☐			
Additional actions needed	☐			

2. PAVEMENT SETTLEMENT ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
Identify areas of pervious pavement settlement	☐	There should be no areas of unexpected settlement within the pervious pavement system.	☐	☐
Remove sections of settled pervious pavement, reset pavement system to designed conditions	☐			
Replace entire pervious paving condition	☐	Comments:		
Additional actions needed	☐			

3. PUBLIC SAFETY ACTIONS:		Expected Positive Results:	Issue Remedied?	
			Yes	No
If ADA accessibility is required, determine if pervious paving is maintaining ADA accessibility compliance (i.e. no trip hazards, has adequate slip resistance, etc.)	☐	Pervious paving should not be a public safety hazard at any time.	☐	☐
Determine if the pervious paving is damaged and poses a safety issue, take actions to remedy damaged areas.	☐	Comments:		
Determine if pervious paving is accepting runoff from hazardous material sources, and take further actions to remedy	☐			
Additional actions needed	☐			

A.6 Appendix 6

Potential Green Infrastructure Funding Source Analysis and Recommendations

(This Page Intentionally Left Blank)

GREEN INFRASTRUCTURE FUNDING NEXUS EVALUATION

Part of a Project for the
San Mateo Countywide Water Pollution Prevention Program:

Green Infrastructure Planning

January 2019

Task 5.7

Project Team:

SCIConsultingGroup

LARRY WALKER ASSOCIATES

(THIS PAGE INTENTIONALLY LEFT BLANK)

TABLE OF CONTENTS

(THIS PAGE INTENTIONALLY LEFT BLANK)

1 INTRODUCTION

1.1 INTRODUCTION

The San Francisco Bay Regional Water Quality Control Board's (Regional Water Board) 2015 Municipal Regional Permit (referred to as MRP 2.0) includes specific provisions for addressing key pollutants of concern, including mercury, PCBs (polychlorinated biphenyls), and trash. The MRP 2.0 also requires jurisdictions to transition from gray, or piped, infrastructure storm drainage systems to green, or landscape-based, systems that capture, treat, and infiltrate runoff. In other words, Green Infrastructure.

The MRP 2.0 defines green infrastructure as: Infrastructure that uses vegetation, soils, and natural processes to manage water and create healthier urban environments that mimic nature by soaking up and storing water. Following this definition to its natural conclusion would mean turning the urban landscape of San Mateo County back into green fields. Clearly, that cannot happen, but every action to permeate the hardened urban surfaces and once more expose the soil to the natural precipitation would move our environment further in that direction.

1.1.1 THE ROLE OF STORMWATER MANAGEMENT

This endeavor falls generally under the umbrella of stormwater management, but it also stretches the meaning of stormwater management as municipalities have long envisioned it. Over the past century of urban expansion, stormwater management meant collecting and conveying "nuisance" runoff to receiving waters. The revisions to the Clean Water Act in the late 1980s and the first NPDES[1] permits for MS4s[2] in the early 1990s are serving to redefine stormwater management profoundly. Over the past two decades the trend in the NPDES permits has become clear – municipalities must change how they view their roles as stormwater managers. Where they had once focused strictly on traditional public infrastructure, NPDES now pushes them to focus on other practices (public AND private) such as pest management, enforcing commercial and industrial discharges, and construction sites – later growing to permanent controls on new development (including low impact development, hydrograph modification, capture and reuse), trash capture, and, finally, green infrastructure (GI). MRP 3.0 and 4.0 promise to move further along this path.

But just when more and more municipalities are realizing that stormwater management should be considered an enterprise or utility on par with water and sewer utilities, others are beginning to realize that stormwater management may have already outgrown "utility" status. It may not actually fit neatly inside the box of a discrete enterprise but must permeate through all their planning and land use responsibilities as well. It is also pushing the limits of what a municipality is empowered to do regarding behavior and practices on private property. This is manifest in the range of documents that make up the Green Infrastructure Plans.

---

[1] Acronym stands for the National Pollutant Discharge Elimination System from the Clean Water Act. Permits are issued under this system to municipalities and other entities that discharge stormwater to receiving waters (creeks, bays, etc.).

[2] Acronym stands for municipal separate storm sewer systems.

1.1.2 GREEN INFRASTRUCTURE STRETCHES PRIOR FUNDING MODELS

Funding for GI is no less vexing. Under the old model, stormwater funding was for management and upgrade/expansion of traditional public stormwater infrastructure (inlets, pipes, pump stations, creeks, channels, and levees). GI expands on the concepts of low impact development and hydrograph modification for private development sites and applies them to the broader universe of infrastructure in general – both public and private – and the funding models for these activities are not well developed.

Traditional stormwater funding has always been a challenging field with many hurdles that are changing as rapidly as the regulations pertaining to stormwater quality. Dedicated and sustainable stormwater funding is usually found in the form of a property-related fee (similar to water and sewer fees). Proposition 218 requires these to be focused around services provided and each property's share of the cost of those services. GI expands the universe of infrastructure beyond the traditional drainage facilities to roads, landscaped areas and other facilities. As a result, great care must be taken as traditional stormwater funding sources are applied to the GI goals. In addition, there are inherent difficulties in applying public funding to private facilities, which will necessarily play a role in meeting the GI goals.

Proposition 218 was a constitutional amendment approved by California voters in 1996 and was intended to make it more difficult for municipalities to raise taxes, assessments and fees (such as property-related fees). As currently interpreted by the courts, Proposition 218 requires that stormwater fees must be approved through a ballot measure – a much higher threshold than for the sister utilities of water, sewer and refuse collection which must only conduct a public hearing. The result is that in the past two decades, only a handful of municipalities have been able to put any new stormwater revenue mechanisms in place. This has served to make stormwater a second-class utility and has dealt a serious blow to achieving the "One Water" goals that are so important to solving challenges such as supply shortages and pollution.

This report looks into common existing funding mechanisms (fees, taxes, developer fees, etc.) as well as recently pioneered funding strategies such as alternative compliance funds, enhanced infrastructure finance districts, etc. Many municipalities are finding that no single source of revenue is adequate to fund its stormwater needs, and GI funding will be no different. It is expected that the most successful funding strategy will be a "portfolio" approach containing multiple funding sources. The end product will be a tool box of options.

1.2 BACKGROUND

The City/County Association of Governments of San Mateo County (C/CAG), a joint powers agency whose members are the County of San Mateo and the 20 incorporated cities and towns, administers the San Mateo Countywide Water Pollution Prevention Program (Countywide Program) to assist its member agencies with meeting requirements to reduce pollutants in stormwater runoff. These requirements are contained in the San Francisco Bay Regional Water Quality Control Board's (Regional Water Board) Municipal Regional Permit (MRP 2.0) and include specific provisions for addressing key pollutants of concern, including mercury, PCBs (polychlorinated biphenyls), and trash. The MRP 2.0 also requires jurisdictions to transition from gray, or piped, infrastructure storm drainage systems to green, or landscape-based, systems that capture, treat, and infiltrate runoff – Green Infrastructure.

The MRP 2.0 defines GI as: Infrastructure that uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, GI refers to the patchwork of natural areas that provide habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, GI refers to stormwater management systems that mimic nature by soaking up and storing water.

To aid jurisdictions in transitioning from gray to green infrastructure, MRP 2.0 requires each agency to prepare and adopt a GI Plan by September 2019. The Regional Water Board describes the purpose of the GI Plans as follows:

- Over the long term, the Plan is intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green – that is, a more resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other GI practices to clean stormwater runoff; and
- The Plan shall also identify means and methods to prioritize particular areas and projects within each Permittee's jurisdiction, at appropriate geographic and time scales, for implementation of GI projects. Further, it shall include means and methods to track the area within each Permittee's jurisdiction that is treated by GI controls and the amount of directly connected impervious area.

The GI Plan is required to include targets for the amount of impervious surface to be retrofitted over time in order to achieve specific reductions in mercury and PCBs discharging to San Francisco Bay. It also must address policies, guidance, funding and other means for jurisdictions to ensure implementation, operation, and maintenance of sufficient GI, to meet these target water quality thresholds.

1.3 GOALS OF THIS REPORT

This report builds on C/CAG's 2014 efforts to develop a dedicated and sustainable funding source. Although that effort has not yet moved to the implementation stage, it did produce a Funding Options Report in 2014 that identified a number of traditional stormwater funding sources. This report is not intended to duplicate that 2014 effort, but rather update it as necessary and supplement it with strategies more in line with GI challenges.

The MRP 2.0 provision C.3.j.i(2)(k) requires a GI Plan to include "an evaluation of prioritized project funding options, including, but not limited to: Alternative Compliance funds; grant monies, including transportation project grants from federal, State, and local agencies; existing Permittee resources; new tax or other levies; and other sources of funds." While other sub-tasks of the project identified a prioritized list of potential public GI projects and estimated the potential redevelopment of private parcels (which would require use of low impact development, or "LID") on a drainage-area-specific basis, this Sub-Task (5.7) will provide an evaluation of funding sources that could potentially pair with the types of projects identified.

It is the goal of this report to identify and evaluate the feasibility of various funding strategies to enable member agencies to complete their GI Plans in a thorough and timely manner. This report will provide a general overview of funding mechanisms common to stormwater management, with keys to how they relate to GI.

1.4 REPORT STRUCTURE

- Chapter 2 provides a background of the overall GI planning efforts by C/CAG including general discussion of the three types of funding needs (Planning, Capital and Operations and Maintenance).
- Chapters 3 and 4 discuss various funding opportunities and strategies. These are grouped into two categories: Traditional funding strategies (such as fees, taxes and assessments), Chapter 3; and potential strategies for meeting GI needs, Chapter 4.
- Chapter 5 provides a summary and a set of recommendations.
- Appendices include:
    - A summary matrix of the various funding mechanisms intended as a quick reference guide to member agencies to help them keep sight of the broad scope of funding possibilities;
    - An alternative compliance case study; and
    - The 2014 C/CAG report: Potential Funding Source Analysis and Recommendations.

It is worth noting that the summary matrix in Appendix A contains some additional information such as pros and cons and applicability to costs for staff, planning, capital and operations and maintenance ("O&M"). This matrix should be considered a key document containing unique information.

2 OVERVIEW OF FUNDING NEEDS

As member agencies have developed early elements of their GI Plans, it has become evident that downstream funding needs will be substantial and varied in its scope. GI, by its very nature, is a flexible and variable approach to reducing stormwater pollutants, and therefore will continue to evolve in the coming years in its efficacy, costs, and approaches. It is difficult to assign dollar amounts to some of the elements at this stage, but below we discuss some of the factors that need to be considered.

By way of structure, we have divided the task into three primary elements: Planning needs; capital improvement needs; and operations and maintenance needs. However, as funding is contemplated it is worth noting that not all of these elements can be funded by all funding sources. For example, bond funding is typically only applicable to capital improvement programs and cannot fund early planning or operations demands downstream. Appendix A contains a matrix of funding sources that cross references each source against the types of activities to which it does or does not apply. This factor should be considered as the GI plans are finalized.

2.1 PLANNING NEEDS

2.1.1 PLANNING EFFORTS TO DATE

There has been a substantial planning effort underway since the issuance of MRP 2.0 to assist member agencies to develop their GI Plans and educate staff and elected officials. This has included the formation of the Technical Advisory Committee to help guide the countywide effort to provide frameworks or work plans for member agencies; and conducting staff workshops and briefings for municipal officials. The planning effort has developed or updated several major documents, collectively referred to as the GreenSuite, to help guide future GI efforts including:

- Green Infrastructure Design Guide:
  - Topics include policy and overview, buildings and sites, sustainable streets, implementation, operations and maintenance among others.
  - Appendices include a glossary, references, typical GI details, specifications for GI materials, O&M checklists, and this GI Funding Nexus Evaluation.
- Regulated Projects Guide

2.1.2 FUTURE PLANNING EFFORTS

Looking forward, member agencies will need to continue to update and supplement these planning documents in order to keep pace with ongoing and future MRP requirements and the information needs of municipal staff to implement GI projects. In addition, each member agency will be required to track and document GI implementation over time. This includes tracking planned and implemented projects and modeling pollutant loads reduced for compliance purposes. Finally, there will be ongoing efforts to coordinate with C/CAG and BASMAA groups in coming years to coordinate regionally consistent approaches to GI planning and implementation.

Also included in the planning category are the ongoing Education and Outreach efforts to help educate the public, developers, agency staff, and elected officials on GI and LID planning, policy, design and implementation.

2.2 CAPITAL IMPROVEMENT NEEDS

MRP 2.0 Provision C.3.h.i.(2)(a) requires each member agency's GI Plan to include the identification of potential and planned GI projects, both public and private, on a drainage-area specific basis for implementation and assessment of potential load reductions by 2020, 2030, and 2040. On the public-sector side, the GI Plans call for the routine incorporation of GI into capital improvement projects to help meet the pollutant reduction requirements. On the private-sector side, development and redevelopment projects have been required to incorporate LID features into project proposals for more than a decade.

C/CAG has worked with its member agencies to define the methods for moving from the long-term planning and estimating of performance of future GI through to the tracking and modeling of actual construction and performance over time. For public sector projects, C/CAG established prioritization criteria and identified potential projects utilizing a methodology for bridging the long-range generalized planning with identification of suitable potential for potential GI projects on public lands using clear and documented assumptions that will allow member agencies to develop capital improvement projects that incorporate GI.

A summary of planned GI projects as well as other projects targeted for retrofitting to impervious surfaces is still being developed.

Funding for capital projects can be obtained from most types of sources including sustainable fees, taxes and assessments, one-time grants and loans, and through creative partnerships and in-lieu programs.

2.3 OPERATIONS AND MAINTENANCE NEEDS

As with all built features, GI will require O&M efforts to keep the improvements in a serviceable condition. However, GI has the added requirement that the "green" element remain as effective as designed. Although many GI improvements appear to be landscape features when viewed from the surface, they are in fact types of mini-treatment facilities, which have more specialized maintenance requirements than typical landscape features. Therefore, the O&M efforts and costs can be substantial and may require a different mix of skills and trained labor to undertake the maintenance. To better define the maintenance needs, C/CAG is developing an Operations and Maintenance Manual.

Funding for O&M is often the most restricted as it rarely can be sustained from grant funds or bond programs. Sustainable fees, taxes and assessments are the most common ways to fund O&M, but those mechanisms often require a ballot measure and therefore are difficult to secure at meaningful levels.

3 TRADITIONAL TYPES OF STORMWATER PROGRAM FUNDING

In 2014 C/CAG engaged SCI to study and make recommendations on strategies to fund water pollution prevention programs required in the previous MRP. One of the deliverables from that effort was the Potential Funding Sources Analysis and Recommendations Report, which described, analyzed and evaluated various funding mechanism alternatives available for stormwater programs. That 2014 Report forms a solid basis from which to evaluate funding options for GI as well. This section will provide a brief overview of the 2014 Report, which is included herein as Appendix C. This discussion will also provide some important updates to the 2014 Report – particularly regarding Senate Bill 231.

There are several ways to categorize funding. This report looks at whether funding is ongoing funding, one-time funding, or debt financing (one-time funds that are repaid in an ongoing manner). This report also distinguishes between balloted and non-balloted, as any funding source that requires a ballot measure will obviously bring with it more challenges. The matrix below helps to visualize these two axes and illustrates a few examples of each.

	Sustainable / Ongoing	**One-Time**	**Long-Term Debt**
Balloted	Taxes, Fees & Assessments		GO Bonds *
Non-Balloted	Regulatory Fees Re-Alignment Developer Fees	Grants	COPs ** Revolving Fund

** General Obligation Bonds; ** Certificates of Participation*

3.1 LOCAL FUNDING STRATEGIES THAT REQUIRE A BALLOTED PROCESS

There are two basic types of balloted measures appropriate for stormwater funding, namely, special taxes and property-related fees. Successfully implemented balloted approaches have the greatest capacity to significantly and reliably fund stormwater management, but they are often very challenging. Generally, the most important key to a successful ballot measure is to propose a project or program that is seen by the voting community to have a value commensurate with the tax or fee. The two greatest challenges are to craft a measure that meets this threshold, and then to effectively communicate the information to the community.

Since balloted funding mechanisms tend to be the most flexible and sustainable, they are often seen as underpinning an agency's entire program. Not only can they pay directly for services or projects, but a dedicated and sustainable revenue stream can also be leveraged to help secure grants, loans, partnerships, and many other opportunities that present themselves. Without such a dedicated revenue stream, those opportunities must often be missed.

3.1.1 SPECIAL TAXES

Special taxes are decided by registered voters and require a two-thirds majority for approval. Traditionally, special taxes have been decided at polling places corresponding with primary and general elections. More recently, however, local governments have had success with single issue special taxes by conducting them entirely by mail and not during primary or general elections. Special taxes are well known to Californians and are utilized for all manner of services, projects, and programs. They are usually legally very stout and flexible and can support an issuance of debt such as loans or bonds in most cases.

There are several types of special taxes, but the most common for stormwater services are parcel taxes. Parcel taxes are levied against real property and can be calibrated for some parcel metric such as acreage, size of building, impermeable area, type of use, or simply a flat rate where each parcel pays the same amount. One thing that distinguishes taxes from fees is that taxes do not necessarily need to have a direct nexus between the amount of the tax and the service received. As such, tax mechanisms can exempt certain types of property (e.g., public property) or owners (e.g., seniors or low income). While exemptions may reduce revenues somewhat, they are usually very popular with voters. Examples of parcel taxes that have been successfully implemented for stormwater services are in the cities of Culver City, Los Angeles, Santa Cruz, and Santa Monica. The most recent successful parcel tax measure was in Los Angeles County where the Flood Control agency passed a tax that will raise as much as $300 million per year for projects that would capture, treat and recycle rainwater.

Other types of special taxes include sales, business license, vehicle license, utility users, and transient occupancy taxes. These types can also be implemented as a general (not special) tax, where they would only require a simple 50% majority for passage. But to qualify as a general tax, it must be pledged only for an agency's general fund with no strings attached, in which case any GI or stormwater services must compete with other general funded services such as police, fire and parks. Although a general tax requires only a simple majority, voters tend to show better support for special taxes where the purpose of the tax is explicitly identified.

3.1.2 PROPERTY-RELATED FEES

A Proposition 218-compliant, property owner balloted, property-related fee is a very viable revenue mechanism to fund stormwater programs. Property-related fees are decided by a mailed vote of the property owners with a simple majority (50%) threshold required for approval, with each parcel getting one vote. The property-related fee process is generally not as well known, and it is more time consuming and is more expensive than the special tax process, but it is much more common for funding stormwater management, and in many communities, more suitable to meet the voter approval threshold. One of the more successful municipalities to implement a property-related fee for stormwater services is Palo Alto, where they have succeeded twice.

As they pertain to GI, property-related fees remain a flexible and stout funding source. However, under Proposition 218 property-related fees must apply to defined services within a defined service area, and the costs of providing those services must be spread equitably over the properties that receive the services. The scope of GI is stretching the traditional boundaries of stormwater services, and great care must be taken when crafting a property-related stormwater fee structure. But just as water agencies have embraced conservation efforts and watershed habitat protections, so, too, can stormwater agencies carefully expand into the area of GI.

3.1.3 GENERAL OBLIGATION BONDS

The voting public is very familiar with general obligation (GO) bond measures, which typically come in the form of a general obligation bond and require a two-thirds majority for passage. Bonds are issued to raise funding up front and are repaid through a tax levied against property on the annual property tax bill. These levies are based on property value, so higher value properties pay a higher portion of these taxes. Because the rate of taxation is based on value, ballot measures cannot state an annual amount that would be paid by an individual. This is usually an advantage, as the voter is presented with a bond amount (e.g., $25 million bond measure) for a project or program, and votes based on that without knowing exactly what it will cost them or for how long.

One primary restriction on GO bonds is that they can only be used for capital projects. While that includes land acquisition, planning, design and construction, the costs for maintenance and operations cannot be paid from the bond proceeds.

Selling bonds for GI has become more viable this year with a clarification from the Government Accounting Standards Board (Statement #62, or "GASB 62") that distributed infrastructure can be considered an asset upon which an agency can capitalize and therefore more easily be included in a bonded debt program. Distributed infrastructure is a term for smaller improvements that are often distributed around an area – sometimes on private property – like green roofs, rain barrels, bioswales, and pervious pavements. GASB goes so far as to include the cost of rebate programs for distributed infrastructure as well.

Examples of stormwater-related GO bonds successfully implemented include Berkeley's Measure M ($30 million – partly for GI, 2012) and Los Angeles' Measure O ($500 million, 2004).

3.1.4 CHALLENGES WITH BALLOTED APPROACHES

Ballot measures are inherently political and are often outside of the areas of experience and expertise of most stormwater managers. For any measure to have a fair chance, the community must be well informed, and their preferences and expectations must be woven into the measure. This requires significant outreach and research, which is something best handled by specialized consultants, and can take considerable time and resources.

Over the past 15 years, there have been fewer than two dozen community-wide measures attempted for stormwater throughout California, and the success rate is just over 50%. Very few attempts have been made to pass a stormwater ballot measure even though there may be over 500 agencies with stormwater needs, because success is not assured. Clearly this is a high bar to clear, and any agency considering a balloted approach must carefully weigh the pros and cons before proceeding.

Funding strategies are discussed in greater detail in Appendix C, which also includes a list of balloted efforts throughout the State along with a discussion on why they succeeded or failed.

3.1.5 KEYS TO A SUCCESSFUL BALLOTED APPROACH

Know your needs and how to fix them: This often will come from a needs analysis or a strategic planning effort. The more popular fixes usually include capital projects that the community sees as fixing a problem they know about. For example, a new storm drain pump station that will alleviate chronic local flooding, or a spreading basin that will replenish the aquifer and create environmental habitat with some recreational opportunities.

Know your community's priorities: If the agency's needs are not seen as priorities by the community, a ballot measure will likely fail. This is usually measured by a public opinion survey, which would identify priorities as well as willingness to pay for the proposed program. Top priorities identified in the survey should be folded back into the proposed measure to demonstrate that the agency is responsive to the community.

Communicate with the voters: Community engagement must be tailored to fit the measure and the community it is designed to serve. It can range from a brief set of outreach materials (website and flyer) to a comprehensive branding and information effort that can take several months or longer, complete with town hall meetings and media coverage. Knowing your stakeholders and opinion leaders is a must, and special efforts with those groups are always recommended. Note that advocacy by a public agency is strictly forbidden by law, so legal counsel should be involved at some point to help distinguish between educational outreach and advocacy.

Know where you stand with the voters: For instance, do voters trust the agency? Do they believe that you will deliver on your promises? How have past ballot measures worked out? Know the answers to questions like these; and if you do not like the answers, figure out how to correct for that.

Plan for the needed resources: Many public agencies hire professional consultants for critical elements of this process from needs analysis to surveys and community engagement. While these consultants can be costly, it is usually well worth the expense if they can deliver a successful measure. Considerable agency staff time may also be required, since this is a very iterative process that must be presented to the public by agency representatives, not consultants.

3.2 SENATE BILL 231 – THE END OF BALLOTING FOR STORMWATER FEES?

As stated earlier, water and sewer fees are exempt from the voter approval requirements of Proposition 218. Senate Bill (SB) 231, signed by Governor Brown on October 6, 2017, provides a definition for sewer that includes storm drainage. This clarification would give stormwater management fees the same exemption from the balloting requirement that applies to sewer, water, and refuse collection fees, and would make stormwater property-related fees a non-balloted option – something very attractive to municipalities. Unfortunately, the Howard Jarvis Taxpayers Association, who authored and sponsored Proposition 218, is expected to file a lawsuit against any municipality that adopts a stormwater fee without a ballot proceeding. Therefore, the SB 231 approach must be given a very cautionary recommendation at this time. Any agency considering moving in that direction should consult with other agencies and industry groups to coordinate their efforts in a strategic manner and avoid setting an unfavorable legal precedent. C/CAG staff is keeping abreast of developments in this area and would be a good first point of contact.

3.3 LOCAL FUNDING STRATEGIES THAT DO NOT REQUIRE A BALLOTED PROCESS

Non-balloted approaches are those which can be implemented without voter approval. They can be as simple as charging a plan check fee, or as complex as realigning functional units or financial budget structures within an agency. The table below illustrates some examples of non-balloted approaches.

Type of Approach	Examples	Comments
Regulatory Fees	Plan Check Fees Inspection Fees	Proposition 26 (2010) has significantly limited the applicability.
Realignment of Services	Water Supply Sewer Refuse Collection	Leverage and integrate stormwater elements that qualify under water, sewer and/or refuse collection categories.
Business License Fees	Business License Fee	Applies to commercial operations with clear impacts on stormwater such as restaurants, vehicle repairs.
AB 1600 Fees	Developer Impact Fees	Similar to impact fees aimed at improving water and sewer systems, or parks and schools.
Integration into Projects with Existing Funding	Transportation or Utility Projects	Takes advantage of multi-benefit projects that also further stormwater goals.

While not subject to local voters' or property owners' "willingness to pay" limitations, these non-balloted approaches may encounter a certain amount of public resistance, particularly from specific groups that will be impacted by these approaches (e.g., businesses will resist additional business license fees). In addition, each one of these approaches requires that a nexus be drawn between the fee and the impact on the payer of the fee in order to not be considered a tax. Therefore, a nexus study or cost of service analysis needs to be developed in each case.

As they pertain to GI funding, developer fees and partnerships with transportation or utility projects may have the most applicability, particularly when integrated into other emerging strategies such as discussed in Section 4 of this report. Realignment of services is discussed in more detail in the following section. All these funding sources are discussed in more detail in Appendix C.

3.3.1 DEVELOPMENT IMPACT FEES

Development impact fees pose an interesting option for cities that anticipate growth of any scale. "A development impact fee is a monetary exaction other than a tax or special assessment that is charged by a local governmental agency to an applicant in connection with approval of a development project for the purpose of defraying all or a portion of the cost of public facilities related to the development project. (Gov. Code § 66000(b).) The legal requirements for enactment of a development impact fee program are set forth in Government Code §§ 66000-66025 (the "Mitigation

Fee Act"), the bulk of which were adopted as 1987's AB 1600 and thus are commonly referred to as "AB 1600 requirements." A development impact fee is not a tax or special assessment; by its definition, a fee is voluntary and must be reasonably related to the cost of the service provided by the local agency. If a development impact fee does not relate to the impact created by development or exceeds the reasonable cost of providing the public service, then the fee may be declared a special tax and must then be subject to a two-thirds voter approval. Developer impact fees are exactions of either money or built improvements from a developer to mitigate the impacts to the public infrastructure of that development."[3]

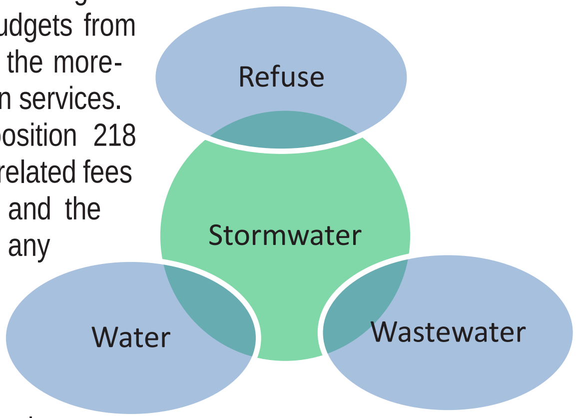
Developer fees are typically done in one of two ways: 1) through predetermined fees tied to a nexus study and charged to applicable development projects; or 2) on an ad hoc basis drafted for a particular development. While the former requires a rigorous nexus study and is often based on the expectation of significant future development, it will apply to all future development and provides a known cost for developers as they plan projects. The latter method is often attractive for municipalities that have no adopted developer fees and allows for flexibility in determining impacts and creative methods for mitigating them. However, the ad hoc method carries with it a higher burden for the agency to demonstrate the reasonable nexus and a rough proportionality to the impact created by the development project. It also deprives developers from knowing in advance the cost to their projects.

One of the impacts of new development that can be tied to a fee is that of stormwater quality. Most new development is already subject to C.3 requirements, which mitigate many of the direct stormwater pollution impacts for a particular site. Therefore, it may be difficult to demonstrate additional impacts that can be mitigated through planned GI. One way would be to tie local or regional GI needs to the community at large and include each project's fair share of the associated costs in a development fee structure for GI. Another way may be to develop an overall stormwater impact fee nexus (including GI) that can be applied to new development.

[3] *A Short Overview of Development Impact Fees*, City Attorneys Department, California League of Cities, 2003. http://www.ca-ilg.org/sites/main/files/file-attachments/resources__overviewimpactfees.pdf

3.3.2 DELIVERY OF STORMWATER SERVICES: RE-ALIGNMENT OF MUNICIPAL SERVICES

One approach for delivering stormwater services that has significant appeal is realignment. Realignment is the term used here to describe the reorganization of management, staffing, service units and/or budgets from "traditional" stormwater management services to the more-easily funded water, sewer and/or refuse collection services. This applies to the distinctions drawn in Proposition 218 between stormwater and the other three property-related fees where stormwater requires a ballot proceeding and the other three enterprises do not. Therefore, any stormwater activity that falls within the scope of the other three services can be funded by fees without a ballot proceeding.



For example, trash capture activities and infrastructure can be considered refuse collection and can be funded by garbage fees. Another example could be certain kinds of low impact development where stormwater is infiltrated into the ground where it contributes to the replenishment of the drinking water aquifer.

This may not be as easy as it seems. First, any fee structure must rely on an analysis of how costs for service are spread across property types. Second, reorganizing budgets or service units within a municipal structure can be challenging, and in many areas those non-stormwater services are delivered by special districts instead of the municipality making reorganization impossible. Finally, just because the water, wastewater or refuse collection services do not need to pursue a ballot measure to increase rates, the public's willingness to pay is still at issue and a public hearing is still required. Many rate payers pay close attention to any rate increase, and elected officials are under constant pressure to keep increases to a minimum.

3.4 GRANTS AND LOANS

3.4.1 GRANTS[4]

Federal, state, and regional grant programs have funding available to local governments to support GI efforts. These grant programs include:

- California Proposition 1 (Water Quantity, Supply, and Infrastructure Improvement Act of 2014) Stormwater Implementation Grant Program;
- US Environmental Protection Agency: San Francisco Bay Water Quality Improvement Fund;

[4] This section is taken from a Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program

- California Water Resources Control Board: 319(h) Non-Point Source Implementation Program;[5]
- California Department of Water Resources: Integrated Regional Water Management Program Implementation Grants;
- California State Parks: Land & Water Conservation Fund and Rails-to-Trails Programs;
- California Department of Forestry and Fire Protection: Urban and Community Program;
- Strategic Growth Council: Urban Greening Program;
- California Office of Emergency Services (OES) 404 Hazard Mitigation Grant Program;
- Caltrans Cooperative Implementation Agreements or Grants Program; and
- One Bay Area Grant Program (transportation projects).

Other potential grant resources that may be tapped in the future to support GI include Greenhouse Gas Reduction Funds derived from the California Cap and Trade Program.

As a result of Senate Bill 985, now incorporated into the California Water Code, stormwater capture and use projects must be part of a prioritized list of projects in a Stormwater Resource Plan in order to compete for state grant funds from any voter-approved bond measures. Advantages of using grant funding may include the following:

- Grants can fund programs or systems that would otherwise take up significant general fund revenues;
- Grants often fund new and innovative ideas that a local agency might otherwise be reluctant to take on using general funds;
- Grants can be leveraged with other sources of funding increasing the viability, benefits, and/or size of a project; and
- Successful implementation of a grant-funded project can establish a record that can lead to other grants.

Challenges with using grants as a funding approach typically include:

- Grants are opportunistic in that local governments have no control over when grant monies will become available. However, in some cases opportunities to apply for grants and the anticipated level and timeline of the funding are scheduled well in advance;
- Grants are often available only once for the same purpose, which can lead to agencies creating ever "new" programs to qualify for funds. Other "strings" can be attached to the grant creating implementation or maintenance complexities;
- Grants are competitive. Considerable resources may be required to apply for a grant with no guarantee of success;

[5] Projects or activities required by or that implement a National Pollutant Discharge Elimination System permit, including urban, area-wide stormwater programs covering discharges from a MS4, are not eligible for funding under Section 319(h) grants.

- Some level of matching funds is usually required. Some types of funds cannot be matched with other types. For example, some federal funds are pass-through via the state, but they are still considered federal and may therefore not be eligible as a match with other federal funds; and
- Most grants have a requirement for the agency to provide adequate post-project maintenance for the improvement. This can impose significant costs on the agency that are not funded by the grant.

While grant funding can help propel a GI program forward, it typically requires another source of funding to cover grant obligations such as matching funds or post-project maintenance. This understanding helps to underscore the importance of an underlying, dedicated and sustainable revenue source such as a stormwater fee or tax.

3.4.2 LOANS

Long-term debt financing can be a valuable tool to use for funding important projects and programs. It is not a source of new funding in and of itself, but rather allows an agency to leverage an ongoing revenue stream by borrowing money for immediate needs such as capital construction, which is then repaid over time. While GO bonds (discussed above) are a type of debt instrument that requires voter approval, other forms of long-term debt do not require voter approval such as certificates of participation (COPs) or loans from a state revolving fund (SRF). COPs are a type of municipal bond that usually has relatively low interest rates but is only secured by the agency's ability to repay and can have substantial administrative costs.

The California Clean Water State Revolving Fund (CWSRF) is one type of SRF that may be a good option for agencies. These loans are secured by a reliable source of revenue such as dedicated fees or taxes, and typically have below-market interest rates and very low administrative costs. In the past these loans have been for wastewater treatment plants but are now opening up to green stormwater projects. The CWSRF also has a principal forgiveness program for projects related to water or energy efficiency and stormwater runoff sustainability or mitigation projects. The program can forgive up to 50% of eligible capital costs and 75% of eligible planning costs, up to a cap of $4 million.

Debt financing for GI has become more viable this year with a clarification from the Government Accounting Standards Board (Statement #62, or "GASB 62") that distributed infrastructure can be considered an asset upon which an agency can capitalize and therefore can more easily be included in a bonded debt program. Distributed infrastructure is a term for smaller improvements that are often distributed around an area – sometimes on private property – like green roofs, rain barrels, bioswales, and pervious pavements. GASB goes so far to include the cost of rebate programs for distributed infrastructure as well.

It is important to note that while long-term debt provides immediate funding for projects, it is not a new source of funds. It simply converts a dedicated, sustainable revenue stream (e.g., fees or taxes) into near-term funding. Without the dedicated, sustainable revenue stream, long-term debt is not usually an option.

3.5 ASSESSMENTS & SPECIAL FINANCING DISTRICTS

Special financing districts are not the same as special districts, which are a form of governance with their own elected board and scope of services. Special financing districts are simply financial structures created by local governments for the purpose of levying taxes, fees, or assessments for specific improvements and/or services provided. These include benefit assessments, community facilities districts, business improvement districts, and infrastructure financing districts.

Most special financing districts require a balloting of affected property owners, but these are typically either a very small area (like a business district) or are applied to single land owners such as a developer in the process of a new development.

3.5.1 BENEFIT ASSESSMENTS

Benefit assessment districts can levy charges that correlate to special benefits conferred on property by virtue of improvements or services. These can range from landscaping, lighting, recreation facilities, parks, fire protection, mosquito abatement, and even cemeteries. Most benefit assessment districts are governed by a statute, which can vary depending on the type of service or improvement. All benefit assessments must comply with Proposition 218, which limits assessments to the special benefits conferred, but cannot be levied based on any general benefit (such as to properties outside the district boundary or to the general public at large). The portion of the benefits that are general must be funded from sources other than the benefit assessments – such as a city's general fund. This general benefit factor can become prohibitive in some cases.

As they pertain to GI, property owners in a watershed could be assessed to fund stormwater runoff management programs that provide direct benefit to properties within that watershed or sub-basin. The watershed unit may be particularly effective and equitable as programs can be tailored to address specific priorities identified within that watershed and would include the diverse socio-economic demographics from the hills to the flatlands typical to a Bay Area urban watershed.

Benefit assessments are not taxes or fees and must be approved by a weighted majority[6] of the affected property owners that cast votes. Benefit assessments typically are collected as part of the annual property tax bill.

3.5.2 COMMUNITY FACILITIES DISTRICTS (MELLO-ROOS)

Community Facilities Districts, more commonly known as "CFDs" or "Mello-Roos Districts", are a form of special tax, and must be approved by property owners or registered voters.[7] Similar to benefit assessments, these are often formed during the development process for a finite set of parcels owned by a single entity, and thus there would only be a single ballot. Oftentimes, formation of a CFD will be included in the conditions of approval for a development, so the balloting is more of a formality.

---

6 In a ballot proceeding for a benefit assessment, ballots are weighted by the amount of the assessment to be levied. As a result, property owners faced with large assessments wield more weight in the balloting.

7 A CFD tax is balloted to property owners if there are fewer than 12 registered voters in the district. Otherwise the balloting is by registered voters.

As a tax, the structure of the charges and the use of the funding is much more flexible than for a benefit assessment. For instance, publicly-owned property can be exempted as well as other classes of properties (such as commercial properties in a school-based CFD). In addition, general benefit does not need to be considered or funded from other sources. Finally, CFD taxes are easily structured to allow for future expansion to other properties that are developed in the future. They need not be contiguous to the original (or seed) development.

As they pertain to GI, the flexibility inherent in a CFD tax would allow flexibility in the types of improvements or services that are funded. However, as a tool primarily used for new development, the proceeds may be restricted to improvements and services for those new developments only.

3.5.3 BUSINESS IMPROVEMENT DISTRICTS

A Business Improvement District (BID) is a mechanism in which businesses and property owners tax themselves and manage the funds to build or maintain certain assets. The BID can be set up and administered by the community members. For example, the Dogpatch and Northwest Potrero Hill Green Benefit District (http://dnwph-gbd.org) is a Green Business Improvement District in San Francisco developed to fund and maintain the public-realm landscaping in the area. The landscape staff used to maintain this landscaping can be trained in GI maintenance practices and qualified in sustainable landscaping services.

3.5.4 ENHANCED INFRASTRUCTURE FINANCING DISTRICTS

In 2014, the California Legislature approved the Enhanced Infrastructure Financing District (EIFD) structure. EIFDs have emerged as a potential replacement for Redevelopment Agencies which were eliminated in 2012. Cities and counties may create EIFDs to capture *ad valorem* tax increments, similar to the now-defunct Redevelopment Agencies, to invest within the specific District boundaries or out-of-area projects that have a tangible benefit to the District. EIFDs are not limited to blighted areas and can directly, or through bond financing, fund local infrastructure including highways, transit, water systems, sewer projects, flood control, libraries, parks, and solid waste facilities. However, similar to grant funding and certain bond financing, EIFD funding cannot be used for ongoing operations and maintenance of facilities.

The tax increment is defined as the increase in ad valorem property taxes due to increases in assessed value associated with improvements. However, the one percent ad valorem tax is split amongst many local agencies with school districts typically receiving approximately 50% of that revenue – a share that is not eligible for EIFD participation. Other tax-sharing agencies can participate in an EIFD, but that participation is strictly voluntary. As a result, the revenue potential of an EIFD is estimated to be about 20% of a comparable redevelopment agency.

The formation of an EIFD requires consent from all the participating local agencies through a Joint Powers Authority but does not require voter approval unless bonds are to be issued. Other requirements include the preparation of an Infrastructure Financing Plan and formation of a Public Finance Authority. If an EIFD is proposed for an area that had been a redevelopment agency, the successor agency must have a Finding of Completion for all redevelopment obligations prior to receiving any new tax increment. An EIFD can run for up to 45 years, which provides flexibility in the issuance of bonded debt.

This financing structure may be a good fit for localized areas where stormwater infrastructure and water quality are major concerns – particularly environmental clean-up on private properties. An EIFD can be created with multiple municipalities, so it can span political boundaries making it a good fit for a watershed approach to GI funding. However, no EIFDs are known to include multiple jurisdictions at this time.

EIFDs also present a few challenges. Very few EIFDs have been formed in the State, and GI has not been highlighted in any of the plans to date (see table below showing the types of improvements of existing EIFDs). The EIFD concept is aimed at funding improvements that spur development in a district, which in turn increases the assessed property value (and thus the property tax revenues). The improvements are therefore seen as an economic engine that generates its own revenue (increased property taxes, or tax increment). Whether GI can be viewed as a viable "economic engine" has not yet been demonstrated, but the case could possibly be made.

Another drawback for EIFDs is the pace of revenues. Because the "economic engine" must come before the properties increase in value, funding is typically provided through bonds (or debt of some sort). This requires a revenue stream of substance and reliable pace in order to qualify for reasonable bond rates. For this reason, EIFDs are typically structured around major, transformative community infrastructure projects such as transportation (e.g., rail station, new freeway access) or primary infrastructure such as streets, sidewalks, parks, water, sewer and other utilities. While GI may fit well within a suite of infrastructure projects, it may be a weak "economic engine" on its own. Furthermore, any agency contemplating the formation of an EIFD (a cumbersome and expensive task) is likely to favor the more high-powered engines. In addition, EIFDs typically rely on other revenue sources such as grants, bonds, assessments, taxes and private sources in order to help cover revenue gaps with the tax increment revenues.

One possible example of a GI-based EIFD could be an industrial area that requires mitigation for PCBs, mercury or other pollutants where the mitigation measure may lie outside the area (e.g., a regional GI project). Since EIFD proceeds may be spent outside the district when there is a tangible benefit to the district, the EIFD may fund part or all of the GI project. Furthermore, if there are fewer than 12 registered voters in the EIFD, the approval for bonds would be a landowner (not registered voter) election – oftentimes more politically viable. Finally, the EIFD may also impose other taxes (subject to voter approval) that could serve as seed-money funding until the tax increment revenues are mature enough to support bonds.

SUMMARY OF PROS AND CONS

Pros	Cons
No voter approval required (unless bonds are to be issued)	Voter approval is required if bonds are to be issued (55% majority)
No blight finding is required	Revenue potential is about 20% of a comparable RDA
Proceeds can be used for a wide variety of improvements	Proceeds cannot be used for operations, maintenance and repairs
May be used with other funding sources such as grants, bonds, assessments, taxes or private sources	Revenues start slow and build only after properties are developed - bonds may have to be delayed until revenues can support them
Proceeds can be spent outside district if a tangible benefit is provided to district	CEQA review may be required
Multiple agencies can join together	Getting approval from other agencies can be difficult
As a legal government entity, an EIFD may impose other taxes and assessments (subject to voter approval)	Improvements must have a 15-year life
No low- or moderate-income housing requirement	
Areas need not be contiguous	

EXAMPLES OF EIFDS

Only a handful of cities have formed an EIFD. Three recent EIFDs are highlighted in the table below to illustrate the process, financial structure, revenue potential and other features of an EIFD.

City	West Sacramento	La Verne	Otay Mesa (San Diego)
Other Agencies	none	none	none
Sub Areas	14	3	none
Size (acres)	4,144	144	~ 9,500
Duration	45 years	45 years	45 years
Housing Relocations?	none	none	none
Improvements	54% - Transportation 23% - Econ Dev 10% - Parks & Rec 10% - Parks & Rec 10% - Parks & Rec 5% - Parking 4% - City Buildings 4% - Water, Sewer, Drainage	57% - Water 21% - Ped Access 9% - Streets & Traffic 7% - Sewer 6% - Other Utility	75% - Transportation 17% - Park 3% - Water & Sewer 2% - Police 2% - Fire 2% - Library
Drainage Improvements	$5m (0.3%)	not specified	not specified
Cost of Improvements	$1.1b (2017)	$33m (2017)	$1.2b (2014)
Other Funding?	yes	yes	
Cumul Tax Increment	$1.23b (2017)	~ $50m (2017)	~ $500m (2014)

For a summary of EIFDs and the processes involved with formation, please visit the League of California Cities website:
https://www.cacities.org/Policy-Advocacy/Hot-Issues/New-Tax-Increment-Tools

4 POTENTIAL STRATEGIES FOR MEETING GREEN INFRASTRUCTURE NEEDS

As discussed above, traditional stormwater funding options were already out of step with a contemporary view of stormwater management imperatives before GI became a priority. Once again, the “need” outstrips the “ability to fund” as GI expands the horizon of possibilities in managing our built environment and the role stormwater and other water elements play in that endeavor. In this section, several emerging strategies are discussed that have been adapted to GI and other stormwater approaches both inside and outside of California. The have been grouped into two categories:

4.1 ALTERNATIVE COMPLIANCE

The MRP 2.0 contains a vast array of elements for which compliance is required, both for private development and for public agencies. For many individual cases, compliance may be impractical or impossible, and the Regional Water Board has shown a willingness to consider alternate compliance in one form or another. Provision C.3.e.i. of the MRP 2.0 allows the following alternative compliance options:

- Construction of a joint stormwater treatment facility;[8]
- Construction of a stormwater treatment system off-site (on public or other private property); and
- Payment of an in-lieu fee[9] for a regional project (on another public or private property).

Each option comes with obligations for municipal staff in addition to other pros and cons for the municipality and developer. Currently, qualified urban infill redevelopment projects in the Bay Area

[8] The MRP 2.0 defines Joint Stormwater Treatment Facility as a facility built to treat the combined runoff from two or more Regulated Projects.

[9] The MRP 2.0 defines In-lieu Fees as a monetary amount necessary to provide both hydraulically-sized treatment (in accordance with Provision C.3.d.) with LID treatment measures of an equivalent quantity of stormwater runoff and pollutant loading, and a proportional share of the operation and maintenance costs of the Regional Project.

that have site constraints that limit use of LID treatment measures often take advantage of the Special Project option in MRP 2.0 Provision C.3.e.ii. However, the Special Project option may not be included in future MRPs, and municipalities may want to start taking advantage of the alternative compliance option to fund and/or construct municipal GI projects. Some municipalities may have to update the stormwater section of their municipal codes to allow for one or more of these alternative compliance options.[10]

There have been numerous examples of off-site construction of LID facilities in the Bay Area. One such example is in the City of Emeryville in 2017. A summary of this project was presented as a case study in the Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program. This is reproduced in Appendix B.

4.1.1 IN-LIEU FEE CHALLENGES

In-lieu fees are attractive in the GI arena as they could be a source of funding for regional projects that help an agency meet their GI Plan goals. There are two basic ways to collect in-lieu fees for alternative compliance: Ad hoc approach; and structured approach.

The ad hoc approach is done on a case-by-case basis and is usually negotiated with an individual developer depending on the financial and logistical circumstances. This presents challenges and opportunities, but the agency's leverage is limited to its discretionary authority and compliance with local regulations and the MRP 2.0. One advantage is that the outcome can be customized to the project. For instance, compliance could be severed into any (or all) of three options: on-site construction; off-site construction; and in-lieu fee contribution. An ad hoc approach allows for out-of-the-box thinking. This is often the course followed for agencies that have few and sporadic development projects. But for agencies with a steady stream of development, it can be laborious to the point of overwhelming.

A structured approach would typically follow the developer fee model (AB 1600). This would end up with a set of in-lieu fees adopted and published in the agency's master fee schedule. However, the path to that end must include a comprehensive nexus study complete with goals, objectives, project lists, and a reasoned methodology linking development impacts or compliance needs to projects – possibly by geographic or watershed zones – and options for variations and other administrative chores. For agencies that are larger and experience numerous development projects (particularly small to midsized projects), the effort to adopt in-lieu fees would be worthwhile. It allows staff to simply apply the scheduled fees to each project as it comes around. At the same time, for larger projects that enter into a developer agreement, those adopted fees could be set aside for a more creative or appropriate ad hoc approach.

One key element to an in-lieu fee program is the identification of in-lieu projects. Since GI is still an emerging art or science, there are few templates available to identify GI projects and their life-cycle

[10] Taken from the Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program.

costs. However, the GI Plans being developed in conjunction with this report will go a long way toward meeting this challenge.

4.1.2 CREDIT TRADING PROGRAM

Another type of alternative compliance program is a credit trading program. Credits are created by one property owner whose project has the capacity to overbuild the on-site LID, which is then traded to other property owners who may not be able to meet their MRP 2.0 requirements. The program is typically managed by a government agency and can create incentives to treat stormwater in excess of the NDPES permit requirements on regulated sites, while also creating incentives to install systems that treat stormwater on non-regulated sites. One example of a credit trading program is the one developed by Washington D.C.'s Department of Energy and the Environment.[11] The MRP 2.0 does not specifically mention credit trading programs, but such a program could be developed in consultation with the Regional Water Board as a form of alternative compliance.[12]

As this applies to GI, the public agency could become more than just the broker of credits and become a creator or consumer of credits to be applied toward its GI goals. These credits would be a form of currency, analogous to the in-lieu fees described in the previous section.

4.2 PARTNERSHIPS AND OTHER STRATEGIES

By teaming up with other entities, an agency may not generate additional funding directly, but partnerships offer many other benefits that can aid in the overall resources needed to deliver projects such as GI improvements. These can come in the form of economy-of-scale savings or multi-benefit projects that can achieve multiple goals for a single price. Several such strategies, as well as some other beneficial strategies, are discussed below.

4.2.1 MULTI-AGENCY PARTNERSHIPS

Some resources and project opportunities do not match agency boundaries, and multi-agency partnerships can take advantage of those situations. For example, regional projects are a natural fit for multi-agency partnerships. Every agency tends to have strengths and weaknesses: Some are excellent at grant writing and obtaining grants but lack in project delivery capacity or local environmental conditions that fit certain grants (such as GI opportunities), while other agencies may have complementary strengths. By sharing resources and funding, regional projects can be delivered more efficiently – "more bang for the buck." Economy-of-scale savings can help cut costs – in some cases substantially – and GI projects and programs are no exception.

Challenges and opportunities abound in such partnerships. For example, developing mechanisms for sharing the planning, capital, operations and maintenance and administrative chores can be challenging. On the other hand, these types of projects can be an opportunity to be either a generator of trading credits or a way to invest trading credits (as described in an earlier section). In addition, such partnerships can be a source of multi-benefit projects – projects that can achieve GI goals as well as other important public and private goals.

---

[11] https://doee.dc.gov/src

[12] Taken from the Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program.

4.2.2 TRANSPORTATION OPPORTUNITIES

For more than ten years, local development projects have been required to incorporate some sort of LID and hydrograph modification features. More recently, transportation projects have come under NPDES requirements to include similar elements. The complete streets and green streets movements have brought more attention to incorporating environmental mitigation elements, such as LID, into traditional transportation projects – even where NPDES permits do not require it. The resulting multi-benefit projects have begun to demonstrate how transportation funding can be leveraged to satisfy stormwater – and GI – goals economically.

In San Mateo County, where the governing body for transportation funding (C/CAG) is the same as for NPDES compliance, there have been many examples of transportation funds being leveraged to include stormwater quality elements. Even for federally funded projects, Caltrans is becoming more flexible in these applications. One example is the Active Transportation funding.

4.2.3 CALTRANS MITIGATION COLLABORATION

Caltrans operates under its own statewide NPDES permit in parallel with municipal permitees. In many cases, Caltrans and local agencies operate along the same drainage system with one discharging into the other's facilities. Thus, NPDES requirements are sometimes a shared obligation. In some cases, Caltrans has funding available to mitigate various pollutant loading that can be shared with local agencies through Cooperative Implementation Agreements to pursue local or regional GI projects. In this way, Caltrans can often meet its pollutant load mitigation requirements outside their limited rights of way while benefiting local watershed objectives using Caltrans funding in partnership with the local agencies.

4.2.4 PUBLIC-PRIVATE PARTNERSHIPS (P3)[13]

Public-Private Partnerships (P3s) have the potential to help many communities optimize their limited resources through agreements with private parties to help build and maintain their public infrastructure. P3s have successfully designed, built, and maintained many types of public infrastructure such as roads and drinking water/wastewater utilities across the U.S. Until a few years ago, there were no efforts to develop P3s specifically for stormwater management or Clean Water Act requirements.

The EPA Region 3 Water Protection Division (WPD), in the mid-Atlantic region, has been researching, benchmarking, and evaluating P3s for their potential adaptation and use in the Chesapeake Bay watershed. On December 6, 2012, the EPA Region 3 WPD hosted a P3 Experts Roundtable in Philadelphia, PA. The goal of the P3 Roundtable was to provide a forum for a targeted group of private sector representatives to discuss in detail the feasibility, practicality, and benefits of using P3s to assist jurisdictions in the finance, design, construction, and O&M of an urban stormwater retrofit program. The results of this Roundtable were published in "A Guide for Local Governments," the foundation and approach for applying a stormwater P3 model across the Chesapeake Bay

[13] This section is taken from the Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program.

watershed. This guide provides communities with an opportunity to review the capacity and potential to develop a P3 program to help "close the gap" between current resources and the funding that will be required to meet stormwater regulatory commitments and community stormwater management needs. In addition, this guide and the tools presented (fees/rebates, credit/offset trades, and grants/subsidies) are a continuing effort, commitment, and partnership between EPA Region 3 and communities in the Chesapeake Bay region. EPA believes it will help to raise the bar and further advance the restoration goals and objectives for the Chesapeake Bay (EPA 2015).

In California, P3-enabling legislation was enacted by the state in 2007, and since then several agencies have used P3s for public infrastructure projects, such as Caltrans with the Presidio Parkway (Doyle Drive) approach to the Golden Gate Bridge in San Francisco, and the State of California judicial system with a courthouse in Long Beach.[14] However, to date, there are no known P3s that have been developed in the state for the explicit purpose of implementing GI. Prince George's County in the Chesapeake Bay watershed is the most often cited example of a GI program using a P3; however, they are able to use their stormwater fee for their program.

In California there is a scarcity of agencies that have stormwater fees that can be leveraged in a P3 program – this is related to the historically difficult Proposition 218 process of establishing dedicated stormwater funding. California stands alone in that regard – all the other states make it easier to establish such funding streams. However, under SB 231, this may be changing in the near future as a select group of municipalities begin to navigate the new options allowed under that legislation.

The non-profit organization, WCX (the West Coast Infrastructure Exchange), has promoted Prince George's P3 model in California and the west coast and released a report on water resiliency projects in 2016.[15] WCX is involved at the state and regional levels to increase awareness of P3s and other infrastructure tools.

Advantages of using P3s include:

- Leveraging public funds while minimizing impacts to a municipality's debt capacity;
- Accessing advanced technologies;
- Improved asset management;
- Drawing on private sector expertise and financing;
- Benefits to the local economic development and "green jobs;" and
- Relieving pressure on internal local government resources.

[14] For other examples of P3s in California go to: https://en.wikibooks.org/wiki/Public-Private_Partnership_Policy_Casebook
[15] http://westcoastx.com/assets/documents/Resilience%20Report/WCX%20Resilience%20Report.pdf

4.2.5 FINANCIAL CAPABILITY ASSESSMENT[16]

In 2014, the EPA implemented a process by which communities that meet certain financial capability criteria can apply for some relief in the schedules for compliance with some of their NPDES stormwater permit elements. This process is called the "Financial Capability Assessment Framework for Municipal Clean Water Act Requirements." The framework is designed to help communities develop a more accurate and complete picture of their ability to pay for Clean Water Act obligations, emphasizing factors beyond the 2% threshold for median income.

The new framework builds on EPA's 1997 "Combined Sewer Overflows—Guidance for Financial Capability Assessment and Schedule Development," but emphasizes the role of supplemental information. The framework mentions a host of factors that can be used to assess a community's financial condition, including poverty rates, income distributions, bond ratings, debt levels, historic water and sewer rates, and more. Additionally, the framework encourages communities to examine all Clean Water Act obligations, from combined sewer overflow consent decree actions, to stormwater permit programs, to wastewater treatment plant upgrades. In this way, the framework also builds on EPA's 2012 Integrated Planning Framework.

It should be noted that this assessment does not help to generate additional funding, nor does it allow an agency to avoid compliance with permit requirements. It can allow an agency to work with the EPA and the Regional Board to work out an alternative compliance schedule depending on the community's financial capabilities.

4.2.6 VOLUNTEERS

Volunteerism is alive and well in the Bay Area. In some cases, local agencies cultivate volunteer programs to assist in achieving various goals; in other cases, volunteer groups work under the direction of non-profit organizations. Habitat stewardship and protection is one area that garners much attention from volunteers, and their work often overlaps with municipal stormwater management services. This type of activity can have some application for GI in the form of planting and caring for landscaped improvements such as rain gardens and bioswales.

While the work performed by a volunteer workforce can help a local agency meet its GI goals, it can also be difficult to recruit, oversee, and manage volunteers. Reliability and quality of work can be challenging at times, too.

Benefits of a volunteer program can include public education and building community support for the agency's stormwater management program (and possibly a future fee implementation). One example of a volunteer program that supports GI is the Green Street Steward Program in Portland, Oregon.

[16] This section is taken from the Green Infrastructure Funding Options technical memorandum dated February 13, 2018 from the Santa Clara Valley Urban Runoff Pollution Prevention Program.

5 SUMMARY, RECOMMENDATIONS AND NEXT STEPS

5.1 SUMMARY

This paper has illustrated the reasons stormwater, as a primary municipal service, is largely less valued and more difficult to fund than similar services including water, sewer, and refuse collection. While stormwater began to emerge as a fully regulated public works enterprise a few years before Proposition 218 was enacted in 1996, that new status was not widely embraced by public agencies or acknowledged by taxpayer advocates. Further, Proposition 218 was not sufficiently explicit on the key question of whether stormwater qualifies for the water, sewer, and refuse collection exemption from the voter approval requirement. This issue was settled in 2002 when the appellate court ruled[17] that any new or increased stormwater fee would be required to obtain voter approval. However, SB 231 (2017) attempts to push back on the Salinas decision, and may prove to be the vehicle for putting funding for stormwater services on par with the other water-related services.

GI funding is both a subset of and an expansion of stormwater funding. By aiming at a significant increase in permeating rain water into the ground, GI enters into the disciplines of aquifer geology, soils engineering, road pavement, transportation, landscaping, habitat management, and other onsite and offsite planning, design and construction considerations. The need to finance activities such as strategic, policy and financial planning, capital construction, and operations and maintenance across these disciplines further complicates the challenge.

No single funding strategy will typically suffice. Most agencies will need to develop several funding sources – a portfolio approach. For instance, a sustainable, dedicated fee or tax will form a solid base from which to work but is rarely sufficient in the amount of revenue that can be realized. However, that type of revenue stream can be leveraged to win grants, take on long-term debt, and pursue opportunities for partnering or participating in credit-trading programs.

5.2 RECOMMENDATIONS

Several funding mechanisms have been explored in this report. However, this is just a starting point for funding the scope of GI projects envisioned by the GI plans. As those GI plans are further drafted and adopted, the funding aspect must be explored further. It is recommended that the member agencies select a limited number of funding options or strategies for further study and identify some specific priority funding options at the outset of GI Plan adoption. For instance, the member agencies may choose to look further into enhanced infrastructure financing districts as a way to fund certain types of GI. Parcel taxes or property-related fees may be worth developing as they would form a backbone of revenue that can open many other possibilities such as grants, partnerships, and long-term debt. And developing a credit trading program can help bring public and private participants to the same table to help achieve the ambitious GI goals of the current and future MRPs.

[17] Howard Jarvis Taxpayers Association versus the City of Salinas, Sixth Appellate District, 2002.

As member agencies proceed to develop their individual GI Plans, they are encouraged to draw from the information contained in this report to select potential funding sources to investigate further. Considerations should include the following elements:

- Collaborating with neighboring agencies to explore cross-boundary opportunities such as EIFDs, watershed-based solutions and regional projects; and
- Reviewing case studies from around the country with discussion of how those examples could be tailored to meet GI goals;
- Collaborating with similar efforts in other Bay Area counties, BASMAA, and CASQA;[18]
- Cultivating support from agency leadership (Council and City Manager); and
- Understanding the costs associated with certain options.

C/CAG may also consider conducting workshops that help educate member agency staff on the nuances of funding opportunities and challenges.

It is also worth noting that, while member agencies are working on their individual GI Plans, the County and C/CAG are currently developing a proposal for a new agency to plan, build and maintain projects of regional significance which could complement, or possibly supplement, local GI needs as well as address sea level rise and flooding challenges. Funding could be provided through a countywide property tax or similar mechanism.

5.3 ADDITIONAL RESOURCES

This report is intended to introduce member agencies to many funding strategies, but there is much more to be learned in the form of case studies, work done in other regions or states, or new, emerging strategies not included here. Several other outlets of information are provided below, and the reader is urged to explore these further.

5.3.1 EPA WATER FINANCE CLEARINGHOUSE

The Environmental Protection Agency has long recognized that funding challenges can be a significant barrier to successful GI implementation. In an effort to help public agencies around the country, they have developed a website as a clearing house for information on funding for drinking water, wastewater and stormwater infrastructure. It can be found at the following url: https://ofmpub.epa.gov/apex/wfc/f?p=165:1::::::

The Water Finance Clearinghouse includes two searchable databases: one contains available funding sources for water infrastructure and the second contains resources, such as reports, weblinks, webinars, etc., on financing mechanisms and approaches that can help communities access capital to meet their water infrastructure needs.

[18] This acronym stands for the California Stormwater Quality Association.

The Water Finance Clearinghouse was developed by EPA's Water Infrastructure Finance and Resiliency Center, an information and assistance center identifying water infrastructure financing approaches that help communities reach their public health and environmental goals.

5.3.2 S.T.O.R.M.S.

The State Water Board has launched a program entitled, "Strategy to Optimize Resource Management of Storm Water" (STORMS, or Storm Water Strategy). One key element of this program is "Project 4b, Eliminate Barriers to Funding Storm Water Programs," which will utilize focused stakeholder workshops to identify barriers to stormwater projects and strategies for local agencies to meet those challenges.

Watch for these workshops in the near future. The website can be found here: https://www.waterboards.ca.gov/water_issues/programs/stormwater/storms/

5.3.3 CASQA WHITE PAPERS

The California Stormwater Quality Association (CASQA) developed the following white papers in 2017:

- Stormwater Funding Barriers and Opportunities (CASQA 2017); and
- Use of Triple Bottom Line Analyses to Support Stormwater Objectives (CASQA 2017).

These and other resources will be posted on the CASQA Stormwater Funding Resources web page: https://www.casqa.org/resources/funding-resources

5.3.4 RESILIENT BY DESIGN FINANCING GUIDE

The Resilient by Design ("RbD") Bay Area Challenge was "a year-long collaborative design challenge bringing together local residents, public officials and local, national and international experts to develop innovative community-based solutions that will strengthen our region's resilience to sea level rise, severe storms, flooding and earthquakes." Part of that effort included a finance advisory team that issued a Financing Guide to provide guidance to design teams. The updated guide (Financing Guide 2.0) produced at the conclusion of the process provides an excellent overview of finance options and strategies for achieving funded projects. That guide can be found at the following url: https://static1.squarespace.com/static/579d1c16b3db2bfbd646bb4a/t/5b5f4da288251b0f228a990e/1532972477684/RBD+Financing+Guide+%28NHA+Advisors%29+Final+Version+2a.pdf

5.4 CONCLUSION

The way forward is not entirely mapped out for GI and other stormwater funding challenges. However, the tools already being used can be put to good use by a multitude of local agencies as they traverse and overcome barriers to stormwater program implementation. Developing multi-benefit projects and multi-agency partnerships will further help open funding doors as well.

Stormwater professionals, including municipal staff, elected representatives, consultants, academics, and others must redouble their efforts to effectively convey to decision-makers and the general public the importance of water quality and the funding of water quality. No longer can stormwater professionals be satisfied with a lower status, but instead, must be creative, progressive, political, forward-thinking and demanding.

6 APPENDICES

The following pages contain three appendices:

A. Funding Matrix – A summary of the funding strategies contained in this report;

B. Alternative Compliance Case Study from Emeryville, CA; and

C. Potential Funding Source Analysis and Recommendations – Draft, C/CAG, 2014.

6.1 APPENDIX A – FUNDING MATRIX

Summary Matrix Contents

Traditional Mechanisms

3.1.1 Parcel Taxes
3.1.1 Other Special Taxes
3.1.2 Property-Related Fees
3.1.3 General Obligation Bonds
3.2 Senate Bill 231
3.3 Regulatory Fees
3.3 Developer Impact Fees
3.3.1 Re-Alignment
3.4.1 Grants
3.4.2 Loans

Special Financing Districts

3.5.1 Benefit Assessments
3.5.2 Community Facilities Districts
3.5.3 Business Improvement Districts
3.5.4 Enhanced Infrastructure Financing Districts (EIFD)

Alternative Compliance

4.1 Alternative Compliance
4.1.1 In-Lieu Fee Challenges
4.1.2 Credit Trading Programs

Partnerships

4.2.1 Multi-Agency
4.2.2 Transportation
4.2.3 Caltrans Mitigation
4.2.4 Public-Private ("P3")
4.2.5 Financial Capability Assessment
4.2.6 Volunteers

(This Page Intentionally Left Blank)

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
Traditional Mechanisms								
3.1.1 Parcel Taxes	Can fund all or any parts of a GI program as stipulated in the ballot question and authorizing ordinance	Usually a 2/3 majority of voters (general taxes require only 50% majority, but can only go to General Fund)	* Flexible and legally stout; * Debt can be issued in most cases; * Most voters are familiar with Parcel Taxes	* Requires voter approval at the 2/3 level; * Must compete with other ballot measures	X	X	X	X
3.1.1 Other Special Taxes	* Business License Tax; * Vehicle License Fees; * Sales Tax; * Utility Users Tax; * Transient Occupancy Tax	Typically require a 2/3 voter approval	* Most are flexible in how they can be used; * 50% threshold can be used if a general tax	* 2/3 voter approval is diffucult to attain; * Ballot measure can be expensive; * If a general tax, then GI must compete with other General Fund needs; * Must compete with other ballot questions	X	X	X	X
3.1.2 Property-Related Fees	Establishes Storm Drainage as a separate utility service and can fund all or any parts of a GI program	Prop 218 compliance; * Rigorous rate study; * Must define services and service area; * Property owners approval for non-Water, -Sewer, and -Garbage	* Flexible and legally stout; * Debt can be issued in most cases	* Ballot measure required if for a Storm Drain service - usually voted on by property owners (Not registered voters); * Ballot measure requires significant public outreach; * Public not familiar with balloted property-related fees	X	X	X	X
3.1.3 General Obligation Bonds	Can fund Capital GI Projects through debt taken on by municipality	* Voter approval at 2/3 level; * Will need Financial Advising Consultant	* Can fund capital projects or programs with debt paid back over time through property taxes; * Typically easier to pass than a parcel tax; * Taxes based on property value, so annual obligation of individual prop owner is vague	Can only be used for capital costs - Cannot be used for O&M or staff costs		X	X	
3.2 Senate Bill 231	Allows for adoption of property-related fees without having to go to ballot	* Cost of Service Analysis * Rate Study * Prop 218 Protest Hearing	Avoids the cost and risk of a ballot measure	* Taxpayers groups vow to sue on grounds of consititution / court provisions; * Governing boards will still have political pressure to not raise rates	X	X	X	X
3.3 Regulatory Fees	Fees and charges for performing administrative activities related to GI	Cannot exceed the actual cost of performing activities such as permit issuance, inspections, on-site mitigation, etc.	* No voter approval is needed; * Usually included in Master Fee Schedule; * Most municipalities already have these in place	Does not pay for capital improvements or O&M	X			

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
3.3 Developer Impact Fees	Could incorporate fees for mitigating stormwater impacts to help fund GI - Would not relieve developer of NPDES requirements	Must comply with AB 1600 and include a rigorous nexus study	Could partially fund GI	* Requires a nexus study, often times by a consultant; * Nexus study must demonstrate connection between development and GI need; * Administration of funds requires resources; * AB 1600 requires 5-year window for programming funds;		X	X	
3.3.1 Re-Alignment	GI that promotes groundwater recharge, diversion to wastewater treatment, or trash capture can be incoporated into existing property-related fee structures without need for ballot measure	Prop 218 compliance for realignment to Water, Sewer or Garbage - must demonstrate applicability	* Existing non-balloted fee mechanisms can help pay for GI services; * Enhances integration of GI into other muncipal activities; * Causes other utilities to recognize the value of GI programs	* Limited to activities attributable to other funded revenue centers; * Prop 218 hawks could challenge; * Outside revenue center will need to raise rates to fund GI activity - politically unpopular; * Has not been widely used; * May be unpopular with Water, Sewer and Garbage managers; * Water or sewer may be handled by separate agencies, making realignment impossible	X	X	X	X
3.4.1 Grants	One-time infusion of funds for qualifying projects from State or other granting authority	* Project concept must conform to grant requirements; * Most grants are competetive with limit funding available	* Grants are outside sources of funding that do not need to be repaid; * Readiness is a plus, so can benefit a project or program that is well developed and possibly designed; * Some State Revolving Fund loans can be converted to grants through forgiveness clauses	* Projects must be tailored to grant requirements, possibly causing scope and schedule creep; * Most grants require matching funds from other sources; * Most grants require commitment to post-project O&M, but do not fund those activities; * Little control over timing - can be difficult to coordinate with other funding sources; * Competitive nature lowers chances of obtaining grant; * Applying for grants can be time-consuming and require outside help from a grant writer; * Grant administration requires significant resources	X	X	X	???

Funding Category		GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
3.5.4	Enhanced Infrastructure Financing Districts (EIFD)	Captures property tax increment similar to redevelopment (RDA) for building and maintaining infrastructure like GI	With No Debt: * Establish a Public Finance Authority; * Adopt a Financing Plan; * Resolution(s) from participating agencies With Debt: * All of the above; * Get approval from at least 55% of voters in District	* Can fund many types of projects; * Does not require a vote (unless debt is part of the plan, then a 55% majority is required); * Can include multiple municipalities and special districts, so area can be tailored to needs (e.g., watersheds, high legacy pollutant areas, countywide); * Does not require a blight finding; * Can overlap with former RDA areas; * Works well with master planned community with a single land owner; * Planning costs can be paid for from proceeds (with limitations); * EIFD can go for up to 45 years	* Education districts are not permitted to participate, so revenues would be much less than RDA; * If overlapping a former RDA area, then cannot proceed until RDA is issued a finding of completion from the State; * GI is only a small piece of what an EIFD can do - it may take a back seat to other, larger community concerns; * Some agencies (i.e., special districts) may not agree to their portion of tax increment to be diverted thereby reducing revenue potential	???	X	X	
Alternative Compliance									
4.1	Alternative Compliance	Allows developers who cannot meeting GI requirements on-site to build (or pay for) off-site construction of GI elements	Municipality would need to have alternative projects ready - could bedone case-by-case	* Enables higher density development in certain areas (such as TOD and PDA); * Enables GI in public spaces that private developers would not normally participate in; * Funds can be pooled to finance larger or regional projects that can be more effective; * Post-project O&M can be added in the form of a cash payment or other consideration; * Municipality can be flexible in enforcement to allow hybrid compliance;	* Ad hoc negotiation with developers can be challenging * Agency will need to have off-site or regional projects ready to bring to negotiation	X	X	X	X

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
3.4.2 Loans	Debt instruments can help accelerate project deliver while paying off debt over time	* Must have dedicated revenue stream to pay off debt; * Must have adequate credit rating to secure reasonable interest rates; * Some Bonds require voter approval	* Can leverage a modest revenue stream by borrowing money up front for rapid project delivery while paying off debt over longer periods of time; * Accelerates project delivery and makes coorination with other funding or projects easier	* Must have dedicated revenue stream to service debt; * Some debt mechanisms require voter approval (GO Bonds, Revenue Bonds, EIFD Bonds)	???	X	X	
Special Financing Districts								
3.5.1 Benefit Assessments	Can fund the construction and maintenance of GI projects	Prop 218 compliance; * Rigorous Engineer's Report; * Must deduct general benefit from special benefit; * Property owners approval is required through a ballot proceeding (weighted voting); * Works best with new development due to voting requirement	* Flexible and legally stout; * Can fund both construction and maintenance; * Can use bonded indebtedness	* General Benefit must be separated and paid for by other sources; * Votes are weighted by assessment amount, favoring large land owners		X	X	X
3.5.2 Community Facilities Districts	Can fund the construction and maintenance of GI projects	Requires vote by majority of landowners or 2/3 majority of registered voters	* Usually formed by developer, so only one ballot is cast; * Very flexible - can fund all aspects; * Subsequent annexation is simple; * Tax rate can be tiered to allow for retirement of debt yet continue with O&M; * Annual administration is more streamline than benefit assessments	* Difficult to form in an existing community due to 2/3 majority requirement; * Known as a Mello-Roos tax - which can have a negative connotation		X	X	X
3.5.3 Business Improvement Districts	Business and property owners tax themselves to build and maintain GI improvements	Formed by a municipality through a notice and protest hearing process.	* Flexible and legally stout; * Can fund both construction and maintenance; * Local improvements can generate local support and involvement * GI improvements can also be amenities; * Can enhance sense of ownership and pride in the neighborhood when results are visible	* Cannot use debt financing; * Opposing businesses can disrupt the progress; * Can burden businesses & property owners so they are unwilling to support other funding measures		X	X	X

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
4.1.1 In-Lieu Fee Challenges	Allows developers who cannot meet GI requirements to pay into fund that would finance off-site or regional projects	Municipality would need to estimate the costs of of mitigation - could bedone case-by-case	* Enables higher density development in certain areas (such as TOD and PDA); * Enables GI in public spaces that private developers would not normally participate in; * Funds can be pooled to finance larger or regional projects that can be more effective; * Municipality can be flexible in enforcement to allow hybrid compliance; * Municipality may consider informal fee process, negotiating each individual developer through COA; * Funds can be leveraged for grants or loans	* Case-by-case approach can be difficult; * Developers will try to evade costs; * May need to comply with AB 1600	X	X	X	X
4.1.2 Credit Trading Programs	Creates GI Credit program for developers and others to trade GI responsibilities to others who have better capability to meet GI goals	A municipality (or regional entity) must create credit trading program including: * Definition of GI Credits; * Relative Value of Credits; * Timing of responsibilities; * Eligibility	* Allows developers who cannot meet NPDES or GI requirements to buy credits created by other entities; * Encourages developers or other entities who have greater GI capacity to over-build GI in order to sell credits in future; * Present value of future O&M costs can be incorporated into credit value; * Allows for flexibility to guide GI to areas with greater pollutant loading need; * May save developers money	* Very few Programs (to use as an example) have been implemented - particularly in California; * Credits may need to stay within same watershed; * Overbuilding GI in some areas may not help other areas; * Overbuilding GI can lead to overlapping GI zones; * Unclear if developers are willing to overbuild on speculation of future sale of credits; * Unclear how value of credits would be established; * Unclear if municipality would be credit broker, or if developers can deal directly with each other; * May be difficult to apply credits to public rights of way; * Costing future O&M is difficult		X	X	X

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
Partnerships								
4.2.1 Multi-Agency	Encourages partnerships with non-Stormwater agencies to explore GI co-benefits in their work	Examples may include: * Spreading basins for groundwater agencies; * GI project sites on school grounds; * GI on housing authority sites	* Can generate credits for Credit Trading Program; * Expands GI potential and awareness; * Flexible; * Can leverage limited GI funding to greater benefit	* Not cookie-cutter; requires customization; * May be diffucult to find partners	X	X	X	???
4.2.2 Transportation	Encourages partnerships with transportation agencies to explore GI co-benefits in their work and take advantage of Complete Streets or Green Streets programs	Examples may include: * Permeable pavements; * Roadside rain gardens; * Cisterns	* Most municipalities are also transportation agencies, so internal project coordination more likely; * Can generate credits for Credit Trading Program; * Expands GI potential and awareness; * Can leverage limited GI funding to greater benefit; * Recent increase in Gas Tax may make more room for GI elements	* Not cookie-cutter; requires customization; * May be diffucult to find partners; * Road condition woes prevail, making it difficult to shift funding to GI and other amenity-type elements; * Transportation grants may preclude using funds for GI	X	X	X	???
4.2.3 Caltrans Mitigation	Caltrans looks for opportunities for off-site mitigation of stormwater impacts of their highways	Local municipalities may enter in a cooperative agreement with Caltrans to build GI as a way for them to mitigate stormwater impacts of their highways	* Caltrans may furnish funding for local or regional projects that help them meet their obligations; * Locals can propose solutions that benefit both Caltrans and the local agencies	* Caltrans cooperative agreements can be cumbersome and bureaucratic; * Projects that work for Caltrans may be difficult to develop		X	X	???
4.2.4 Public-Private ("P3")	Private enterprises can provide overall solutions to GI programs through better access to resources and capital	P3 is primarily a delivery system for projects where debt provides near-term funding and project acceleration	* Bypasses some of the bureaucracy; * Can make existing funding sources work more efficiently; * Draws on private sector expertise and financing; * Debt may be tax-exempt; * Debt accelerates project delivery; * Can include design, build, finance, operate; * Debt is private - may not affect public ageny's debt capacity	* Does not provide additional funding; * Dedicated revenue stream is needed - cash flow is an important element		X	X	X

Funding Category	GI Nexus	Requirements	Pros	Cons	Staff	Planning	Capital	O&M
4.2.5 Financial Capability Assessment	Can allow an agency to delay compliance with certain NPDES permit requirements	Follow EPA guidelines for application	Allows a qualifying agency to defer compliance with certain Permit compliance requirements	* Not a source of funding - only can grant time extenstions to Permit compliance; * Communities must meet several criteria such as poverty rates, income distibutions, bond ratings, etc.				
4.2.6 Volunteers	Volunteer groups can be a resource for GI operations and maintenance (O&M) as well as program planning	* To be effictive, volunteers need organization and oversight; * Can be used to supplement paid contractors, or perform entire projects	* "Free" labor; * Some volunteers provide needed expertise; * Increases awareness of GI program; * Some non-profit organizations have ready-made volunteer groups that are trained and organized; * Can build public support for dedicated revenue mechanism such as a fee; * Education program for community	* Requires significant staff resources to recruit, organize, train and plan & supervise the work; * Can be unreliable - hard to build schedule and cost forecasts around volunteer work force; * Can create conflict with prevailing wage requirements; * Difficult to incorporate into project construction work		X	???	X

(This Page Intentionally Left Blank)

6.2 APPENDIX B – ALTERNATIVE COMPLIANCE CASE STUDY IN EMERYVILLE, CA

In July 2017, the City Council of the City of Emeryville approved the use of an alternative compliance option for a portion of a private property owner's 14.5-acre mixed use redevelopment project building 674 multi-family residential units, 180,000 square feet of retail, and 120,000 square feet of office space. The majority of the project will use on-site LID to treat stormwater runoff. However, because one four-acre parcel of the site contained several existing buildings and pavement that were to be retained and required treatment, the property owner chose to propose to the City the use of an alternative compliance option in the MRP 2.0. There are several challenges to constructing LID stormwater treatment measures on this parcel including contaminated soil, a high seasonal groundwater table, conflicts with existing and planned utilities, clayey soils, tidal flows, and limited space.

The City used an "Off-site Stormwater Improvement Agreement" to detail the requirements of the property owner, who will construct approximately 6,300 square feet of GI measures (bioretention facilities) in the City's public right-of-way and in a City park to treat runoff from an amount of impervious surface greater than what would have been treated on-site. The key purposes of the agreement are to:

- Describe the conditions that led to the approval of off-site stormwater treatment;
- Set forth a process and timeframe for approval of plans and construction; and
- Describe maintenance responsibility and a calculation of cost for maintenance.

The off-site locations for GI were chosen through a consensus-based process and provide benefits to both the City and the property owner, including the following:

- Net water quality benefit compared with on-site provision of treatment measures through increases in pollutant of concern type and load reductions and increases of square footage of catchment and treatment area using the C.3.d sizing criteria;
- Increased cyclist and pedestrian safety through the use of stormwater curb extensions as traffic calming measures at intersections and in mid-block areas;
- Replacement of trees in poor health with new trees and improved planting conditions;
- Replacement of turf and other conventional landscapes with new sustainable, Bay-Friendly landscaping with a lower maintenance cost;
- Reductions in pollutant (e.g., PCBs, mercury and trash) discharges to the Bay by treating runoff from a larger variety of land uses and roadways as opposed to just roof tops on-site;
- Lower net cost for the property owner; and

- Progress towards meeting MRP 2.0 GI implementation long-term goals.

The developer has agreed to bear the costs of design, construction and post-project operations and maintenance. The developer will contract with design and construction firms and pay for the City-required plan check fees, insurance and permits necessary to build the improvements. The system designs will be approved by the City and inspected via the normal process for any work in the public right-of-way or on public property.

Operation and maintenance costs for the planned improvements were calculated based on the present value of a growing annuity. The present value of maintenance for a period of thirty years has been agreed upon by the City and the developer at $154,000 (or approximately $0.80 per square foot of treatment area per year in today's dollars), to be provided to the City by the developer as described in the Improvement Agreement in a lump sum after the improvements have been accepted by the City. The City will then assume responsibility for the maintenance of the treatment areas.
The O&M agreement for the on-site LID measures of the development project will reference the Improvement Agreement and the approval by the City of the alternative compliance option.

6.3 APPENDIX C – POTENTIAL FUNDING SOURCE ANALYSIS AND RECOMMENDATIONS

In 2014 C/CAG engaged SCI to study and make recommendations on strategies to fund water pollution prevention programs required in the previous MRP. One of the deliverables from that effort was the Potential Funding Sources Analysis and Recommendations Report, which described, analyzed and evaluated various funding mechanism alternatives available for stormwater programs at that time. That 2014 Report forms a solid basis from which to evaluate funding options for GI as well.

This report is included on the following pages.

Click here to view the Potential Funding Source Analysis and Rcommendations Report

A.7 Appendix 7

Guidance for Sizing Green Infrastructure Facilities in Streets

(This Page Intentionally Left Blank)

Guidance for Sizing Green Infrastructure Facilities in Street Projects

with companion analysis:

Green Infrastructure Facility Sizing for Non-Regulated Street Projects

BASMAA
Bay Area Stormwater Management Agencies Association

Prepared by
Dan Cloak Environmental Consulting
EOA, Inc.

June 2019

Introduction and Regulatory Background

Provision C.3.j. in the reissued Municipal Regional Stormwater Permit[1] (MRP) requires each Permittee to "complete and implement a Green Infrastructure (GI) Plan for the inclusion of low impact development drainage design into storm drain infrastructure on public and private lands, including streets, roads, storm drains, parking lots, building roofs, and other storm drain infrastructure elements."

Provision C.3.j.i.(g) further mandates that these plans include:

> *Requirements that projects be designed to meet the treatment and hydromodification sizing requirements in Provisions C.3.c. and C.3.d. For street projects not subject to Provision C.3.b.ii. (i.e., non-Regulated Projects) Permittees may collectively propose a single approach with their Green Infrastructure Plans for how to proceed should project constraints preclude fully meeting the C.3.d. sizing requirements. The single approach can include different options to address specific issues or scenarios. That is, the approach shall identify the specific constraints that would preclude meeting the sizing requirements and the design approach(es) to take in that situation. The approach should also consider whether a broad effort to incorporate hydromodification controls into green infrastructure, even where not otherwise required, could significantly improve creek health and whether such implementation may be appropriate, plus all other information as appropriate (e.g., how to account for load reduction for the PCBs or mercury TMDLs).*

This document represents the "single approach" collectively proposed by the Permittees for how to proceed when constraints on GI projects affect facility sizing in street projects. For other types of projects, information on hydraulic sizing is provided in the technical guidance manuals for Provision C.3 developed by each countywide stormwater program.

Hydraulic Sizing Requirements

MRP Provision C.3.d contains criteria for sizing stormwater treatment facilities. Facilities may be sized on the basis of flow, volume, or a combination of flow and volume. With adoption of the 2009 MRP, a third option for sizing stormwater treatment facilities was added to Provision C.3.d. This option states that "treatment systems that use a combination of flow and volume capacity shall be sized to treat at least 80 percent of the total runoff over the life of the project, using local rainfall data."

This option can also be used to develop sizing factors for facilities with a standard cross-section (i.e., where the volume available to detain runoff is proportional to facility surface area). To calculate sizing factors, inflows, storage, infiltration to groundwater, underdrain discharge, and overflows are tracked for each time-step during a long-term simulation. The continuous simulation is repeated, with variations in the treatment surface area, to determine the minimum area required for the facility to capture and treat 80% of the inflow during the simulation.

[1] Order R2-2015-0049

Such an analysis was conducted for BASMAA by Dubin Environmental Consulting and is described in the attached Technical Report. The analysis shows that bioretention facilities with the current-standard cross-section can capture and treat the Provision C.3.d amount of runoff when sized to 1.5% - 3% of tributary equivalent impervious area, depending on location.

Hydromodification Management

A principal objective of LID is to mimic natural hydrology in the post-development condition. This is accomplished by retaining and infiltrating runoff flows during small to medium events. Flows from larger events are detained and slowed.

MRP Provision C.3.g. includes requirements and criteria for implementing hydromodification management (HM). These HM requirements apply to Regulated Projects that create or replace an acre or more of impervious area, increase the amount of impervious area over the pre-project condition, and flow to creeks that are at risk of erosion. As such, the HM requirements do not apply to street projects that retrofit drainage systems that receive runoff from existing roofs and paving.

However, Provision C.3.j.i.(g) states that the Permittees' approach to sizing GI facilities "…should also consider whether a broad effort to incorporate hydromodification controls into green infrastructure, even where not otherwise required, could significantly improve creek health and whether such implementation may be appropriate…"

Various criteria for HM design have been used in California and throughout the U.S. These criteria have been based on one or more of the following principles:

- Maintaining watershed processes
- Maintaining a site-specific water balance
- Maintaining the value of the curve number used in the NRCS method of computing peak runoff
- Controlling increases in peak flows from a specified storm size
- Controlling increases in the duration of flows at each intensity within a specified range (flow duration control)
- Controlling the likelihood of downstream erosion in streams (erosion potential, or Ep)

Generally, for any HM criterion used, facilities with more storage and a larger infiltrative area will be more effective in meeting the criterion than facilities with less storage and a smaller infiltrative area.

In the statewide municipal stormwater NPDES permit for small MS4s, Provision E.12.f. includes the following HM standard applicable to Bay Area small MS4s: "Post-project runoff shall not exceed estimated pre-project flow rate for the 2-year, 24-hour storm…"

Dubin (2014) conducted modeling to evaluate whether this standard would be met in the San Francisco Phase II counties (Marin, Sonoma, Napa, and Solano) by a bioretention facility meeting the minimum requirements in that permit's Provision

E.12.f. Dubin's analysis found that a facility sized to 4% of tributary equivalent impervious area, and having a 6-inch deep reservoir with 2 inches of freeboard, 18 inches of treatment soil, and a 12-inch-deep "dead storage" gravel layer below the underdrain, would meet this standard, even in the wettest portions of the Bay Area.

Additional Considerations for Bioretention Sizing

In summary, bioretention facilities for street projects sized to 1.5% - 3% of tributary equivalent impervious area (depending on their location in the Bay Area) can meet the criteria in Provision C.3.d., according to the modeling study documented in the attached Technical Memo.

There are many reasons to design and build facilities larger than the Provision C.3.d. minimum. Building larger facilities helps ensure the facilities perform to the minimum hydraulic capacity intended, despite minor flaws in design, construction, and maintenance, providing an engineering safety factor for the project. Further, larger-sized facilities may more effectively address objectives to maximize the removal of pollutants (particularly pollutants in dissolved form), to operate as full trash capture devices, and to manage hydromodification effects.

However, municipalities often face considerable challenges in retrofitting existing streetscapes with GI facilities. Constraints and design challenges typically encountered in the public right-of-way include:

- The presence of existing underground utilities (known and unknown during the design phase);
- The presence of existing above-ground fixtures such as street lights, fire hydrants, utility boxes, etc.;
- The presence of existing mature trees and root systems;
- The elevation of or lack of existing storm drains in the area to which to connect underdrains or overflow structures;
- Challenges of defining and controlling any catchment areas on adjacent private parcels that drain to the roadway surface;
- Low soil permeability and strength, and the need to protect the adjacent roadway structure;
- Competition with other assets & uses for limited right-of-way area; and
- Presence of archeologic/cultural deposits.

Use of the sizing factors in the attached Technical Memo will provide municipalities flexibility in design of bioretention facilities for street projects where constraints are present.

Recommendations for Sizing Approaches for Green Infrastructure Retrofit Facilities in Street Projects

1. Bioretention facilities in street projects should be sized as large as feasible and meet the C.3.d criteria where possible. Constraints in the public right-of-way may affect the size of these facilities and warrant the use of smaller sizing factors.

Bioretention facilities in street projects may use the sizing curves in the attached memorandum to meet the C.3.d criteria. Local municipal staff involved with other assets in the public right of way should be consulted to provide further guidance to design teams as early in the process as possible.

2. Bioretention facilities in street projects smaller than what would be required to meet the Provision C.3.d criteria may be appropriate in some circumstances. As an example, it might be appropriate to construct a bioretention facility where a small proportion of runoff is diverted from a larger runoff stream. Where feasible, such facilities can be designed as "off-line" facilities, where the bypassed runoff is not treated or is treated in a different facility further downstream. In these cases, the proportion of total runoff captured and treated should be estimated using the results of the attached memorandum. In cases where "in-line" bioretention systems cannot meet the C.3.d criteria, the facilities should incorporate erosion control as needed to protect the facility from high flows. See Figures 1 and 2 below for illustration of the in-line and off-line concepts.

3. Pollutant reduction achieved by GI facilities in street projects will be estimated in accordance with the Interim Accounting Methodology[i] or the applicable Reasonable Assurance Analysis[ii].

Figure 1: Off-line system in El Cerrito where low flow is diverted to the sidewalk planter and high flows continue down the gutter.

Figure 2: In-line system in Berkeley/Albany where low and high flows enter the system and overflows exit through a drain within the system.

---

[i] The Interim Accounting Methodology for TMDL Loads Reduced Report (BASMAA 2017) describes the methodology that is being used to demonstrate progress towards achieving the PCB and mercury load reductions required during the term of MRP 2.0. The methodology is based on the conversion of land use from a higher to a lower PCB or mercury loading rate during the redevelopment of a parcel. See: www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/Municipal/POC/Final%20Interim%20Accounting%20Methodology%20Report%20v.1.1%20(Revised%20March%202017).pdf

[ii] A Reasonable Assurance Analysis (RAA) is a methodology used to demonstrate that implementation of pollutant control measures (such as GI facilities) over a specified time period will meet required pollutant load reductions associated with a TMDL. The Bay Area Reasonable Assurance Analysis Guidance Document (BASMAA 2017) establishes a regional framework and provides guidance for conducting PCBs and mercury RAAs in the San Francisco Bay Area. See: http://basmaa.org/Announcements/bay-area-reasonable-assurance-analysis-guidance-document

(This Page Intentionally Left Blank)

Bay Area
Stormwater Management Agencies
Association

Green Infrastructure
Facility Sizing For Non-Regulated Street
Projects

Prepared by:
Dubin Environmental
December 13, 2017

1. Introduction

The San Francisco Bay Regional Water Quality Control Board's reissued Phase I Municipal Regional Stormwater Permit (Order No. R2-2015-0049, issued 11/19/2015 and referred to as "MRP 2.0") includes a requirement that Permittees complete and implement green infrastructure plans to promote the increased use of green infrastructure in urban areas. These plans will guide the integration of green stormwater facilities into streets, parking lots, parks, building rooftops and similar places where there is an opportunity to retrofit traditional gray infrastructure systems and increase the removal of pollutants and improve water quality.

Provision C.3.j states:

> *Over the long term, the (Green Infrastructure) Plan is intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green—that is, to a more-resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other green infrastructure practices to clean stormwater runoff.*

Provision C.3.j.i.(2)(g) requires that projects be designed to meet the treatment and hydromodification sizing requirements in Provisions C.3.c. and C.3.d. However, the provision further states that for street projects that are not Regulated Projects:

> *…Permittees may collectively propose a single approach with their Green Infrastructure Plans for how to proceed should project constraints preclude fully meeting the C.3.d sizing requirements. The single approach can include different options to address specific issues or scenarios. That is, the approach shall identify the specific constraints that would preclude meeting the sizing requirements and the design approach(es) to take in that situation.*

To address this provision and further define the C.3.d sizing requirements for green infrastructure projects, the Bay Area Stormwater Management Agencies Association (BASMAA) contracted with Dubin Environmental to conduct continuous simulation hydrologic modeling to evaluate relationships of facility size (e.g., area, depth, flow rate) to facility performance. The BASMAA Development Committee, and BASMAA member agencies, intend to use these relationships to develop and justify an approach, to be created by the Development Committee, for implementing green street projects when there are constraints on facility size.

This report describes the modeling analysis that was performed to better understand the relationship between bioretention configuration and annual runoff treatment across the different BASMAA stormwater agencies and their climate zones. Long-term continuous modeling was used to compute stormwater runoff, simulate bioretention hydraulics, and estimate the annual percentage of stormwater that is treated. The analysis was performed for 10 different rain gauges that together represent the full range of climate conditions across the BASMAA member agency area. The analysis also considered different bioretention configurations and treatment goals. BASMAA member agencies can use these results to help establish policies and design guidelines to include in their green infrastructure plans.

2. Project Approach

The performance of bioretention facilities was modeled using HSPF (Hydrologic Simulation Program Fortran), which is a physically based, hydrologic model that is maintained and distributed by the US EPA.

HSPF has been used since the 1970s to conduct hydrologic analyses and size stormwater and flood control facilities. For this project, an HSPF model was developed to simulate runoff from a fully paved, 1-acre reference site and route this flow through a bioretention facility. This section describes the rain gauge selection and the HSPF modeling approach. Section 3 describes the modeling results.

2.1 Rainfall and Evapotranspiration Data

There are more than two dozen rain gauges with long-term, hourly data located within the BASMAA area. A list of candidate gauges was prepared from the National Center for Environmental Information (NCEI; formerly the National Climate Data Center or NCDC) network and then evaluated for inclusion. The evaluation focused on gauge data that could downloaded directly from EPA's National Stormwater Calculator, because these datasets have been reviewed and missing records filled with data from available nearby stations (similar to the data included with the EPA BASINS software). The list of candidate gauges was narrowed to 19 locations with 35+ years of data that are geographically distributed through the BASMAA area. The rain gauges were organized into tables that show a) mean annual precipitation (MAP) and b) 6-month, 1-year, and 2-year accumulations for 1-year and 24-hour durations. The different storm depth statistics were used to identify any outliers among the rain gauge data that could indicate problems that would hinder the effort to create regressions among the model results. The rain gauge locations were also plotted in ArcGIS.

The recommended sites were presented to the BASMAA project work group who provided helpful input about their preferences and experiences with different rain gauges. Based on this input, six stations were selected for inclusion in the modeling analysis. After developing the HSPF input and output routines, the number of gauges was increased to 10 by including higher rainfall locations to allow development of regression relationships that span the rainfall characteristics at any likely project location. Table 1 lists the candidate rain gauges included in the modeling analysis. For all gauges, a common 37 year period was used to eliminate the influence of drought and wet periods that occurred when some gauges were operational but not others. Figure 1 shows the mean annual rainfall and Figure 2 shows their locations. The 1-year and 24-hour storm durations are included in Appendix A.

TABLE 1. SELECTED RAIN GAUGES FOR GREEN INFRASTRUCTURE MODELING

2	Name	County/Agency	Years of Record	Mean Annual Rain (in)
049001	Tracy Pumping Plant	Contra Costa	37	12.7
047821	San Jose	Santa Clara	37	15.2
045378	Martinez Water Plant	Contra Costa	37	19.6
047769	SF Airport	San Francisco	37	20.4
047772	SF Downtown	San Francisco	37	21.9
046336	Oakland Museum	Alameda	37	22.8
042934	Fairfield	Fairfield-Suisun	37	24.1
043714	Half Moon Bay	San Mateo	37	28.6
047807	San Gregorio	San Mateo	37	30.0
044500	Kentfield	Marin	37	48.1

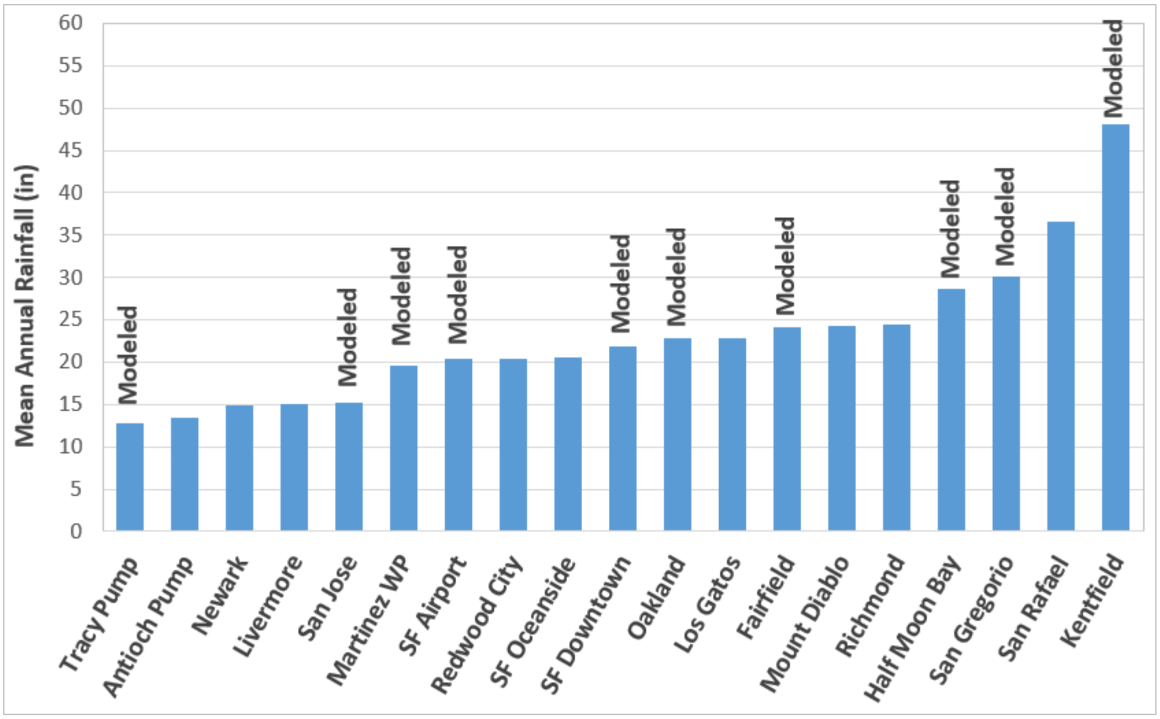
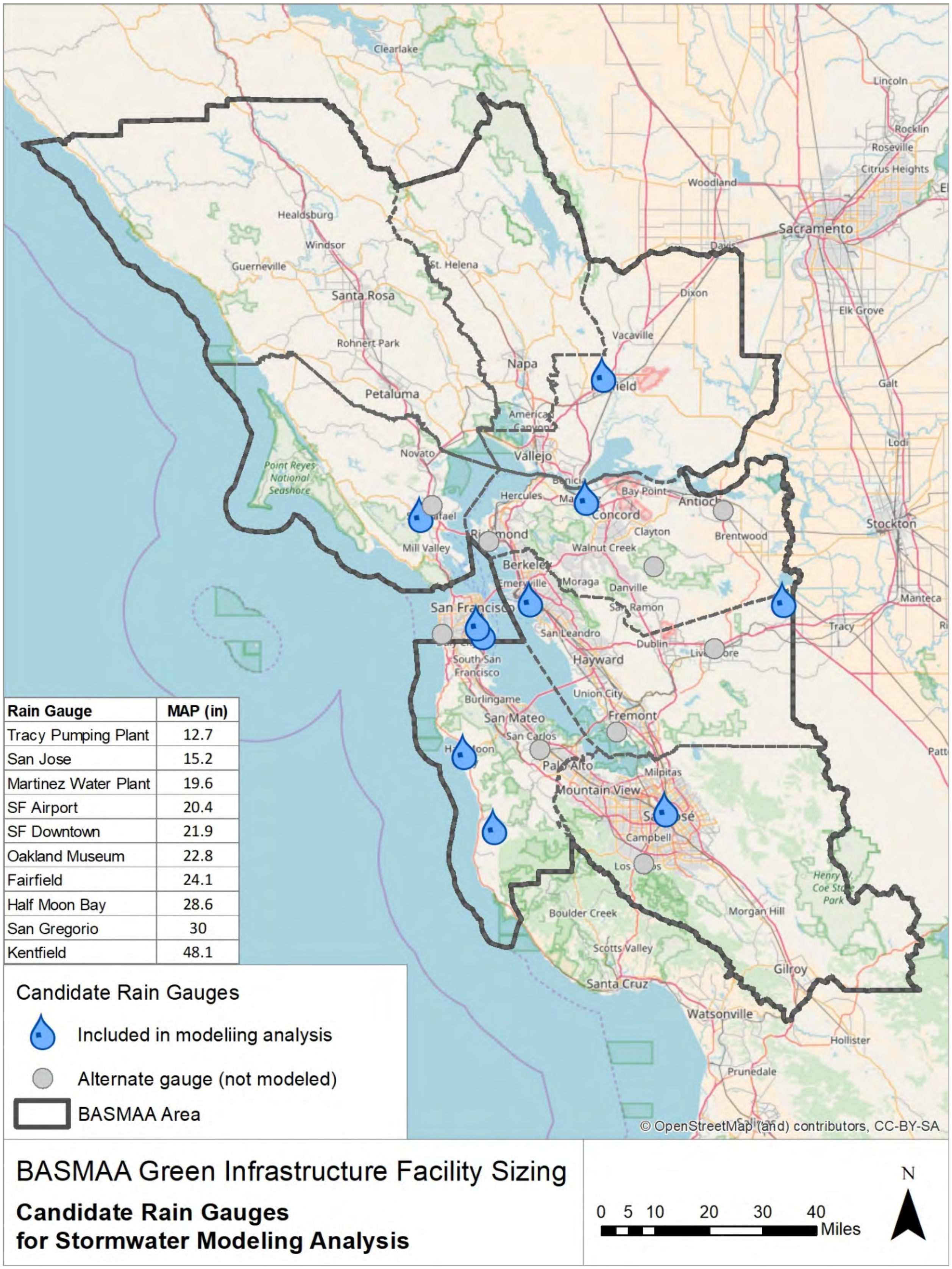


Figure 1. Candidate and selected rainfall sites with mean annual rainfall



Rain Gauge	MAP (in)
Tracy Pumping Plant	12.7
San Jose	15.2
Martinez Water Plant	19.6
SF Airport	20.4
SF Downtown	21.9
Oakland Museum	22.8
Fairfield	24.1
Half Moon Bay	28.6
San Gregorio	30
Kentfield	48.1

Figure 2. Location of rain gauges used in the modeling analysis

2.2 HSPF Model Setup

An HSPF model was developed to simulate runoff from a fully paved, 1-acre reference area and route this flow through a bioretention facility. The model outputs were then evaluated to determine the fraction of incoming stormwater receiving water quality treatment (defined as the fraction filtered through the bioretention media, evaporated or transpired). The HSPF model was developed with Excel/VBA-based code that enabled us to easily modify the rain gauge, bioretention area, and surface reservoir depth to determine how these watershed and configuration parameters affect the fraction of stormwater being treated.

The model parameters and approach to simulating bioretention hydraulics are discussed in detail below:

- Stormwater runoff flows across the reference 1-acre paved area and enters the bioretention facility. This water is initially detained in a shallow surface reservoir and then infiltrates to the bioretention media.
- Stormwater infiltrates through the bioretention media into an underlying gravel layer. The saturated soil permeability was set to 5 inches per hour (based on the media specification). For unsaturated soils, the relationship between soil moisture and permeability was based on monitoring data collected at three installations in Pittsburg (Contra Costa, 2013). The data showed very little infiltration occurs until the soil reaches about two-thirds saturation, and then infiltration increases roughly linearly until reaching 5 inches per hour at 90 percent saturation. Evapotranspiration also occurs in this layer.
- Stormwater within the gravel layer can move freely and infiltrate to surrounding soils, based on their capacity. If runoff enters the gravel layer more rapidly than it infiltrates, the saturation level in the gravel layer will rise until it reaches the elevation of a perforated pipe underdrain. When this occurs, water will flow through the underdrain to a downstream discharge point (typically the municipal storm drainage system).
- The surface reservoir is also equipped with an overflow structure that will become active if runoff enters the surface reservoir more rapidly than it infiltrates through the bioretention media and the surface reservoir fills to its maximum depth. Water discharged via the overflow relief structure does not receive treatment.

The bioretention configuration was based on the water quality treatment design criteria listed in the MRP 2.0 and accepted design practice in the Bay Area. Table 2 lists the dimensions of the bioretention layers as modeled in HPSF.

TABLE 2. BIORETENTION CHARACTERISTICS IN HSPF MODEL

Component	Characteristics
Surface reservoir	• Area = bioretention area (varies from 0.5% to 5% of upstream impervious area) • Depth = 6 or 12 inches with overflow relief set 2 inches from top of reservoir
Bioretention soil media	• Area = bioretention area • Depth = 18 inches • Saturated permeability = 5 inches per hour • Unsaturated permeability = variable, based on Contra Costa's 2013 monitoring data
Storage (gravel) layer	• Area = bioretention area • Depth = 12 inches • Permeability of surrounding soils = 0.024 inches per hour
Underdrain	• Located at top of gravel layer • Assumed 4-in diameter pipe

2.3 Model QA/QC Process

The HSPF input files and initial model results were carefully examined during the QA/QC process. Model errors and warnings were systematically eliminated and then the results were compared with the results generated from three independent calculation methods:

1. An Excel-based bioretention hydraulics calculator
2. A Matlab-based bioretention algorithm that was used for bioretention modeling in the Central Coast region
3. An EPA SWMM model using the LID module to represent bioretention hydraulics

The comparison was performed for the San Jose and Fairfield gauges with a bioretention sizing factor of 0.02 (i.e., bioretention surface area equal to 2 percent of the upstream impervious area). The estimated annual runoff treatment percentages agreed to within 3 percent, which confirmed the HSPF model was performing as intended.

3. Modeling Scenarios and Results

The HSPF modeling analysis was used to develop bioretention sizing criteria and support policy decisions. Working collaboratively with the BASMAA Development Committee, the modeling analysis addressed the following issues, which are presented in this section:

1. Bioretention area necessary to treat 80 percent of annual stormwater runoff
2. Relationships for estimating annual stormwater treatment percentage across a range of bioretention sizes and mean annual precipitation depths
3. Relationships for estimating annual stormwater treatment percentage for bioretention facilities without an underdrain
4. Bioretention treatment percentage for facilities with no infiltration to surrounding soils
5. Bioretention treatment percentage for facilities with lower bioretention media permeability

The results are summarized graphically here. The full set of results and underlying data were provided separately to the BAASMA Development Committee on 7/28/2017 and are available from BASMAA upon request.

3.1 Bioretention Sizing for Treatment of 80 Percent of Annual Runoff

The performance of bioretention facilities was modeled for 10 different rain gauges and bioretention footprint areas, ranging from 0.5 to 5.0 percent of the upstream tributary area, using the approach described in Section 2. Bioretention configurations with 6-inch and 12-inch deep surface reservoirs were modeled. For each of the model runs, the runoff treatment percentage was computed, and the results were plotted. Figure 3 shows an example for the San Jose gauge. Appendix B shows results for the other rain gauges.

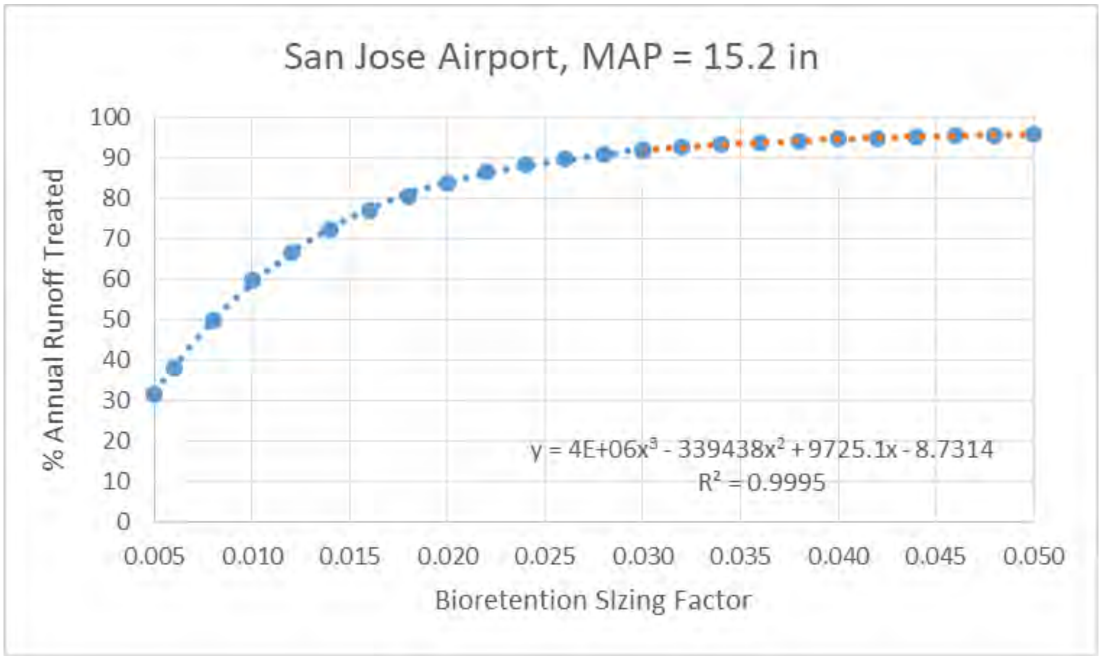


Figure 3. Percent of annual runoff treated for range of bioretention facility sizes using San Jose rain gauge

Using a polynomial regression equation, the model results for each rain gauge/surface reservoir depth scenario were interpolated to estimate the bioretention sizing factor needed to provide 80 percent annual runoff treatment, which is the treatment criterion for regulated water quality projects in the MRP 2.0. The results across the 10 rain gauges showed a clear linear relationship between mean annual rainfall and the bioretention footprint needed for 80 percent annual runoff treatment. Figure 4 and Figure 5 show the results for the 6-inch and 12-inch surface reservoir configurations, respectively.

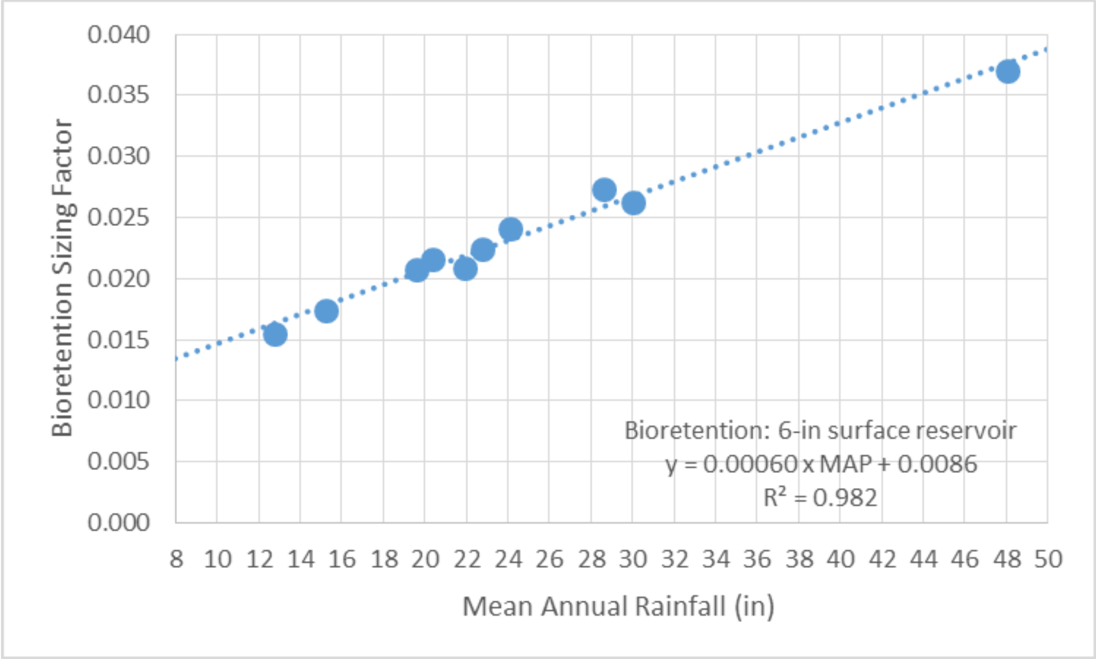


Figure 4. Bioretention size needed to provide treatment of 80 percent of annual runoff; 6-in surface reservoir

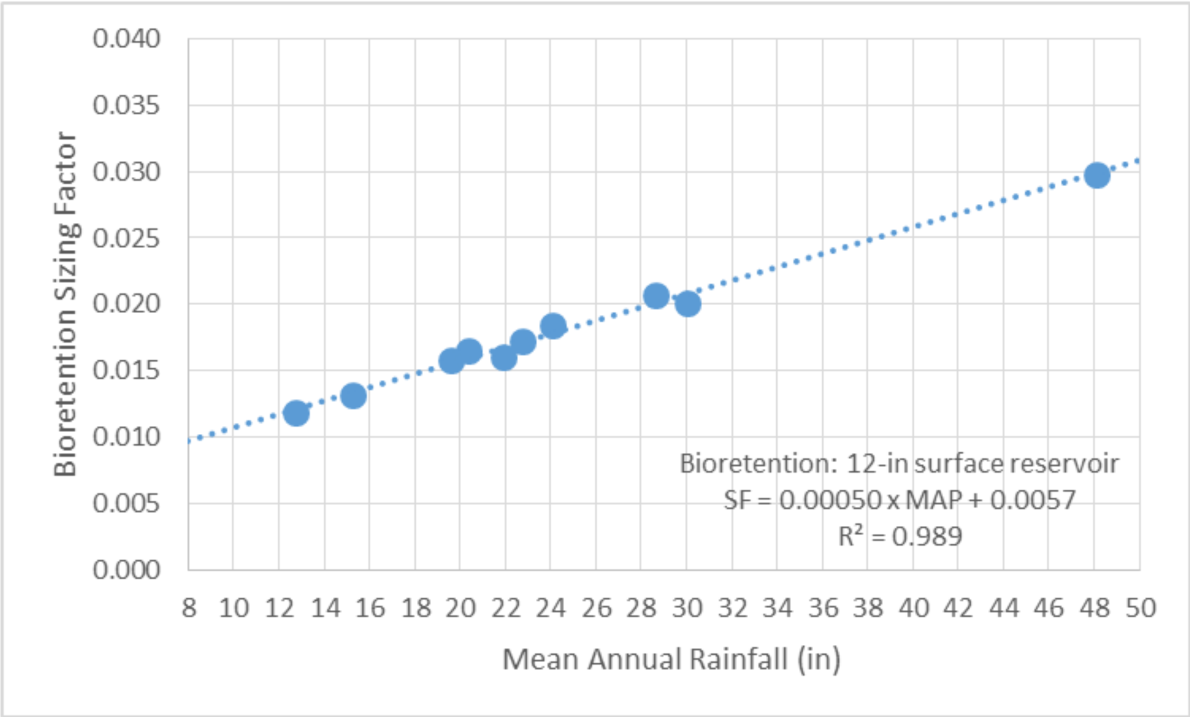


Figure 5. Bioretention size needed to provide treatment of 80 percent of annual runoff; 12-in surface reservoir

The results shown above could be used by BASMAA agencies to set minimum bioretention sizing criteria for projects that must provide treatment of 80 percent of annual runoff. The following equations could be included in BASMAA guidance for green infrastructure manuals.

For bioretention with 6-in surface reservoir configuration:

$$SizingFactor = 0.00060 \times MAP(in) + 0.0086$$

For bioretention with 12-in surface reservoir configuration:

$$SizingFactor = 0.00050 \times MAP(in) + 0.0057$$

3.2 Relationship Among Bioretention Sizing, Annual Precipitation, and Percent of Annual Runoff Treated

The modeling results generated in the previous section were then further evaluated to develop more general relationships among a) bioretention sizing factor, b) mean annual rainfall, and c) annual runoff treatment percentages. The following steps were used for the 6-inch and 12-inch reservoir depth configurations:

1. A polynomial regression was fit to the annual runoff treatment results for each of the 10 rain gauges (see example in Figure 3 above) and surface reservoir depths of 6 and 12 inches.
2. For each rain gauge/surface reservoir depth combination, the regression equation was used to estimate the sizing factors needed to provide 50, 60, 70, 80, 90, and 95 percent annual runoff treatment. This step generated 10 pairs of mean annual rainfall/bioretention sizing factor data for each rain gauge/surface reservoir depth combination (120 pairs in total). Excel's solver function was used for these calculations.

3. For each runoff treatment percentage level (50 percent, 60 percent, etc.), the mean annual rainfall (x-axis) and computed sizing factor (y-axis) were plotted and a linear regression was fit to the data in a manner similar to Figure 4 and Figure 5 above.
4. The linear regressions created for each runoff treatment level (50 percent, 60 percent, etc.) and surface reservoir depth were then plotted together to create a nomograph. Figure 6 and Figure 7 show nomographs for the 6-inch and 12-inch reservoir depths, respectively.

These nomographs are simple but powerful tools that municipal planners can use to estimate the annual treatment percentage for any bioretention facility within the BASMAA member agency area that uses the standard bioretention configuration (i.e., 6-in or 12-in reservoir, 18-in soil media, 12-in gravel layer, underdrain at top of gravel layer). The nomographs should be read as follows:

Step 1: Find the mean annual rainfall for the project location along the horizontal axis

Step 2: Move vertically up the chart to the bioretention sizing factor for the project/installation (note: this step assumes the tributary impervious area and bioretention area have already been planned)

Step 3: Visually interpolate between the closest two "treatment lines" to estimate the percent of annual runoff treated for this location/project.

These nomographs and instructions could be included in BASMAA guidance for green infrastructure manuals and used to a) evaluate the water quality benefits of proposed projects or b) evaluate the treatment provided by existing facilities with the layer depths described above.

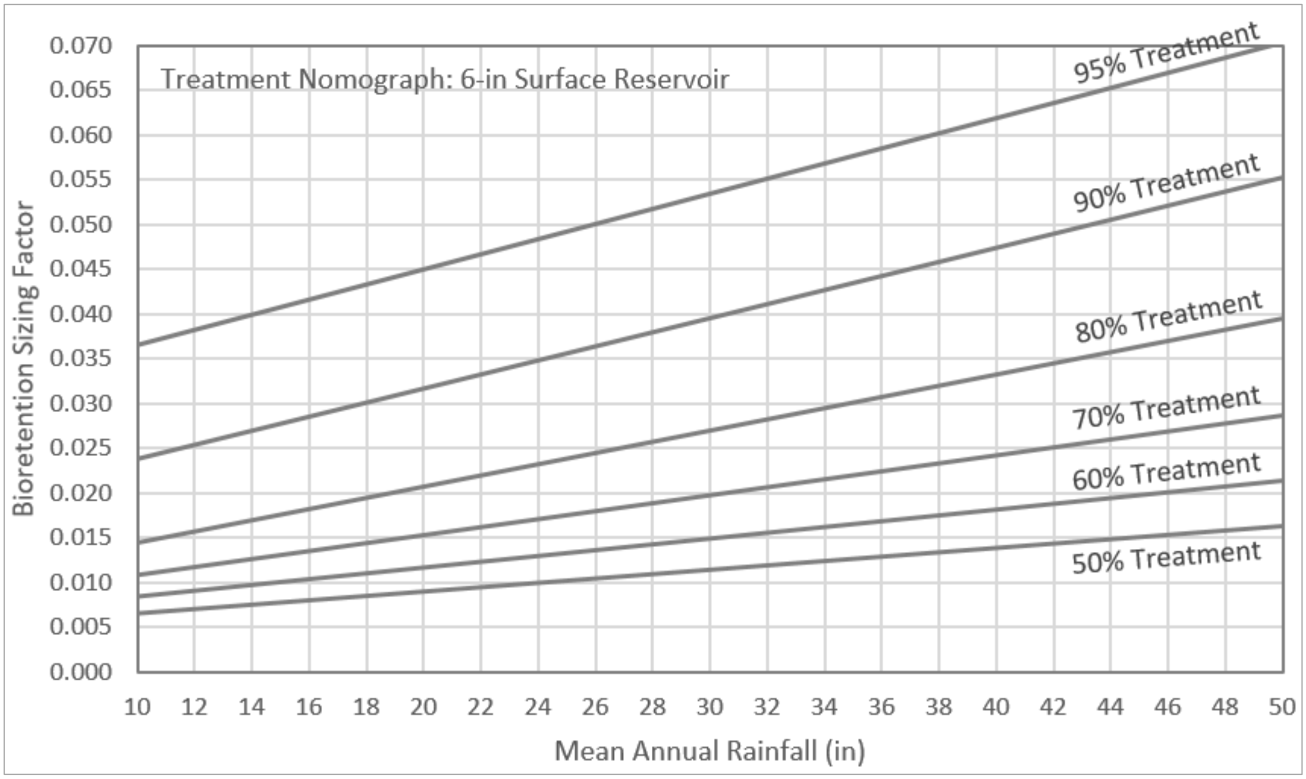


Figure 6. Percent of annual runoff treatment nomograph for bioretention facility with 6-in surface reservoir

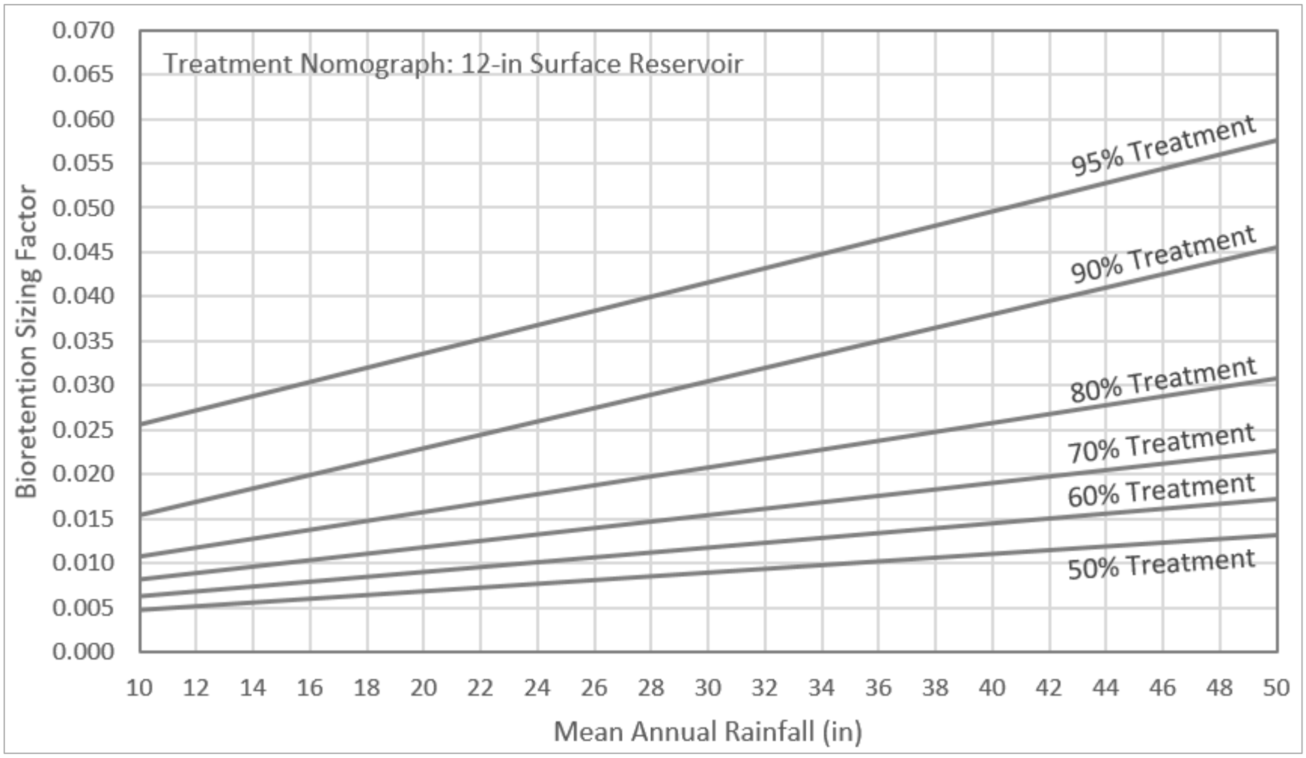


Figure 7. Percent of annual runoff treatment nomograph for bioretention facility with 12-in surface reservoir

3.3 Percent of Annual Runoff Treated by Bioretention Facilities with No Underdrain

Bioretention facilities are occasionally designed with no underdrain, including bioretention facilities in the following conditions:

- High permeability of surrounding (native) soils
- Isolated projects with no downstream drainage system for the underdrain connection
- Small projects that would not justify the additional design and construction costs associated with underdrains and cleanouts
- Projects that were designed and built prior to the development of the current standards

The HSPF model setup was modified to eliminate the underdrain outflows and allow the permeability of the surrounding soils to vary. The annual runoff treatment percentage was computed for a) three rain gauges representing drier, average and wetter than average conditions, b) six rates of permeability of surrounding soils, and c) two bioretention surface reservoir depths (Table 3).

TABLE 3. BIORETENTION WITH NO UNDERDRAIN SCENARIOS

Component	Characteristics
Rain gauges	• San Jose (MAP = 15.2 in) • San Francisco Airport (MAP = 20.4 in) • Fairfield (MAP = 24.1 in)
Permeability of surrounding (native) soils	• 0.2, 0.5, 1.0, 2.0, 3.0, 4.0 inches per hour • Underdrain results also plotted

TABLE 3. BIORETENTION WITH NO UNDERDRAIN SCENARIOS

Component	Characteristics
Surface reservoir depths	• Depth = 6 inches • Depth = 12 inches
Bioretention sizing factors	• Area = 0.5% to 5.0% of upstream impervious acre

Figure 8, Figure 9 and Figure 10 show the modeled annual runoff treatment results for the three rain gauges and a surface reservoir depth of 6 inches. Results for the 12-inch surface reservoir are shown in Appendix C. For rates of permeability of 4 inches per hour, there is little drop off in performance. The annual runoff treatment percentage declines gradually between rates of permeability of 2 to 4 inches per hour and then declines more rapidly for rates of permeability of 1 inch per hour or less. The reduction in performance is more pronounced in wetter areas (as seen in the Fairfield results). These results could be incorporated into the BASMAA guidance for green infrastructure manuals to assess the general performance of existing facilities that were installed with no underdrain.

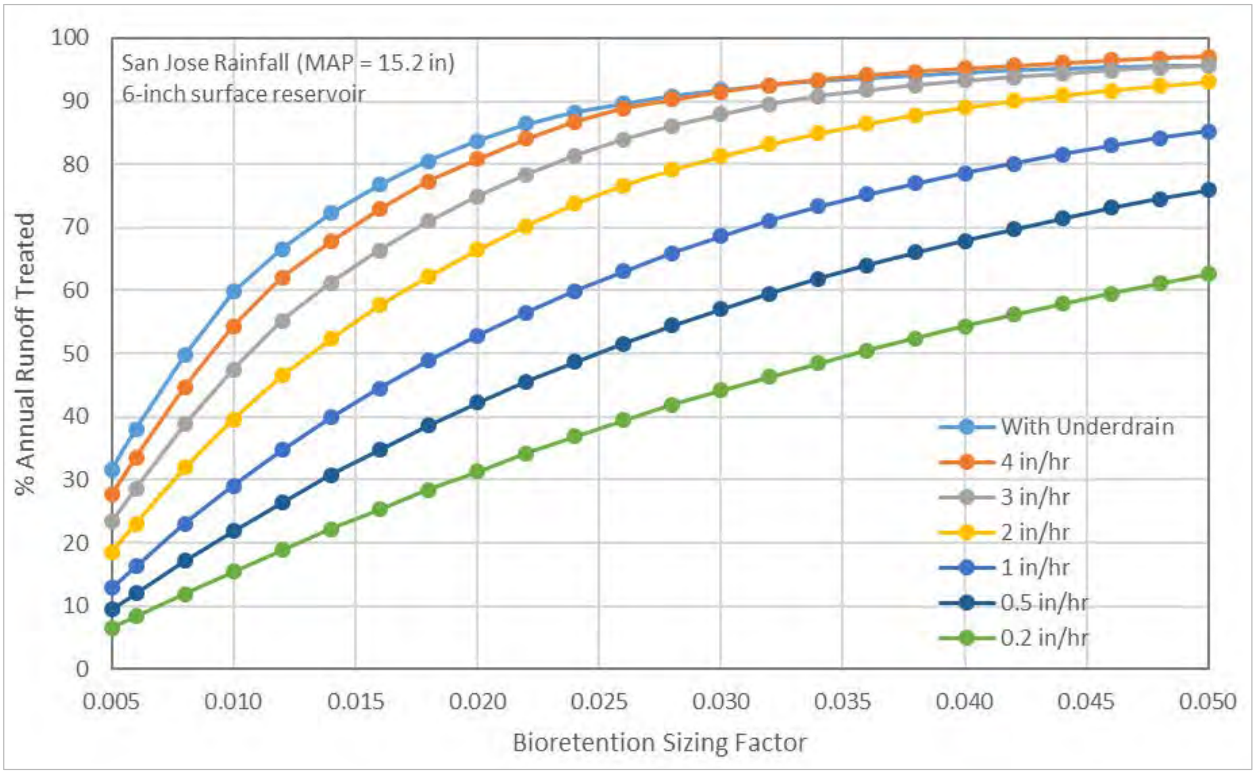


Figure 8. Treatment results for bioretention with no underdrain, San Jose gauge (MAP = 15.2 in), for varying rates of permeability of surrounding soils

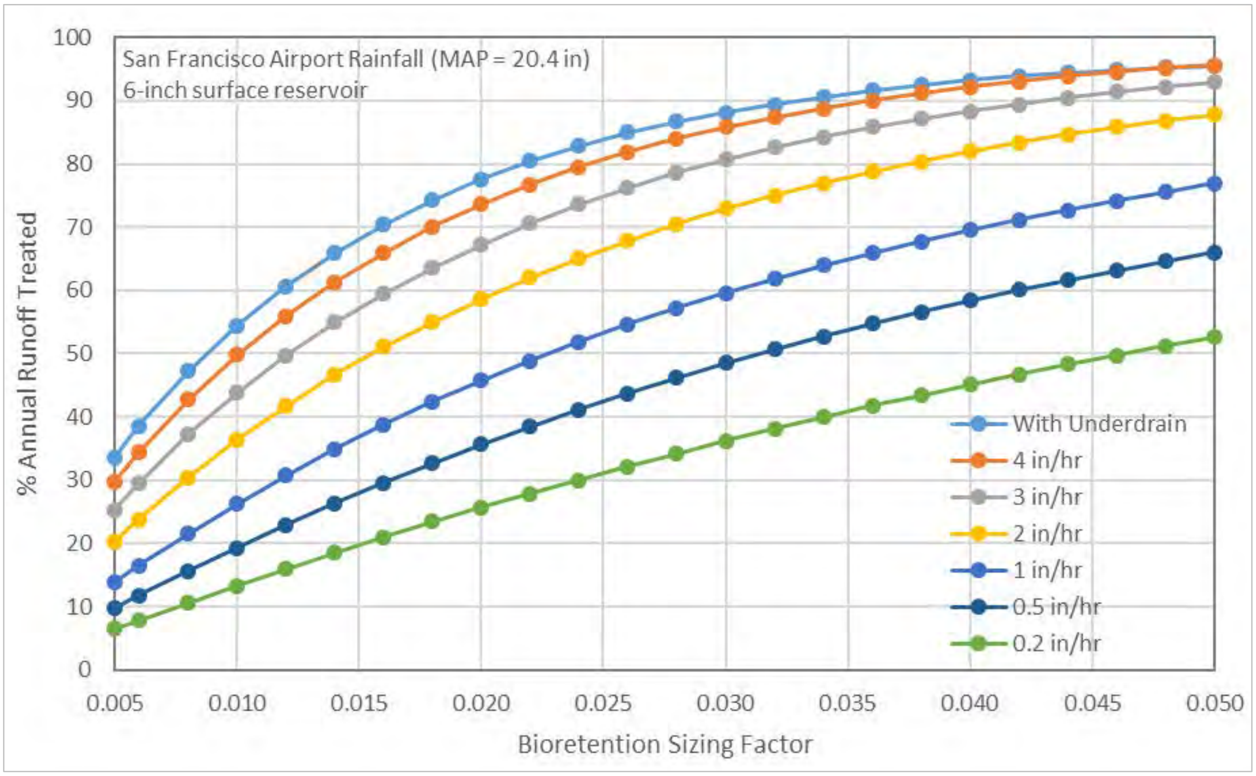


Figure 9. Treatment results for bioretention with no underdrain, San Francisco Airport gauge (MAP = 20.4 in), for varying rates of permeability of surrounding soils

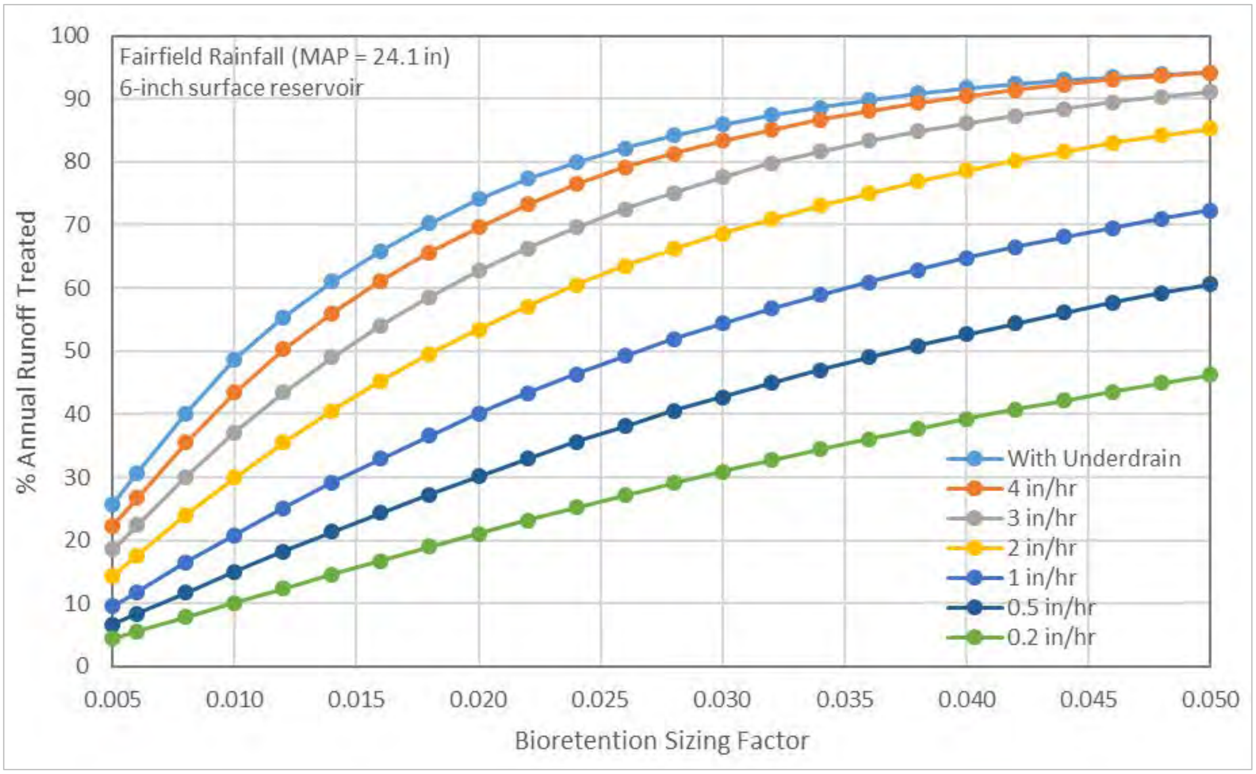


Figure 10. Treatment results for bioretention with no underdrain, Fairfield gauge (MAP = 24.1 in), for varying rates of permeability of surrounding soils

3.4 Percent of Annual Runoff Treated for Bioretention Facilities with No Infiltration to Surrounding Soils

The previous simulations described in Sections 3.1 and 3.2 were conducted for bioretention facilities located in NRCS hydrologic soil group D soils, which are low permeability soils, such as clays. These model simulations used a conservative permeability of 0.024 inches per hour from the bioretention gravel layer to surrounding soils. It was assumed the permeability of surrounding soils would have a negligible effect on the results because the hydraulic capacity of the underdrain is much higher than the permeability of D soils and that when the bioretention media becomes saturated, stormwater would exit mostly via the underdrain. If this assumption is correct, a lined bioretention facility or flow-through planter with no infiltration into surrounding soils should have similar performance.

This assumption was tested directly by running a limited number of simulations with the permeability of the surrounding soils set to a value of zero (i.e., an impervious layer directly below the bioretention facility). The annual treatment percentages were then compared to the previous modeling results (with D soil permeability set to 0.024 inches per hour). These simulations were performed for the Fairfield rain gauge and a bioretention facility with a 6-inch surface reservoir for sizing factors ranging from 0.005 to 0.050.

Figure 11 shows the two sets of model results. For the impermeable bottom scenario, the annual treatment percentage was on average 0.8 percent less the scenarios with a D soil permeability of 0.024 inches per hour (minimum difference = 0.4 percent; maximum difference = 1.5 percent). Therefore, the sizing curves and nomographs in Figure 4 through Figure 7 can be used for lined facilities with no infiltration.

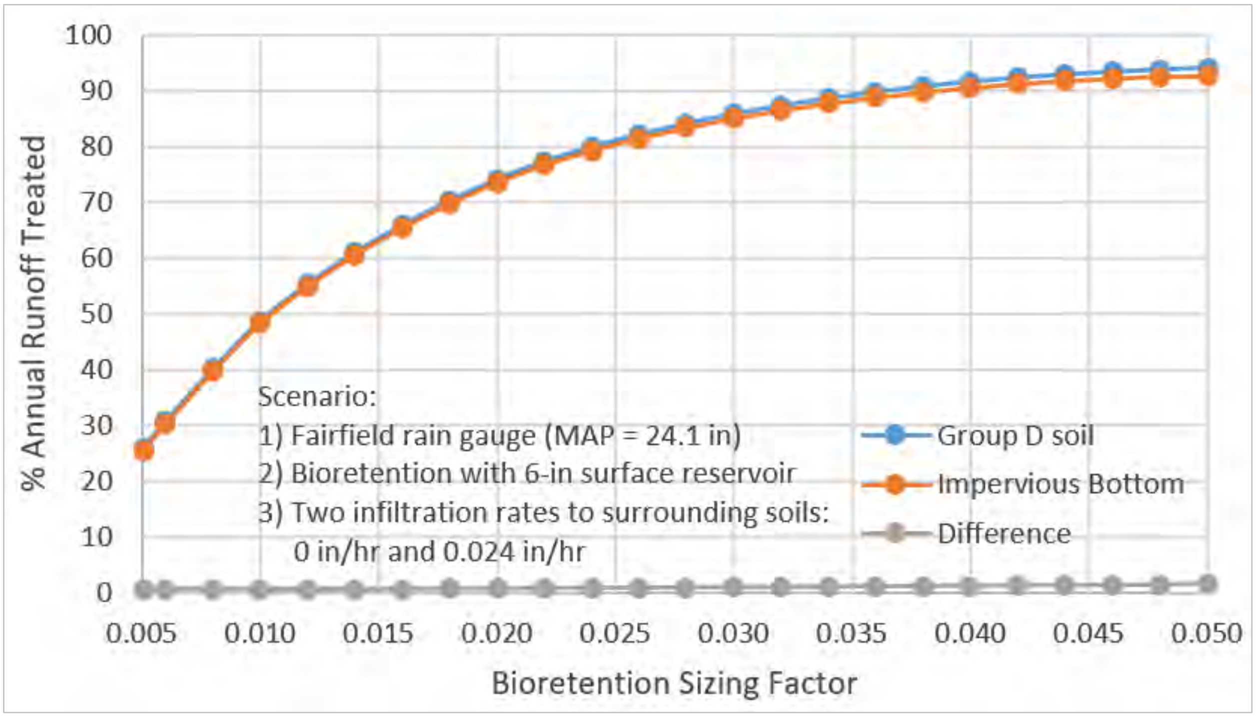


Figure 11. Comparison of model results for Group D soils and impermeable bottom scenarios

3.5 Percent of Annual Runoff Treated for Bioretention Facilities with Lower Media Permeability

The final modeling analysis examined the effect of modifying the bioretention media properties to reduce its saturated permeability from 5 inches per hour to 2 or 3 inches per hour. A lower permeability media would expand the list of available plantings and provide additional flexibility for landscape designers. However, the lower permeability would also reduce the bioretention's capacity for treating runoff during intense storms.

Due to budgetary constraints, this modeling analysis was limited to two scenarios: San Jose rain gauge, 6-inch surface reservoir depth, sizing factors ranging from 0.005 to 0.05, and saturated bioretention media permeability of 2 and 3 inches per hour. Figure 12 shows the percentage of annual runoff treated across the range of bioretention sizing factors and permeability rates. All of the scenarios include an underdrain, so the media permeability is the facility characteristic that controls the treatment percentage (i.e., the rate limiting step). The reduction in treatment percentage could be significant, particularly for smaller facilities. For example, the percent of annual runoff treated for a bioretention facility with a sizing factor of 0.02 would be reduced from 84 percent to 74 or 65 percent (for media permeability rates of 3 and 2 inches per hour, respectively).

Another way to consider the effect of lower media permeability is to estimate *how much larger a facility would need to be* to treat 80 percent of annual runoff. For the San Jose gauge, a sizing factor of 0.017 is needed with the standard bioretention media specification. If the media permeability were reduced to 3 or 2 inches per hour, the sizing factor needed to treat 80 percent of annual runoff would be 0.024 or 0.030, respectively, which represents a 37 to 75 percent increase in the facility footprint.

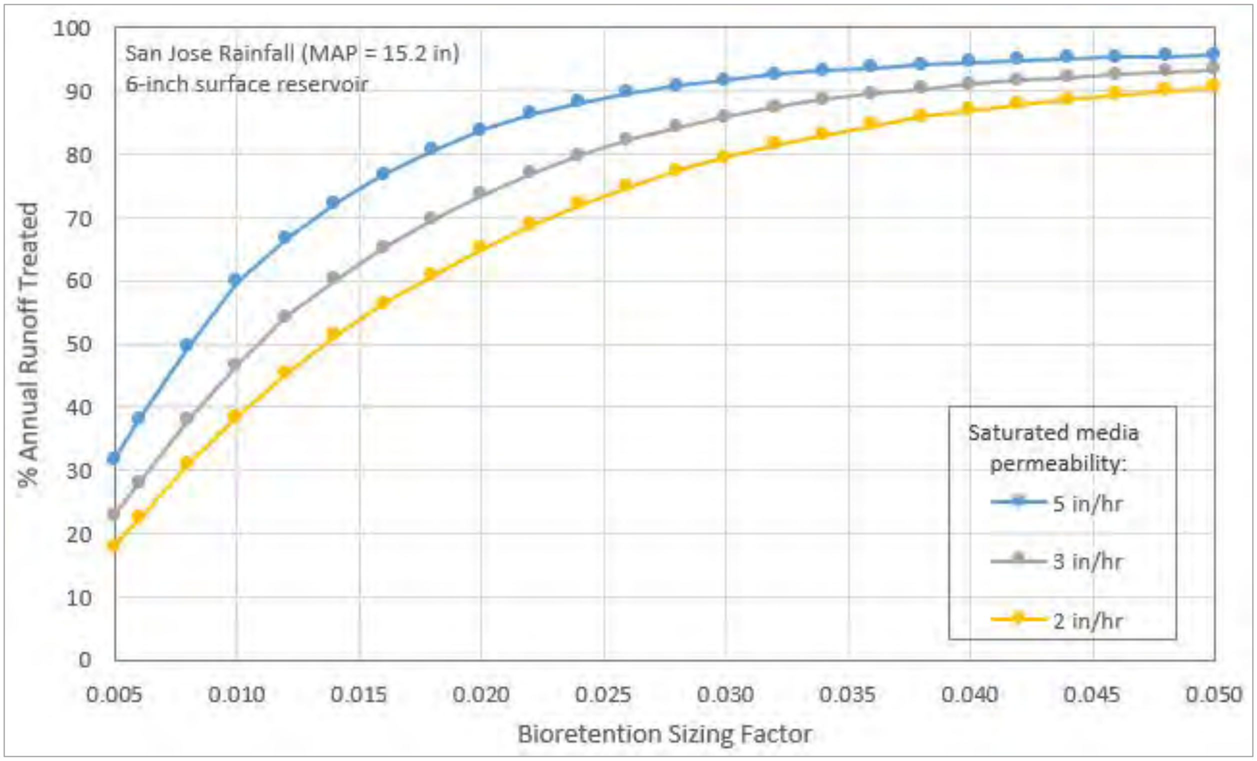


Figure 12. Treatment results for bioretention with variable media permeability, San Jose gauge (MAP = 15.2 in)

As a final note, the media permeability modeling was limited to two scenarios (one rain gauge, one facility configuration, two permeability rates). However, these results could be extended by noting that they are generally similar to the “no underdrain” results shown in Section 3.3 (e.g., comparing the results for a media permeability of 2 inches per hour to a 2-inch per hour permeability of surrounding soil). When comparing the two sets of results, the percent of annual runoff treated for the lower media permeability is a little lower (0.5 to 2.5 percent) than the corresponding “no underdrain” scenario and the shape of the curve in Figure 12 is similar to the Figure 8 in Section 3.3.

4. Summary and Conclusions

Bioretention facilities are a useful and flexible approach for improving stormwater quality in urban areas. This project developed a set of useful tools that will help municipal staff plan green infrastructure projects in constrained public rights-of-way and assess the effectiveness of existing facilities.

1. Bioretention Sizing Criteria for 80 Percent Annual Runoff Treatment

   The modeling analysis in Section 3.1 showed that bioretention facility performance is closely related to mean annual rainfall. For most locations, the bioretention area necessary to treat 80 percent of annual stormwater ranges from 1.5 to 2.5 percent of the connected upstream impervious area. The precise bioretention area necessary for any project within the BASMAA area (under the guidelines to be developed by BASMAA) can be calculated using the regression equations in Section 3.1.

2. General Sizing Relationships that Apply Throughout the BASMAA Area

   The modeling analysis in Section 3.2 developed nomographs that estimate the annual stormwater treatment percentage across a range of bioretention facility sizes and mean annual rainfall depths. These nomographs can be used to estimate the annual treatment percentages for retrofit projects with space constraints and will enable municipal staff to compare bioretention with other treatment technologies. These nomographs can also be used to assess the effectiveness of existing facilities.

3. Performance of Bioretention Facilities with No Underdrain and Varying Rates of Permeability of Surrounding Soils

   The modeling analysis in Section 3.3 demonstrated the relationship between stormwater treatment percentage and level of permeability of surrounding soils for bioretention facilities without an underdrain. Graphics were developed for rain gauges in wetter and drier areas. The results of this analysis can help assess existing installations and also inform designers about the benefits and tradeoffs of constructing bioretention with no underdrain.

4. Performance of Bioretention Facilities with No Infiltration

   The modeling analysis in Sections 3.1 and 3.2 included the conservative assumption that bioretention facilities were installed in NRCS Group D soils with a very low permeability. The modeling analysis in Section 3.4 compared these results to bioretention facilities with no infiltration to surrounding soils (e.g., facilities with a liner or concrete bottom). The results were very similar, which confirms that the sizing guidance developed in Sections 3.1 and 3.2 can apply to flow-through planters or similar facilities that do not infiltrate to surrounding soils.

5. Sizing Criteria for Facilities with Lower Permeability Soil Media

   The modeling analysis in Section 3.5 demonstrated the relationship between percent of annual runoff treated and bioretention soil media permeability. Reducing media permeability would allow for a wider range of bioretention plantings but would also result in a reduction in the percent of annual runoff treated for the same size drainage area. The reduction would be particularly notable for bioretention facilities with smaller sizing factors. The results of the bioretention media permeability analysis were similar to the no underdrain scenarios in Section 3.3 The Section 3.3 results could be used to estimate how reducing media permeability would influence treatment percentages across a wider range of scenarios.

In general, the bioretention surface area sizing criteria for treating 80% of the annual runoff derived from the modeling analyses described herein are significantly lower than the sizing factors that municipalities in the Bay Area have been requiring regulated projects to meet for compliance with permit requirements for some time. As stated in the Introduction (Section 1), the BASMAA Development Committee and BASMAA member agencies intend to use these sizing relationships to develop and justify a "single approach" for implementing non-regulated green street projects when there are constraints on facility size. A work group of the Development Committee was formed to develop policies and guidelines for implementing the new sizing criteria and addressing other related issues. These include defining the conditions, constraints, and types of projects for which the reduced sizing factors can be used; the method for applying the sizing factors; guidelines for when dimensions of other components such as media depths can be adjusted; how the design of other types of green infrastructure measures may be modified; the effectiveness of smaller or modified green infrastructure facilities in terms of pollutant load reduction; and other considerations.

5. References

Contra Costa Clean Water Program (CCCWP). 2006. Hydrograph Modification Management Plan. April 16, 2006.

Contra Costa Clean Water Program (CCCWP). 2013. IMP Monitoring Report, IMP Model Calibration and Validation Report. September 20, 2013.

Appendix A: Storm Depths for 1-Hour and 24-Hour Durations

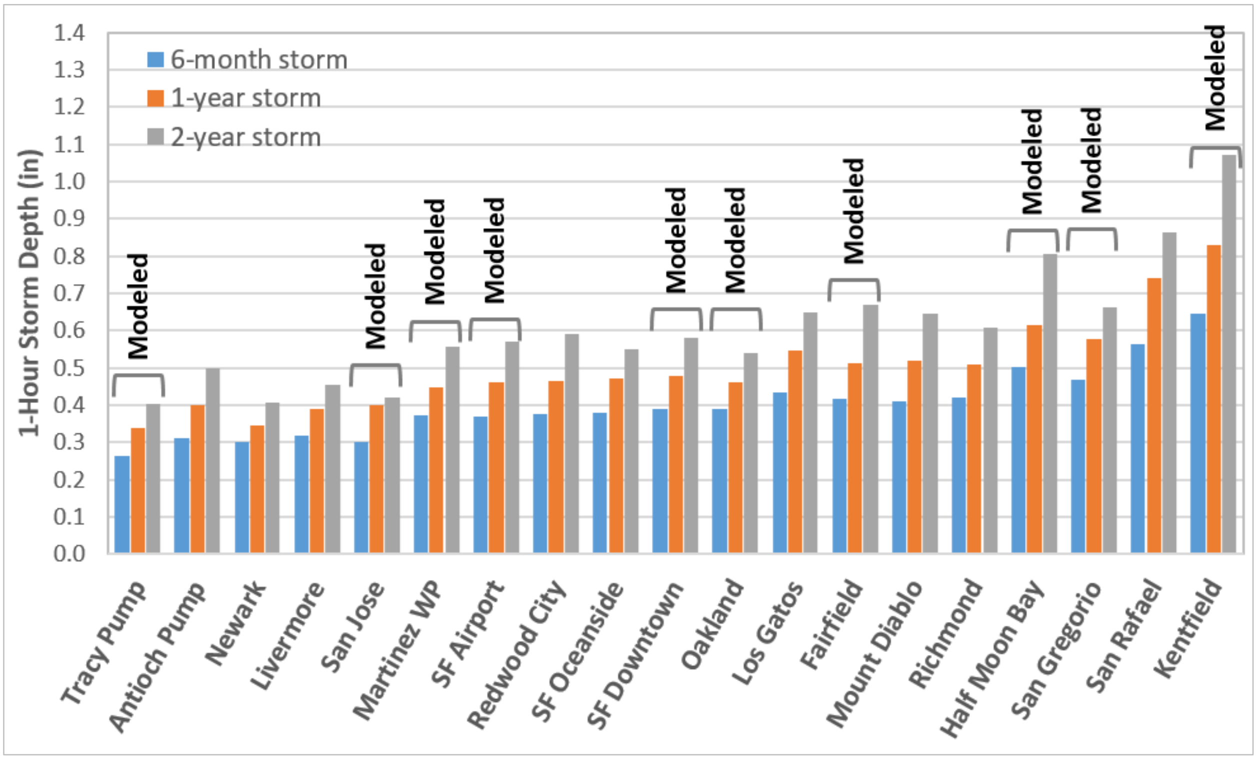


Figure 13. Storm depths for 1-hour duration

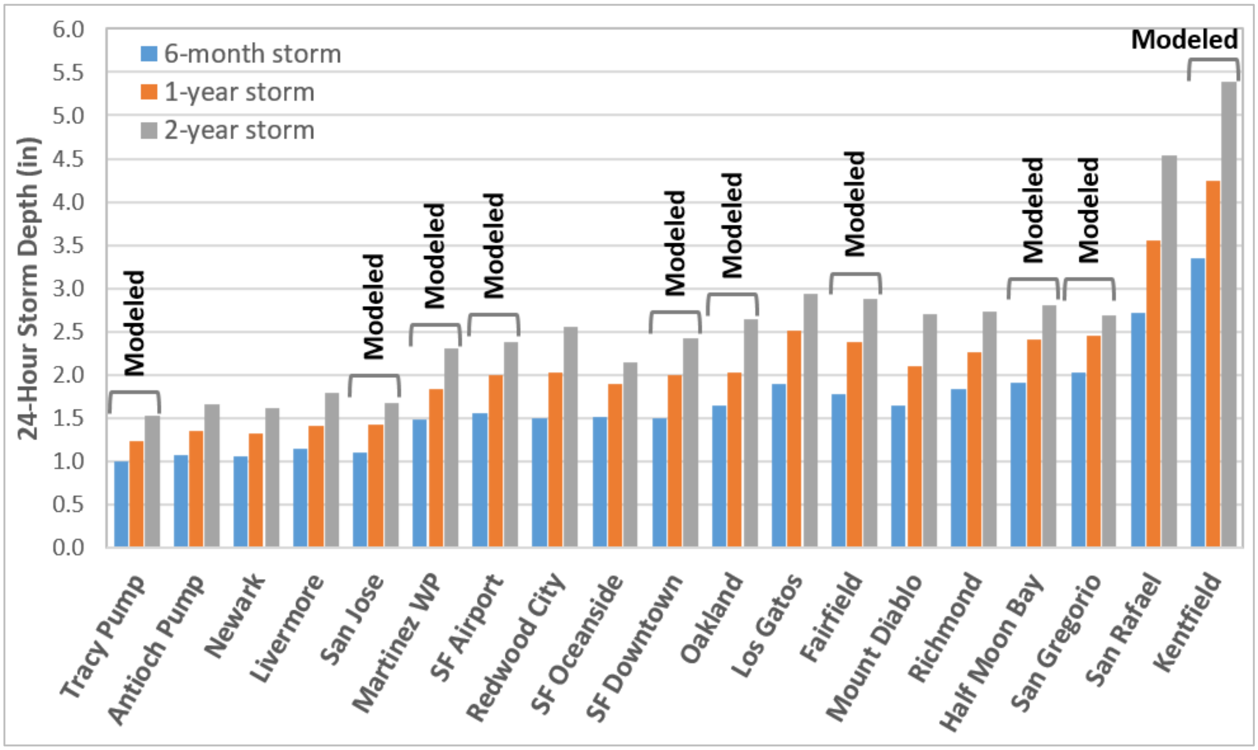


Figure 14. Storm depths for 24-hour duration

Appendix B: Treatment Percentage Results Graphics for All Rain Gauges

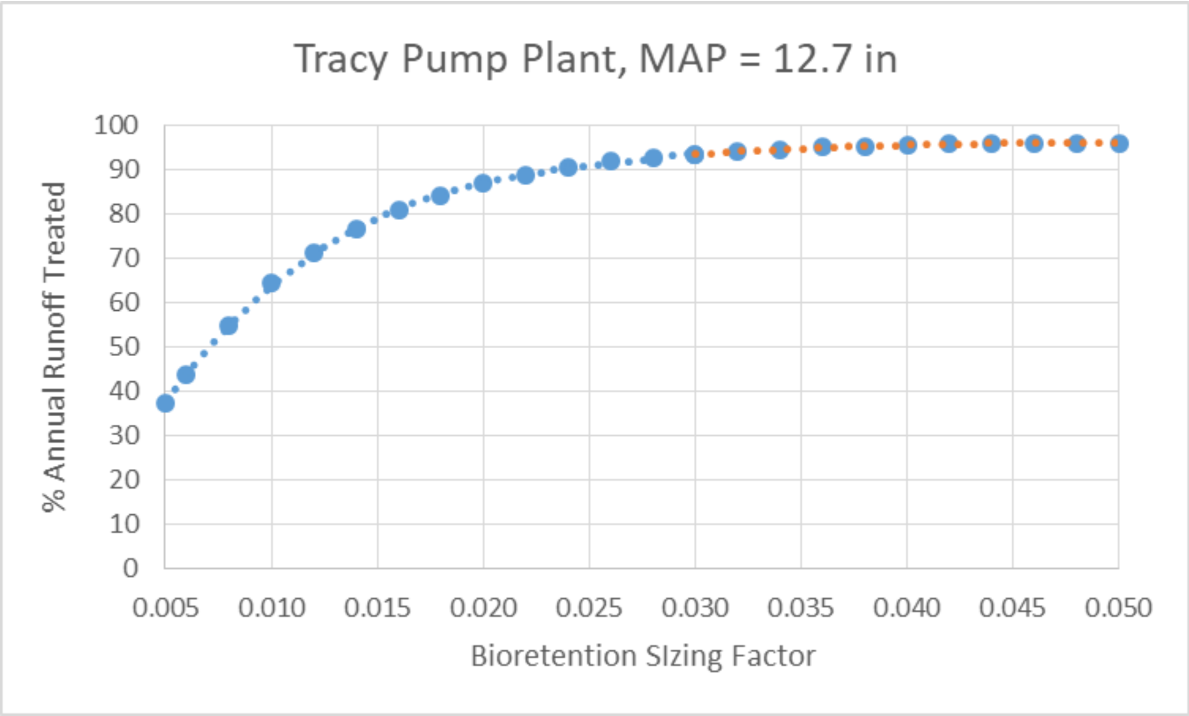


Figure 15. Annual treatment percentage for the Tracy Pump Plant rain gauge

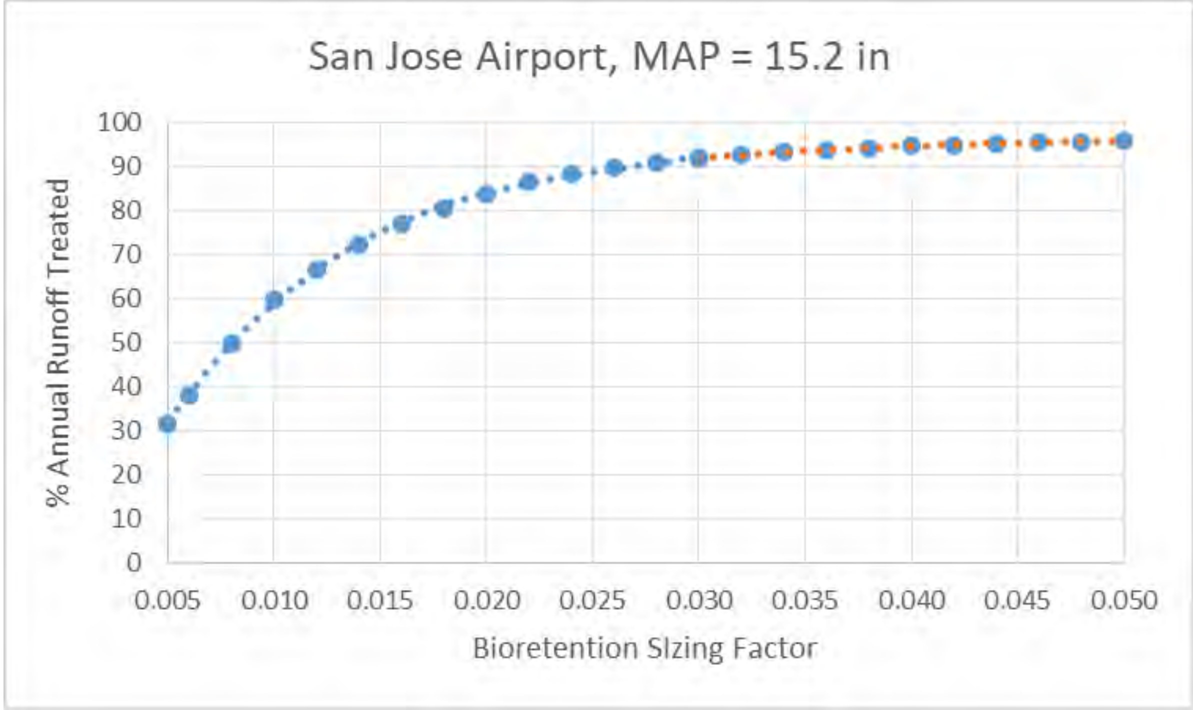


Figure 16. Annual treatment percentage for the San Jose rain gauge

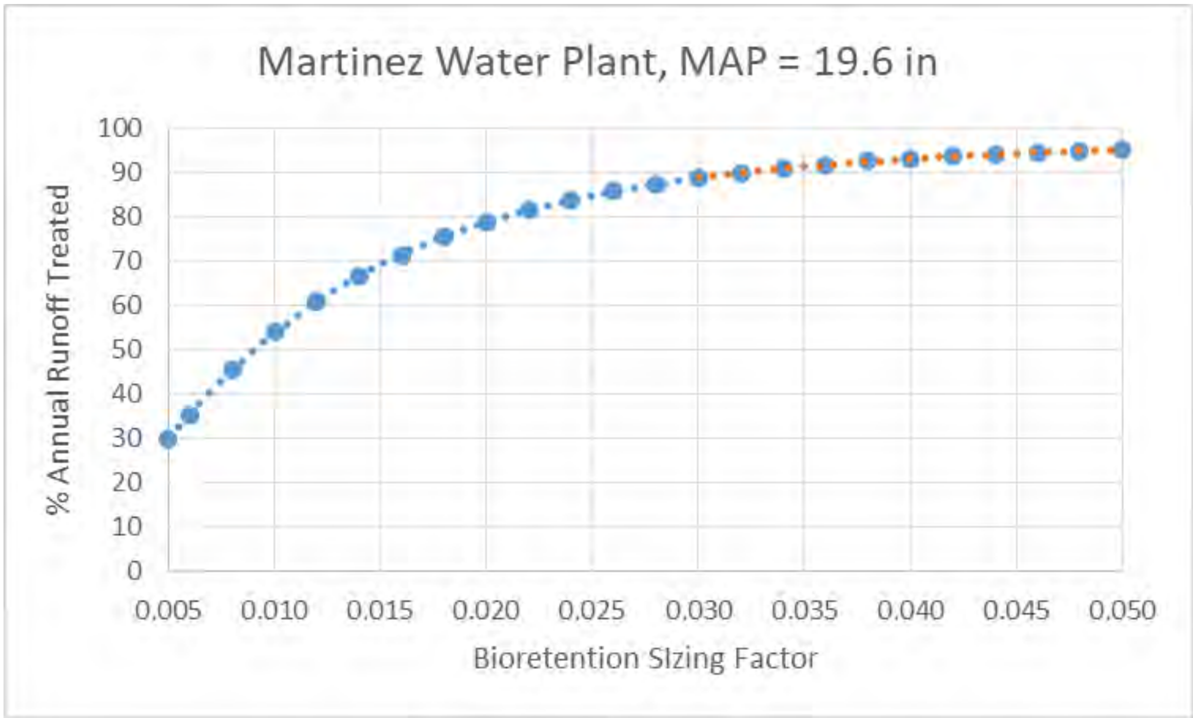


Figure 17. Annual treatment percentage for the Martinez Water Plant rain gauge

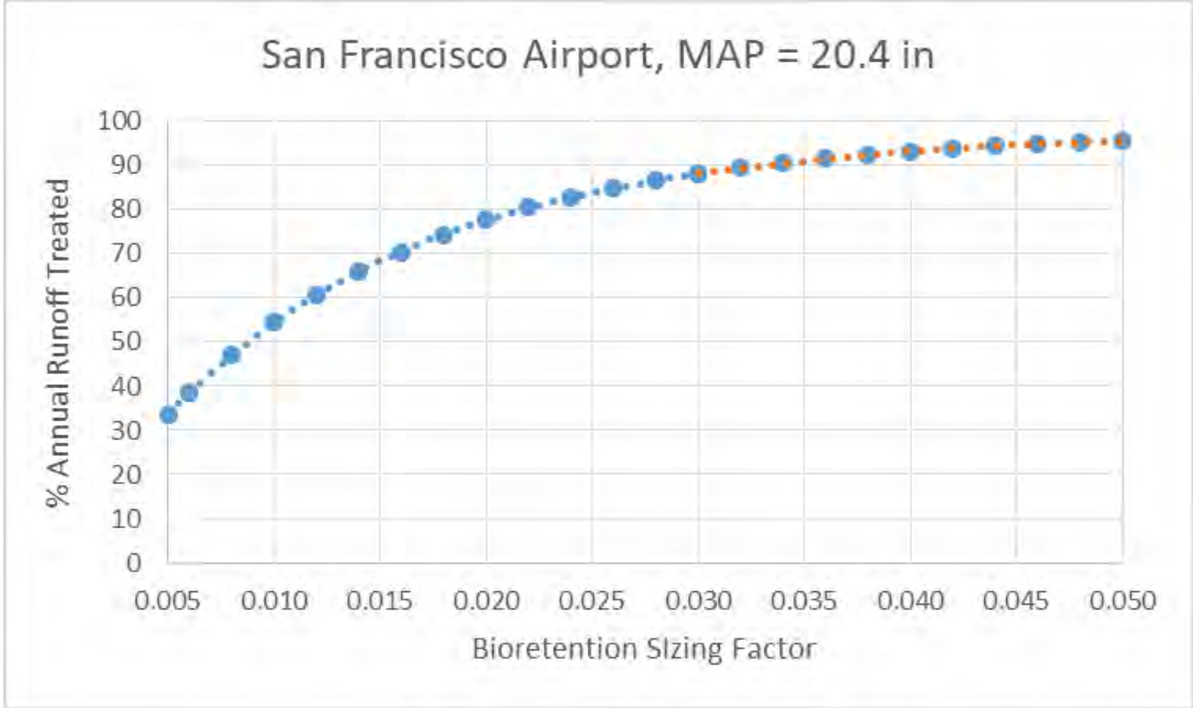


Figure 18. Annual treatment percentage for the San Francisco Airport rain gauge

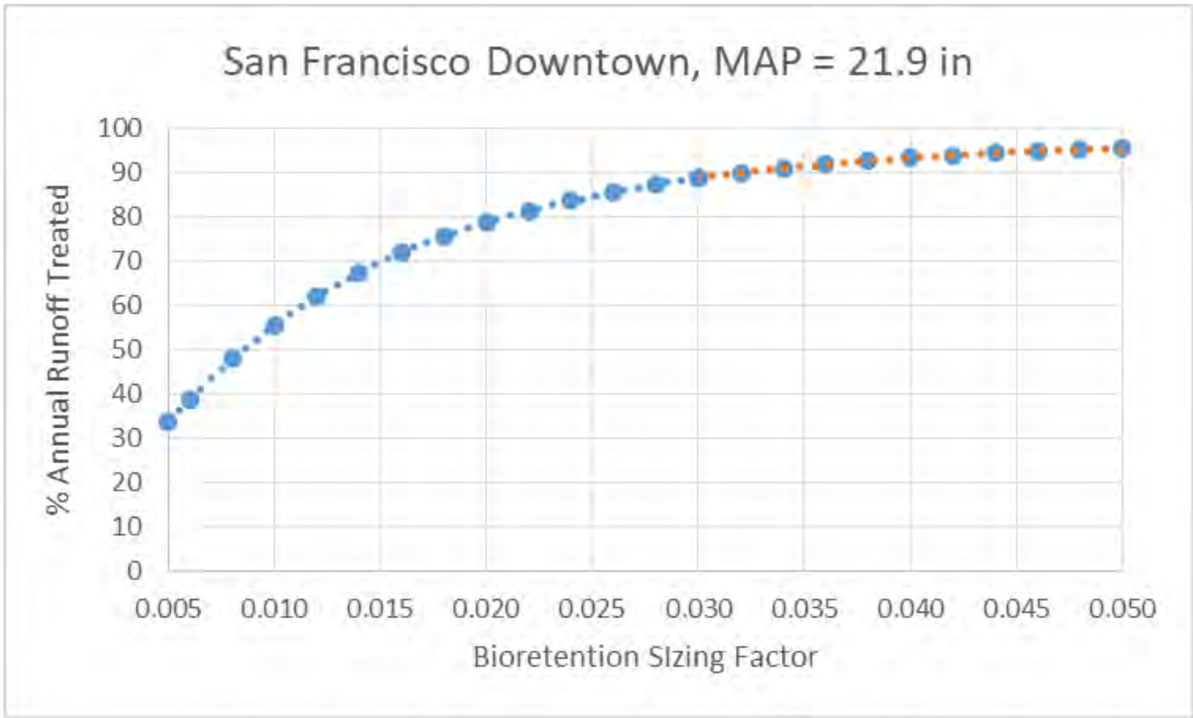


Figure 19. Annual treatment percentage for the San Francisco Downtown rain gauge

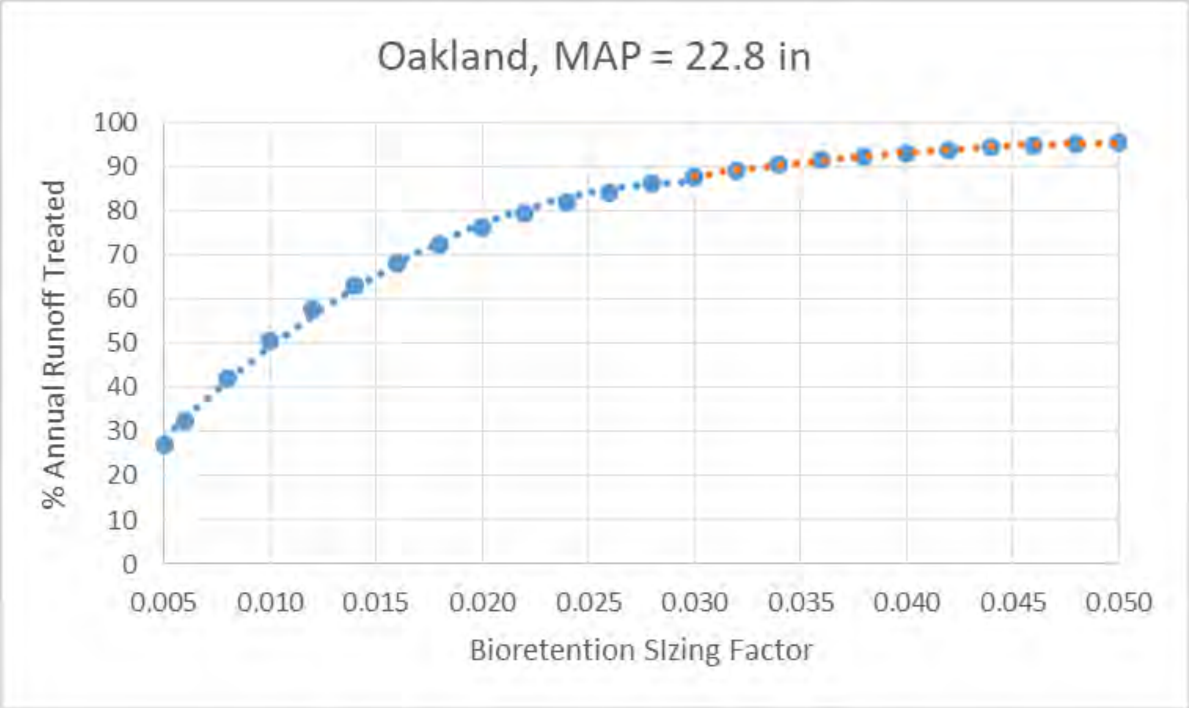


Figure 20. Annual treatment percentage for the Oakland rain gauge

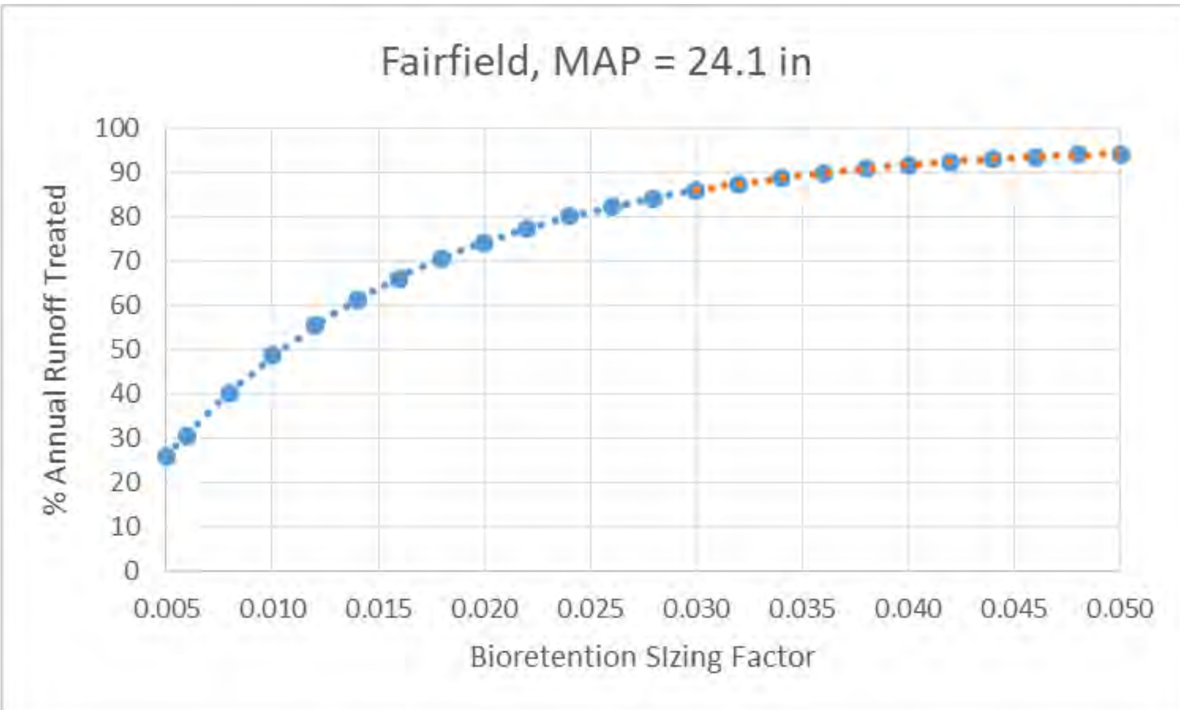


Figure 21. Annual treatment percentage for the Fairfield rain gauge

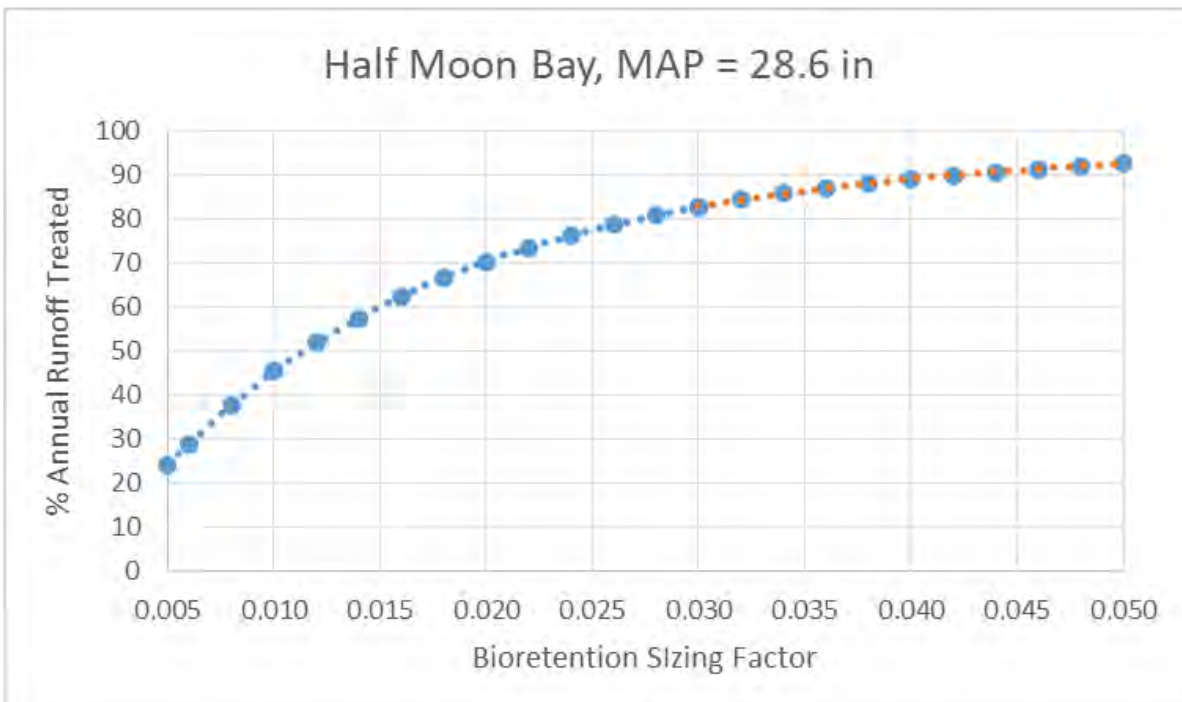


Figure 22. Annual treatment percentage for the Half Moon Bay rain gauge

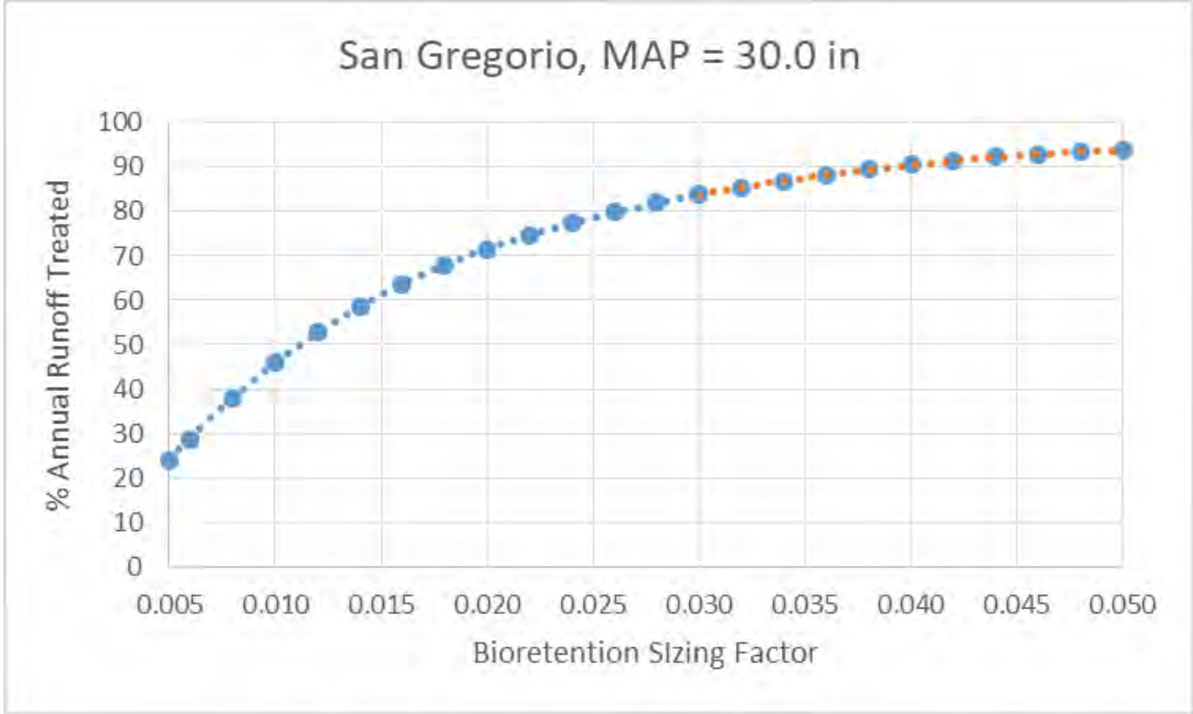


Figure 23. Annual treatment percentage for the San Gregorio rain gauge

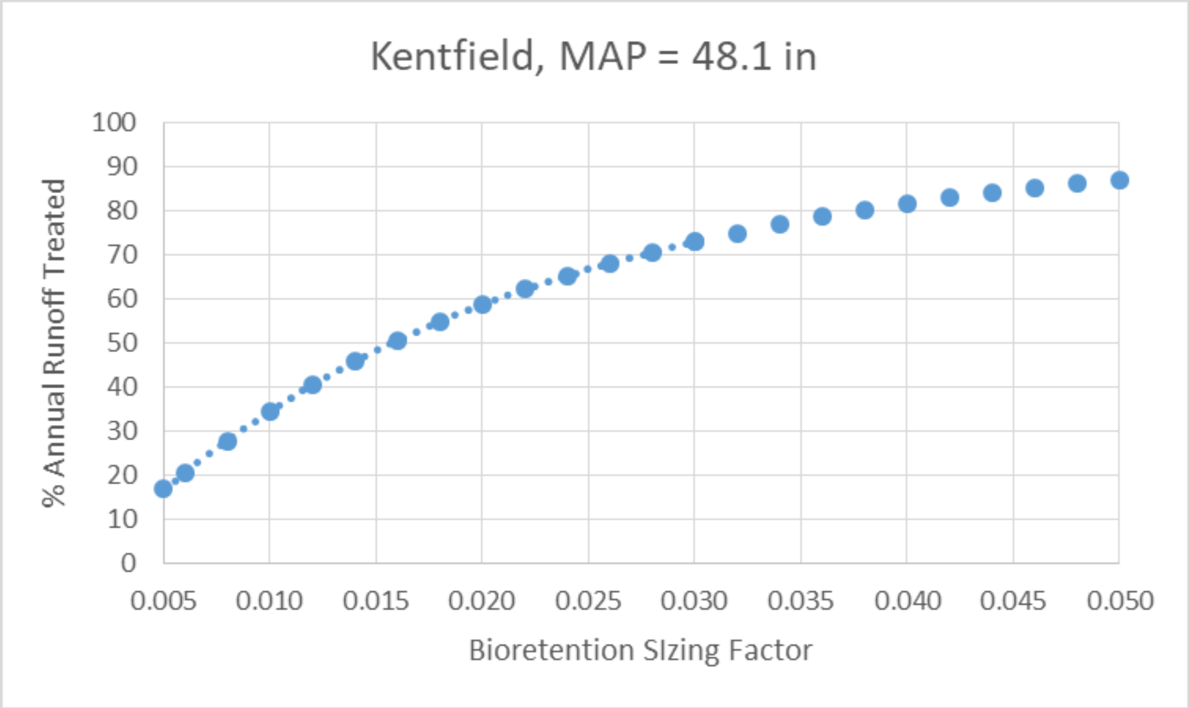


Figure 24. Annual treatment percentage for the Kentfield rain gauge

Appendix C: Bioretention with No Underdrain, 12-inch Surface Reservoir Results

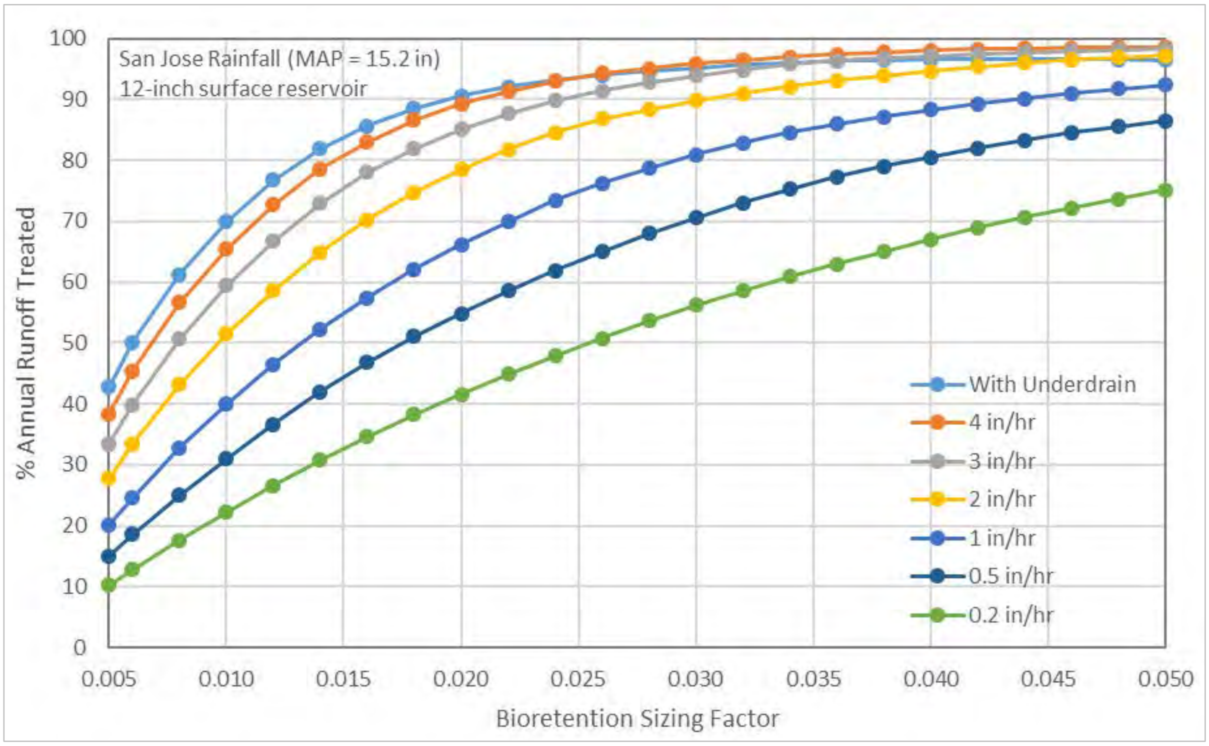


Figure 25. Treatment results for bioretention with no underdrain, San Jose gauge (MAP = 15.2 in)

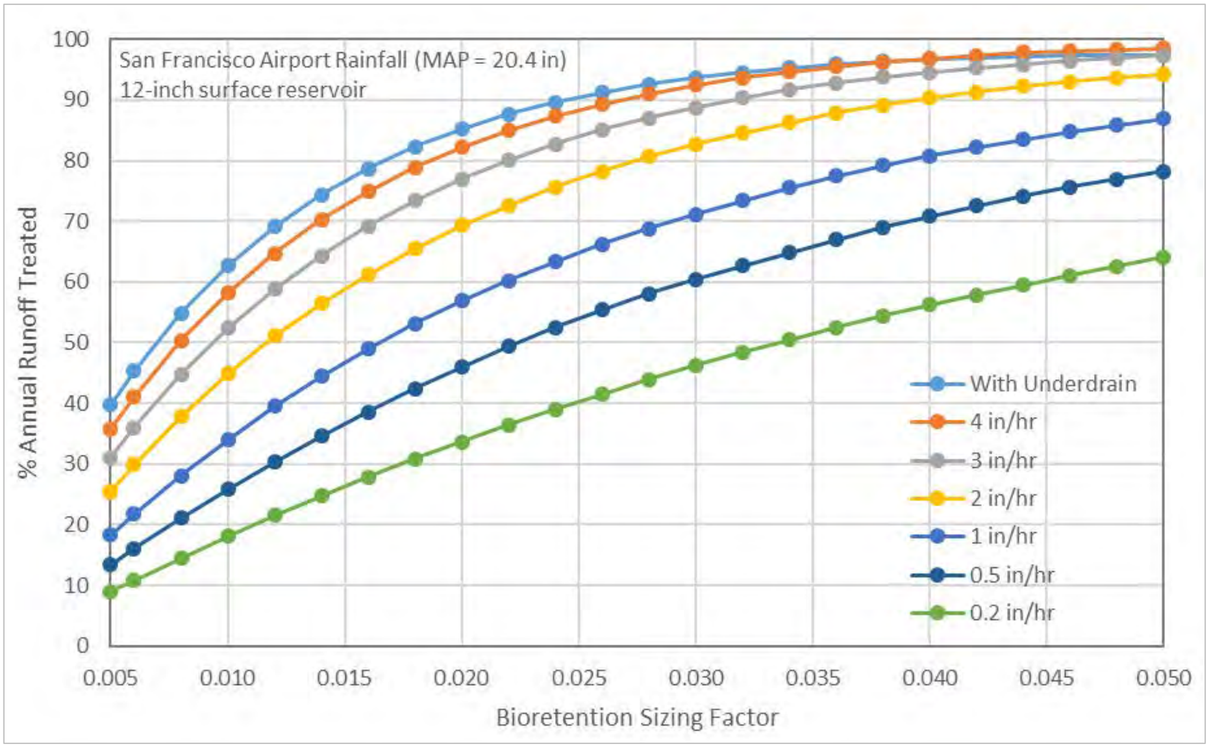


Figure 26. Treatment results for bioretention with no underdrain, San Jose gauge (MAP = 15.2 in)

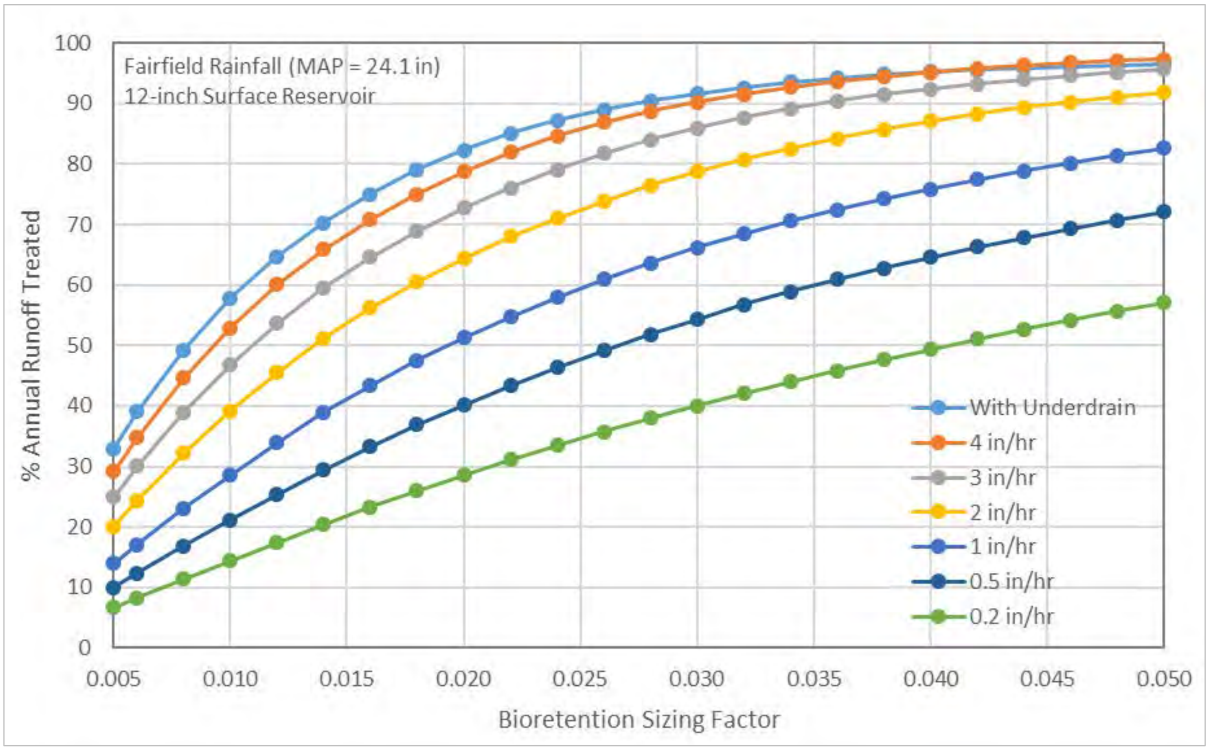


Figure 27. Treatment results for bioretention with no underdrain, San Jose gauge (MAP = 15.2 in)