Chapter 5: General Technical Guidance for Treatment Measures

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Introduction

This general technical information in this section applies to the full range of stormwater treatment measures for all types of new development and redevelopment projects. See Chapter 6 for technical guidance tailored to specific types of stormwater treatment measures. See Chapter 3 and 4 of the GI Design Guide for example designs incorporating the typical guidance recommendations included in this chapter.

5.1 Hydraulic Sizing Criteria

Stormwater treatment measures on regulated projects[17] are sized to treat runoff from ***relatively small sized storms*** that comprise the vast majority of storms. The intent is to treat most of the stormwater runoff, recognizing that it would be infeasible to size stormwater treatment measures to treat runoff from large storms that occur every few years. (See Section 5.6 for more information on how stormwater treatment measures that are sized to treat runoff from small, frequent storms can be designed to also handle flows from large, infrequent storms).

How Much of Project Site Needs Stormwater Treatment?

The Municipal Regional Stormwater Permit requires all regulated projects must provide stormwater treatment for runoff from the project site. Municipalities may require stormwater treatment for projects that are smaller than the regulated project threshold or meet other criteria, and in these cases, stormwater treatment is required to the maximum extent practicable (MEP) as determined by the permitting municipality. Exceptions to the stormwater treatment requirement for regulated projects are pervious areas that are "self-treating" (including areas of pervious pavement with a hydraulically-sized aggregate base layer) as described in Section 4.2, and "self-retaining areas" designed to store and infiltrate runoff from rooftops or paved areas as described in Section 4.3.

Flow-Based Versus Volume-Based Treatment Measures

For hydraulic sizing purposes, stormwater treatment measures can be divided generally into three groups: flow-based, volume-based, and treatment measures that use a combination of flow and volume capacity. The ***flow-based treatment measures*** remove pollutants from a moving stream of stormwater through filtration, infiltration or biological processes, and the treatment measures are sized based on hourly or peak flow rates. Examples of flow-based treatment measures include bioretention areas, flow-through planters, media filters and high flow-rate tree well filters. The ***volume-based treatment measures*** detain stormwater for periods of time to allow treatment through settling and/or infiltration processes or use of stormwater for irrigation or indoor non-potable demands. Examples of volume-based stormwater treatment measures include pervious pavement, infiltration trenches, sub-surface infiltration galleries and rainwater harvesting systems. Flow-through planters and bioretention areas are typically sized using flow-based hydraulic sizing criteria, but in constrained areas they may use a ***combination of flow and volume capacity*** for stormwater treatment. Table 5-1 shows which hydraulic sizing method is appropriate for commonly used stormwater treatment measures.

[17] "Regulated projects" are projects that create and/or replace 10,000 square feet or more of impervious surface and 5,000 square feet of impervious surface for surface parking areas, restaurants, auto service facilities, and gasoline outlets. See Section 2.3.1 of this Guide for more details.

Table 5-1: Flow and Volume Based Treatment Measure Designs

	Type of Treatment Measure	Type of Hydraulic Sizing Criteria to Use
6.1	Bioretention	Flow-based or combination flow and volume
6.2	Flow-through planter	Flow-based or combination flow and volume
6.3	Tree well filter	Flow-based
6.4	Infiltration trench	Volume-based
6.5	Extended detention basin	Volume-based
6.6	Pervious pavement[18]	Volume-based
6.7	Reinforced grid paving	Volume-based
6.8	Green roof	Volume-based
6.9	Rainwater harvesting	Volume-based
6.10	Media filter	Flow-based
6.11	Subsurface infiltration system	Volume-based

5.1.1 Volume-Based Sizing Criteria

The Municipal Regional Stormwater Permit specifies two alternative methods for hydraulically sizing volume-based stormwater treatment measures. One of the permit-approved methods, the "Urban Runoff Quality Management Approach," is based on simplified procedures that are ***not recommended*** for use when information is available from continuous hydrologic simulation of runoff using local rainfall records (see "Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87.) Because the results of continuous simulation modeling based on local rainfall are available, ***the Countywide Program recommends using the "California BMP Handbook Approach," or "80 percent capture method",*** shown in the text box.

Volume-Based Sizing Criteria

Design volume-based treatment measures to treat stormwater runoff equal to the volume of annual runoff required to achieve 80 percent or more capture, determined in accordance with methodology set forth in Appendix D of the California Stormwater BMP Handbook, using local rainfall data.

The ***80 percent capture method*** should be used when sizing volume-based treatment measures. The 80 percent runoff value is determined by running a continuous simulation hydrologic model to convert rainfall

[18] In order to be considered self-treating areas or self-retaining areas, as described in Sections 4.2 and 4.3, areas with pervious pavement and reinforced grid paving need to be sized to store and infiltrate/evapotranspirate the water quality design volume in the pore space of supporting media.

to runoff based on a long-term local rainfall record[19]. This method for sizing volume-based stormwater treatment measures is described in the California Stormwater Quality Association's 2003 Stormwater BMP Handbook New Development and Redevelopment, and is the basis for the method described below.

To size volume-based treatment measures, use the following steps, which may be performed using the volume-based sizing criteria Excel worksheet referred to in Appendix B.

1. **Identify Rainfall Region and Site Mean Annual Precipitation (MAP)**

   Determine which rainfall region the project site is located in using Figure 1 in Appendix C. San Mateo County has been divided into seven different regions based on local rainfall patterns. Use Figure 2 to determine the MAP of the project site.

2. **Determine the Effective Impervious Area for Each Drainage Management Area**

   - Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to a treatment measure. Implement the steps below for each DMA with a volume-based treatment measure.
   - Minimize the amount of landscaping or pervious pavement that will contribute runoff to the treatment measures. Refer to Sections 4.2 and 4.3 to design areas of landscaping or pervious pavement as "self-treating areas" or "self-retaining areas," so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.
   - For each DMA in which 5 percent or more of the area that will contribute runoff to the treatment measure includes pervious surfaces (landscaping or properly designed pervious pavement), multiply the area of pervious surface by a factor of 0.1. Then add the product obtained in the previous step to the area of impervious surface, to obtain the "effective impervious area". For DMAs with less than 5 percent pervious area, use the entire DMA area as the effective impervious area.

3. **Unit Basin Storage Volume**

   - Refer to Table 5-2 to determine the ***unit basin storage volume*** that corresponds to the rainfall region. When using the effective impervious area method, use the unit basin storage volume corresponding to a runoff coefficient of 1.0.
   - Adjust the unit basin storage volume to the appropriate value for the project site by applying the following correction factor based on the ratio of the mean annual precipitation (MAP) of the project site to the MAP of the reference rain gage:

     $$\text{Correction factor} = MAP_{site} \div MAP_{gage}$$

     For example, if the MAP of the site is 23 inches, and the site is in Region 5 (San Francisco) with a reference gage MAP of 21 inches, the correction factor would be 23/21 inches, or 1.095.

     Multiply the unit basin storage volume by the correction factor to get the ***adjusted unit basin storage volume***.
   - Calculate the ***water quality design volume ("C.3.d volume")*** by multiplying the effective impervious area of the drainage management area, determined in step 2, by the adjusted unit basin storage volume (in units of inches converted to feet). For example, if the adjusted unit basin storage volume

[19] The Storage, Treatment, Overflow, Runoff Model (STORM) developed by the U.S. Army Corps of Engineers was used to generate the 80 percent runoff values in this guidance manual.

is determined to be 0.5 inches, and the effective impervious area draining to the bioretention facility is 7,000 square feet. Then the required capture volume would be 0.5 inches × (1 foot/12 inches) × 7,000 square feet = 292 cubic feet.

Table 5-2: Unit Basin Storage Volumes in Inches for 80 Percent Capture Using 48-Hour Drawdown Time

		Unit Basin Storage Volume for Effective Impervious Area of Drainage Management Area
Region[1]	Meteorological Station and Mean Annual Precipitation (Inches)	Coefficient of 1.00
1	Boulder Creek, 55.9"	2.04
2	La Honda, 24.4"	0.86
3	Half Moon Bay, 25.9	0.82
4	Palo Alto, 14.6"	0.64
5	San Francisco, 21.0"	0.73
6	San Francisco Airport, 20.1"	0.85
7	San Francisco Oceanside, 19.3"	0.72
Source: CDM memo dated May 14, 2004 [1] See Appendix C to locate the applicable Treatment Measure Design Criteria Region.		

4. Depth of Infiltration Trench or Pervious Pavement Base Layer

If designing an infiltration trench, or area of pervious pavement that will receive runoff from impervious surfaces, determine the surface area that is available for the trench, or the area of pervious pavement. Given that surface area, the depth required for the trench or for the aggregate base layer below the pervious pavement (***below the underdrain***), may be calculated by dividing the required capture volume by 0.35 (which represents the assumed void space available within the rock-filled trench or base), and then dividing the rock volume by the surface area of the proposed trench or area of pervious pavement.

5.1.2 Flow-Based Sizing Criteria

The Municipal Regional Stormwater Permit specifies three alternative methods for hydraulically sizing flow-based stormwater treatment control measures. These three methods are described in Table 5-3.

Table 5-3: Flow-based Sizing Criteria Included in MRP Provision C.3.d

Flow-based Sizing Criteria	Description	Practice Tips
Percentile Rainfall Intensity	Ranks the hourly depth of rainfall from storms over a long period, determines the 85th percentile hourly rainfall depth, and multiplies this value by two.	This approach requires hydrologic studies that have not been conducted in San Mateo County.
0.2 Inch-per-Hour Intensity ***(Recommended Method)***	Simplification of the Percentile Rainfall Intensity Method: the flow of runoff resulting from a rainfall intensity equal to 0.2 inches/hour	The 4 percent sizing method, which is recommended for use throughout San Mateo County, is derived from this approach.
10% of the 50-year peak flow rate ("Factored Flood Flow Approach")	Rainfall intensity is determined using Intensity-Duration-Frequency curves published by the local flood control agency or climactic data center.	This approach may be used if the 50-year peak flow has been determined. This approach has not been used locally.

The percentile rainfall intensity method is based on ranking the hourly depth of rainfall from storms over a long period, determining the 85th percentile hourly rainfall depth and multiplying by two. For rain gages in the Bay Area at lower elevations, the resulting value is generally around 0.2 inches/hour. The permit also allows the use of 0.2 inches/hour as one of the three alternative methods regardless of the results from calculating values from local rainfall depths.

Sizing Bioretention Areas

For design of bioretention areas, the 0.2 inches/hour criteria can be simplified to the "4 percent method," which assumes a runoff inflow of 0.2 inches per hour, and an infiltration rate through Biotreatment Soil Media (BSM) of 5 inches per hour (0.2 in/hr divided by 5 in/hr = 0.04). Because two of the permit allowed methods yield similar results and the third method requires data that may not be readily available, the ***Countywide Program recommends using the 4 percent method to design bioretention areas*** and other LID treatment systems that may use flow-based hydraulic sizing criteria.

Remember

The Countywide Program **recommends the use of the 4% method** (which is based on a rainfall of 0.2 inches/hour) to hydraulically size bioretention areas in regulated projects.

The 4 percent method requires the surface area of the treatment measure to be 4 percent of the impervious area that drains to it (1,750 square feet of bioretention area per impervious acre). If areas of landscaping or pervious pavement contribute runoff to the treatment measure, the area of these pervious surfaces is multiplied by a factor of 0.1 to obtain the amount of "effective impervious surface" (as described in Section 5.1.1).

To apply the 4 percent method, use the following steps.

1. Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to one LID treatment measure. Implement Steps 2 through 5 for each DMA.
2. Minimize the amount of landscaping or pervious pavement that will contribute runoff to the LID treatment measures. Refer to Sections 4.2 and 4.3 to design areas of landscaping or pervious pavement as "self-treating areas" or "self-retaining areas," so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.
3. For each DMA in which 5 percent of more of the area that will contribute runoff to the treatment measure consists of pervious surfaces (landscaping or pervious pavement), multiply the area of pervious surface by a factor of 0.1.
4. For applicable DMAs, add the product obtained in Step 3 to the area of impervious surface, to obtain the area of "effective impervious surface."
5. Multiply the impervious surface (or effective impervious surface in applicable DMAs) by a factor of 0.04. This is the required surface area of the LID treatment measure.

Appendix B includes an example of sizing bioretention areas using the 4 percent method.

Sizing Other Flow-Based Treatment Measures

Other flow-based stormwater treatment measures, such as media filters (where allowed on a project), are sized using the Rational Method, which computes the runoff resulting from the design rainfall intensity. The Rational Method formula is:

$$Q=CiA$$

Where:

Q= flow in cubic feet/second

C= composite runoff coefficient (unitless – see Table 5-4)

i = rainfall intensity in inches/hour

A= drainage area in acres

To compute the water quality design flow, ***use the following steps***:

1. Determine the ***runoff coefficient,*** "C," from Table 5-4. Note that it is more accurate to compute an area-weighted "C-factor" based on the surfaces in the drainage area, if possible, than to assume a composite C-factor.
2. Use a design intensity of ***0.2 inches/hour*** for "i" in the Q=CiA equation.
3. Determine the ***drainage area***, "A," in acres for the stormwater treatment measure.
4. Determine the design flow (Q) using Q = CiA:

   Q = [Step 1] × 0.2 in/hr × [Step 3] = ______ cubic ft/sec[20]

[20] Note that the Rational Method formula produces a result with units of "acre-in/hour"; however, the conversion factor from acre-in/hour to cubic feet/second is approximately 1.0.

Table 5-4: Estimated Runoff Coefficients for Various Surfaces During Small Storms

Type of Surface	Runoff Coefficients "C" factor
Roofs	0.90
Concrete	0.90
Asphalt	0.90
Grouted pavers	0.90
Pervious concrete	0.10
Pervious asphalt	0.10
Pervious or permeable pavers	0.10
Reinforced grid paving with grass or aggregate surface	0.10
Crushed aggregate	0.10
Grass	0.10
Note: These C-factors are only appropriate for small storm treatment design and should not be used for flood control sizing. When available, locally developed small storm C-factors for various surfaces may be used.	

5.1.3 Combination Flow and Volume Design Basis

The Countywide Program recommends the use of the 4 percent method for sizing flow-based LID treatment facilities wherever possible, in order to maximize infiltration of treated runoff from these facilities. The 4 percent method, in which the surface area of the treatment measure is designed to be 4 percent of the impervious area that drains to the treatment measure, is conservative in that it does not account for any storage provided in the surface ponding area of the treatment facility.

For projects on sites where infiltration should be avoided, or that are planned to maximize density at redevelopment or infill[21] sites, municipal staff may allow the use of the combination flow and volume design basis for bioretention areas and flow-through planters. In these treatment measures, volume-based treatment is provided when stormwater is stored in the surface ponding area. The surface ponding area may be sized so that the ponding area functions to retain water before it enters the soil at the design surface loading rate of 5 inches per hour required by MRP Provision C.3.c(2)(b)(vi).

[21] For the purpose of selecting hydraulic sizing criteria, this Guide defines infill sites as properties served by existing roadways and other infrastructure, for which all adjacent properties are occupied by existing development or have previously been developed. Redevelopment sites are defined as properties occupied by existing development that will be removed, or partially removed, to construct the proposed project. Individual municipalities may have stricter definitions for the purpose of selecting hydraulic sizing criteria.

Provision C.3.d of the MRP specifies that treatment measures 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 sizing approach is best applied when using a continuous simulation hydrologic model to demonstrate that a treatment system is in compliance with C.3.d. However, when doing sizing calculations by hand, compliance with C.3.d. can be demonstrated by showing how the treatment system design meets both the flow-based and volume-based criteria.

Where allowed by the municipality, lined bioretention areas and flow-through planters in locations where infiltration should be avoided or on redevelopment or infill sites (as defined above) may use the approach described below to take into consideration both the flow of stormwater through the planting media and the volume of stormwater in the surface ponding area. This approach will allow for a reduction in the surface area of the treatment measure, which may be appropriate for projects that are planned to maximize density at redevelopment or infill sites, and therefore offer environmental benefits such as reduced disturbance of previously undeveloped land and reduced vehicle miles traveled, when compared with comparable development projects in areas with little or no prior development.

To apply the combination flow and volume approach, use the following steps, which may be performed using the combination flow and volume sizing criteria Excel worksheet referred to in Appendix B. Note the first three steps below are the same as the first three steps to size volume-based treatment measures on page 48.

1. ***Identify Rainfall Region and Site Mean Annual Precipitation (MAP)***
   - Determine which rainfall region the project site is located in using Figure 1 in Appendix C. San Mateo County has been divided in to seven different regions based on local rainfall patterns. Use Figure 2 to determine the MAP of the project site.
2. ***Determine the Effective Impervious Area for Each Drainage Management Area***
   - Based on the topography of the site and configuration of buildings, divide the site into drainage management areas (DMAs), each of which will drain to a treatment measure. Implement the steps below for each DMA with a volume-based treatment measure.
   - Minimize the amount of landscaping or pervious pavement that will contribute runoff to the treatment measures. Refer to Sections 4.2 and 4.3 to design areas of landscaping or pervious pavement as "self-treating areas" or "self-retaining areas," so that they do not contribute runoff to the LID treatment measure and may be excluded from the DMAs for the treatment measures.
   - For each DMA in which 5 percent or more of the area that will contribute runoff to the treatment measure includes pervious surfaces (landscaping or properly designed pervious pavement), multiply the area of pervious surface by a factor of 0.1. Then add the product obtained in the previous step to the area of impervious surface, to obtain the "effective impervious area". For DMAs with less than 5 percent pervious area, use the entire DMA area as the effective impervious area.
3. ***Unit Basin Storage Volume***
   - Determine the ***unit basin storage volume*** from Table 5-2 based on the composite effective impervious area runoff coefficient of 1.0 and the rain gauge area.

- Adjust the unit basin storage volume to the appropriate value for the project site by applying the following correction factor based on the ratio of the mean annual precipitation (MAP) of the project site to the MAP of the reference rain gage:

$$\text{Correction factor} = MAP_{site} \div MAP_{gage}$$

  For example, if the MAP of the site is 23 inches, and the site is in Region 5 (San Francisco) with a reference gage MAP of 21 inches, the correction factor would be 23/21 inches, or 1.095.

  Multiply the unit basin storage volume by the correction factor to get the adjusted unit basin storage volume.

- Calculate the ***water quality design volume ("C.3.d volume")*** by multiplying the effective impervious area of the DMA, calculated in step 2, by the adjusted unit basin storage volume (in units of inches converted to feet). For example, if the adjusted unit basin storage volume is determined to be 0.5 inches, and the effective impervious area draining to the bioretention facility is 7,000 square feet. Then the required capture volume would be 0.5 inches × (1 foot/12 inches) × 7,000 square feet = 292 cubic feet.

4. *Estimate the Duration of the Rain Event*

- Assume that the rain event that generates the required design volume of runoff determined in Step 3 occurs at a constant rainfall intensity of 0.2 inches/hour from the start of the storm (i.e., assume a rectangular hydrograph). Calculate the ***duration of the rain event*** by dividing the adjusted unit basin storage volume by the intensity. In other words, determine the amount of time required for the unit basin storage volume to be achieved at a rate of 0.2 inches/hour. For example, if the unit basin storage volume is 0.5 inches, the rain event duration is 0.5 inches ÷ 0.2 inches/hour = 2.5 hours.

5. *Make a Preliminary Estimate of the Surface Area of the Facility*

- Make a ***preliminary estimate of the surface area*** of the bioretention facility by multiplying the DMA's area of impervious surface (or equivalent impervious surface from step 4, if applicable) by the 4 percent method sizing factor of 0.04. For example, a drainage area of 7,000 square feet of impervious surface × 0.04 = 280 square feet of bioretention treatment area.
- Assume a bioretention area that is about 25% smaller than the bioretention area calculated with the 4 percent standard. Using the example above, 280 – (0.25 × 280) = 210 square feet.
- ***Calculate the volume of runoff that filters through the treatment soil*** at a rate of 5 inches per hour (the design surface loading rate for bioretention facilities), for the duration of the rain event calculated in Step 5. For example, for a bioretention surface area of 210 square feet, with an infiltration rate of 5 inches per hour for a duration of 2.5 hours, the volume of treated runoff = 210 square feet × 5 inches/hour × (1 foot/12 inches) × 2.5 hours = 219 cubic feet.

6. *Initial Adjustment of Depth of Surface Ponding Area*

- Calculate the portion of the water quality design volume ***remaining after treatment is accomplished by filtering*** through the treatment soil. The result is the amount that must be stored in the ponding area above the reduced bioretention area assumed in Step 6. For example, the amount remaining to be stored comparing Step 6 and Step 9 is 292 cubic feet – 219 cubic feet = 73 cubic feet. If this volume is stored over a surface area of 210 square feet, the average ponding depth would be 73 cubic feet ÷210 square feet = 0.35 feet or 4.2 inches.

- Check to see if the ***average ponding depth is approximately 6 inches (or up to a maximum of 12 inches if allowed by the municipality)***, which is the recommended ponding depth in a bioretention facility or flow-through planter.

7. Optimize the Size of the Treatment Measure

- If the ponding depth is less than 6 inches, the bioretention design can be optimized with a smaller surface area (i.e., repeat Steps 6 and 7 with a smaller area). If the ponding depth is greater than 6 inches (or the depth allowed by the municipality), a larger surface area will be required. (In the above example, the recommended size of the bioretention area is 190 square feet with a ponding depth of 6 inches.)

Appendix B includes an example of sizing bioretention areas using the combination flow and volume-based method.

5.2 Applicability of Non-Low Impact Development (LID) Treatment Measures

Since December 1, 2011, the MRP has placed ***restrictions on the use of non-LID treatment measures.*** However, per Provision C.3.e, Special Projects may be allowed some limited use of two types of non-LID treatment measures for stand-alone treatment of stormwater - vault-based media filters and high flow rate tree well filters – if allowed by the municipality. As further discussed in Appendix J of this Guide, Special Projects that meet certain criteria are allowed to treat specified percentages of the C.3.d amount of stormwater runoff with these non-LID treatment measures. Alternatively, the municipality may choose to require 100% LID treatment of all on-site runoff and disregard the options in C.3.e. See Appendix J for additional guidance on Special Projects.

> **Key Point**
>
> Since December 1, 2011, there have been restrictions on the use of non-LID treatment measures.

Underground vault-based, non-LID treatment measures typically require frequent maintenance to function properly, and experience has shown that because these systems tend to be "out of sight, out of mind," they often do not receive adequate maintenance. Where underground vaults are allowed, they must be sealed to prevent mosquito access, or be designed to completely drain or have no standing water for longer than 72 hours, and include suitable access doors and hatches to allow for frequent inspections and maintenance. But even when maintained properly, many underground vault systems lack the detention time required to remove ***pollutants associated with fine particles.*** See Appendix D for more information regarding non-LID treatment measures.

The GI Design Guide has additional information on the use and maintenance of non-LID measures and alternative GI measures. See Chapter 2 for design information and Chapter 6 for maintenance information of non-LID measures such as media filters, tree well filters with high-flow rate media and underground trash capture device vaults as well as alternative GI measures such as vegetated swales, stormwater trees and green gutters.

5.3 Using Manufactured Treatment Measures

In the limited cases (Special Projects) where a municipality does approve the use of one or more manufactured treatment measures in a development project, the project applicant is responsible for installing the unit(s) so that they will function as designed and for following the manufacturer's instructions for maintenance. When installed and maintained properly, manufactured media filters (see Section 6.10) may have adequate pollutant removal levels for fine particles and their attached pollutants. Media filters typically include two chambers: the first chamber allows coarse solids to settle, and the second contains the filters that consist of a proprietary media. When installed and maintained properly, hydrodynamic separators may be effective in removing trash and coarse sediment, but not dissolved pollutants, and they may be installed upstream of other treatment measures.

The ***applicant is responsible*** for ensuring that the manufactured treatment measures used in the project are sized in accordance with the Provision C.3.d hydraulic sizing criteria to treat the amount of runoff that will flow to these treatment measures. The surface loading rate of the media filter should be based on the Washington State TAPE approved rate (see Section 6.10).

Planning permit submittals should include a description of the product(s) proposed for use, along with preliminary sizing calculations, and conceptual plans showing the proposed locations of treatment measures on the site. ***Building permit submittals*** should include detailed sizing calculations, construction-level drawings, and a copy of the manufacturer's instructions for construction and maintenance. Maintenance plans for manufactured treatment measures must follow the manufacturer's maintenance instructions.

5.4 Using Treatment Trains

Stormwater can be directed to flow through a series of different types of stormwater treatment measures that are each designed to treat different broad categories of stormwater pollutants. These groupings of stormwater treatment measures have been called "stormwater treatment trains" or a "multiple treatment system." The use of a ***series of treatment measures*** is most effective where each treatment measure optimizes the removal of a particular type of pollutant, such as coarse solids and debris, pollutants associated with fine solids, and dissolved pollutants. Targeting specific treatment processes by constituent is referred to as "unit process" design. ***Each stormwater treatment measure in a treatment train should be sized using the appropriate Provision C.3 numeric sizing criteria.***

Key Point

What Is A Treatment Train?

A treatment train is a multiple treatment system that uses two or more stormwater treatment measures in series, for example, a settling basin/ infiltration trench combination

The simplest version and most common use of a treatment train consists of ***pretreatment*** prior to the stormwater reaching the main treatment system. For example, a hydrodynamic separator can be used to remove trash and coarse sediment upstream of a media filter or subsurface infiltration system. ***Note that non-LID treatment measures may be used in the treatment train as long as the last measure in the train is a LID treatment measure.***

Another option for a treatment train is to provide upstream storage for a treatment measure which may allow the treatment measure to be reduced in size. For example, a rainwater cistern may be used to store and slowly release water to a bioretention facility. Conversely, the bioretention facility can be used to treat the overflow from the cistern if there is insufficient irrigation or toilet flushing demand to empty the cistern prior to the next rain event.

5.5 Infiltration Guidelines

Infiltration is a preferred LID treatment measure and a cost-effective method to manage stormwater – if the conditions on the site allow. A wide-range of site-design measures and stormwater treatment measures can be used to increase stormwater infiltration and can be categorized as follows.

- *Site design measures* -- such as clustering development or otherwise laying out the site to reduce impervious area, routing drainage from building roofs to landscaped areas, and using pervious pavement.
- *Indirect infiltration* methods, which allow stormwater runoff to percolate ***into surface soils***. Runoff may reach groundwater indirectly, or it may be underdrained into subsurface pipes. Examples of indirect infiltration methods include bioretention areas and shallow infiltration trenches or basins. Unless geotechnical considerations preclude it, all projects should maximize infiltration of stormwater runoff through methods such as bioretention (see Section 6.1).
- *Direct infiltration* methods, which are designed to ***bypass surface soils*** and transmit runoff directly to subsurface soils for groundwater recharge. These types of devices must be located and designed to limit the potential for stormwater pollutants to reach groundwater. Examples of direct infiltration methods include deep infiltration trenches and dry wells. Direct infiltration systems are regulated by the EPA (Class V well certification) and pretreatment is required. Direct infiltration measures may also require coordination with local groundwater purveyors and/or public health agencies. In San Mateo County, contact the Groundwater Protection Program of the County Health Department[22].

The local jurisdiction may require a geotechnical review for the project, or, at a minimum, information regarding the site's hydrologic soil type. When selecting site design and stormwater treatment measures that promote on-site infiltration, be sure to ***follow the geotechnical engineer's recommendations*** based on soil boring data, drainage pattern, and the current requirements for stormwater treatment. The geotechnical engineer's input will be essential to prevent damage from infiltrated water to surrounding properties, structures and/or public improvements.

> **Warning**
>
> Follow the geotechnical engineer's recommendations for infiltration-based treatment measures to prevent any damage to surrounding properties.

Appendix E provides guidelines to help determine whether the project site is suitable for using site design and/or stormwater treatment measures that increase stormwater infiltration. Appendix E also describes regulatory requirements that apply to direct infiltration methods, as well as practical tips for design and construction.

[22] For more information, go to www.smchealth.org/gpp.

5.6 Bypassing High Flows

Although stormwater treatment measures are sized to remove pollutants from flows resulting from frequent, small storms, projects must be designed to handle flows for stormwater treatment and drainage from large infrequent flows to ***prevent flooding***. The integration of flood control and stormwater treatment may be accomplished in one of two ways, which are described below.

One option is to have the flows that are larger than those required by the hydraulic sizing criteria (given in Section 5.1) handled ***within the stormwater treatment measure.*** This includes making sure that landscape-based treatment measures do not re-suspend and flush out pollutants that have been accumulating during small storms, and that landscape-based stormwater treatment measures do not erode during flows that will be experienced during larger storms. Most extended detention basins are designed to handle flood flows, although they would not be providing much treatment during these flows. The technical guidance in Chapter 6 for treatment measures that operate in this manner includes design standards to accommodate flood flows associated with larger storms.

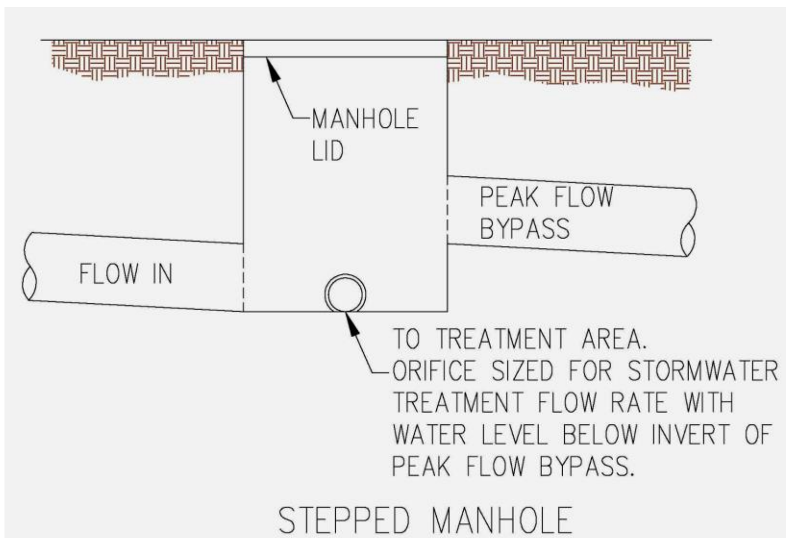


Figure 5-1: Stepped manhole design directs low flows to treatment measure and diverts high flows to storm drain system. (Credit: BKF Engineers)

Bioretention areas, flow-through planter boxes, and other treatment systems that rely on filtering or infiltrating stormwater through soils must have overflow systems that allow flood flows larger than the increment of flow that can be treated to bypass the stormwater treatment measure. These systems have to include an alternative flow path for high flows, otherwise stormwater would back up and flood the project area. The technical guidance in Chapter 6 for treatment measures that operate in this manner includes design standards for high-flow bypasses.

For some types of stormwater treatment measures that are designed as low-flow systems, it is often necessary to restrict stormwater flows and ***bypass the flows around the facility.*** In these instances the stormwater treatment measures are designed to treat only the water from small storm events. Bypassing larger flows helps prevent hydraulic overload and resuspension of sediment, and it can protect stormwater treatment measures from erosion.

Flow splitter devices may be used to direct the design runoff flow into a stormwater treatment measure, and bypass excess flows from larger storm events around the facility into a bypass pipe or channel. The bypass may connect directly to the storm drain system, or to another stormwater treatment measure that designed to handle high flows. This can be accomplished using a stepped manhole (Figure 5-1), a vault or box with a weir (Figures 5-3 and 5-4) or a proprietary flow splitter. As illustrated in Figure 5-2, runoff enters the device by way of the inlet at the left side of the figure; low flows are conveyed to the stormwater treatment measure by way of the outlet pipe at the lower right. Once the treatment measure reaches its design capacity, water backs up in the low-flow outlet pipe and into the flow splitter. When the water level in the flow splitter reaches the bypass elevation, stormwater begins to flow out the overflow pipe in the upper right of the figure, bypassing the stormwater treatment measure. The bypass generally functions by means of a weir inside the flow splitter device.

Figure 5-2: StormGate^{TM} proprietary flow splitter structure. (Credit: Contech Construction Products Inc). The use of this illustration is for general information only and is not an endorsement of this or any other proprietary device.

Figure 5-3: Details of flow splitter boxes - *Left*: Flow splitter vault with weir
Right: Flow splitter box with weir (Credit: EOA Inc)

5.7 Plant Selection and Maintenance

Selecting the appropriate plants and using sustainable, horticulturally sound landscape installation and maintenance practices are essential components of a successful landscape-based stormwater treatment measure. ***See Section 4.11 and Chapter 6 of the GI Design Guide for additional guidance on these topics.***

Plant Selection Guidance

Plant selection must consider the type of development and location, uses on the site and an appropriate design aesthetic. Ideally, a Landscape Architect will be involved as an active member of the design team ***early in the site design phase*** to review proposed stormwater measures and coordinate development of an integrated solution that responds to all of the various site goals and constraints. In some cases, one professional will design a stormwater control, while another designs the rest of the landscaping. In these situations it is essential for the professionals to work together very early in the process to integrate their designs. Appendix A provides user-friendly guidance in selecting planting appropriate to the landscape-based stormwater treatment measures included in Chapter 6 and the site design measures in Chapter 4.

This plant guidance applies to systems designed to retain up to 6” of runoff. When deeper systems are used, have the plant selection verified by a landscape architect. Developers and design teams can also select plant materials outside of the list in Appendix A, but should consult with a landscape architect or horticulturalist, and may require approval from the municipality.

Bay-Friendly Landscaping (ReScape California)

Bay-Friendly Landscaping is a holistic approach to the ***design, construction and maintenance*** of landscapes in order to support the integrity and sustainability of the local watershed. Project sponsors are encouraged to use landscape professionals who are familiar with and committed to implementing Bay-Friendly (and Ocean-Friendly) Landscaping practices from the initial plant selection through the long-term maintenance of the site. Rescape Qualified Professionals receive training on Bay-Friendly principles and practices and certification from ReScape California. Appendix A summarizes Bay-Friendly Landscaping practices that may be implemented to benefit the water quality of the Bay, Ocean and their tributaries, based on the Bay-Friendly Landscaping Guidelines (available at www.rescapeca.org)[24]. ReScape California’s eight principles for regenerative landscapes are shown in Figure 5-5.

Figure 5-4: ReScape Principles (Credit: ReScape California)

[24] The Bay-Friendly Landscaping Coalition changed its name in 2016 to ReScape California.

Integrated Pest Management

Integrated pest management (IPM) is a holistic approach to mitigating insects, plant diseases, weeds, and other pests. Projects that require a landscaping plan as part of a development project application are encouraged to use IPM, as indicated in each agency's source control measures list. ***Avoiding pesticides and quick release synthetic fertilizers*** is particularly important when maintaining stormwater treatment measures to protect water quality. IPM is one aspect of the Bay-Friendly Landscaping program.

Figure 5-5: Beneficial insects can help control pests.

IPM encourages the use of many strategies for first preventing, and then controlling, but not eliminating, pests. It places a priority on fostering a healthy environment in which plants have the strength to resist diseases and insect infestations, and out-compete weeds. Using IPM requires an understanding of the life cycles of pests and beneficial organisms, as well as regular monitoring of their populations. When pest problems are identified, IPM considers all viable solutions and uses a combination of strategies to control pests, rather than relying on pesticides alone. As a last resort pesticides with low levels of toxicity may be used. More information on IPM is included in Appendix A.

Warning

Avoid pesticides and synthetic fertilizers to protect water quality.

Wetland Regulations and Treatment Measures

The Water Board's "Policy on the Use of Constructed Wetlands for Urban Runoff Pollution Control" (Resolution No. 94-102) recognizes that stormwater treatment wetlands that are constructed and operated pursuant to Resolution 94-102 and are constructed outside a creek or other receiving water are stormwater treatment systems, and, as such, are not waters of the United States subject to Sections 401 and 404 of the federal Clean Water Act.

Water Efficient Landscaping Requirements

The California Water Conservation in Landscaping Act of 2006 requires municipalities to adopt, by January 1, 2010, landscape water conservation ordinances that are at least as effective with regard to water conservation as the Model Water Efficient Landscape Ordinance (MWELO) prepared by the Department of Water Resources (DWR). The MWELO automatically went into effect, on January 1, 2010, in municipalities that have not adopted a local Water Efficient Landscape Ordinance (WELO).

The California Water Commission approved the revised MWELO on July 15, 2015. The deadline for local agencies to adopt the MWELO or adopt their own WELO, which must be at least as effective in conserving water, was December 1, 2015. The deadline for local agencies creating a regional ordinance was February 1, 2016. The MWELO is scheduled for another update in 2020.

Most new and rehabilitated landscapes are subject to a WELO. The MWELO applies to the following public and private development projects:

1. New construction projects with an aggregate landscape area equal to or greater than 500 square feet requiring a building or landscape permit, plan check or design review; or
2. Rehabilitated landscape projects with an aggregate landscape area equal to or greater than 2,500 square feet requiring a building or landscape permit, plan check, or design review.

The municipality will ***determine whether the project is subject to the MWELO*** or a comparable local WELO.

5.8 Mosquito Control

Some types of stormwater treatment measures are designed to hold water, and even treatment measures that are designed to eliminate standing water between storms have the potential to ***retain standing water*** if they are not properly designed, constructed and maintained.

The Countywide Program developed a Vector Control Plan to help reduce the potential for stormwater treatment measures to breed mosquitoes. The Vector Control Plan describes the need to include physical access for mosquito control staff to monitor and treat mosquitoes, and it includes guidance for designing and maintaining stormwater treatment measures to control mosquitoes. The San Mateo County Mosquito Abatement District staff has identified a ***five-day maximum*** allowable water retention time, based on actual incubation periods of mosquito species in this area. With the exception of certain stormwater treatment measures that are designed to hold water permanently (e.g., CDS units and wet ponds), all treatment measures should drain completely within five days to prevent mosquito breeding. *Please note that the design of LID treatment measures* **does not require** *that water be standing for five days,* even though this is allowable for vector control. Pervious pavement and infiltration trenches are typically designed to drain within 48-72 hours, and properly designed bioretention systems should drain within a few hours.

Treatment measure designs and maintenance plans must include mosquito control ***design and maintenance strategies*** from the countywide Vector Control Plan, which are included in Appendix F. Project plans that include stormwater treatment measures (and their maintenance plans) may be routed to the San Mateo County Mosquito Abatement District for review. Project applicants may wish to consult with Mosquito Abatement District staff for guidance.

Key Point

Treatment measure designs and maintenance plans must include mosquito control design and maintenance strategies from the Vector Control Plan, which are included in Appendix F.

5.9 Incorporating Treatment with Hydromodification Management

In addition to the requirement to treat stormwater runoff to remove pollutants, the MRP also requires that stormwater runoff be detained and released in a way that ***prevents increased creek channel erosion*** and siltation. The amount of stormwater flow and the duration of the flow must be limited to match what occurred prior to the currently proposed development or re-development. These hydromodification management (HM) requirements apply to projects that create one acre or more of impervious surface in certain areas of San Mateo County. The requirements do not apply to projects that drain directly to the bay or tidal channels nor to projects where stormwater flows into channel segments that have been hardened on three sides and/or are culverted continuously downstream to their outfall in a tidal area.

The HM requirements have been in effect since 2007 and may be required on the project in addition to stormwater treatment, low impact development, and flood control requirements (if any). To prevent hydromodification, HM facilities are designed to match post-project flow durations to pre-project durations ***for a range of 10 percent of the two-year peak flow up to the ten-year peak flow.*** This is different from the sizing criteria that are used for stormwater treatment measures and the design criteria used for flood control facilities. Implementing low impact development site design and treatment measures in the project may help to reduce the size of required HM facilities.

Figure 5-6: Detention pond used for hydromodification management.

To help applicants meet the HM requirements, the Countywide Program developed the Bay Area Hydrology Model (BAHM) with assistance from the municipal stormwater programs in Santa Clara and Alameda Counties. The BAHM can be used to ***automatically size stormwater detention measures*** such as detention vaults, tanks, basins and ponds for Flow Duration Control of post-project runoff. The BAHM takes into consideration the implementation of low impact development site design and treatment measures when calculating the required size of HM facilities. Chapter 7 provides more detail on HM requirements and the BAHM.

5.10 Treatment Measures in Areas of Bay Fill

Warning

Some areas of San Mateo County are not suitable for treatment measures that rely on infiltration. Consult the infiltration guidance in Appendix E for more information.

Extensive portions of San Mateo County's bayside consist of historic Bay wetlands that were filled long ago to accommodate development pressure. These areas typically have ***high water tables***, and the fill soils have a tendency to settle. Both of these characteristics can lead to problems with building foundations. Treatment measures that rely on direct infiltration to treat stormwater, such as infiltration trenches, are inappropriate to use on properties with a high-water table. Be sure to consult the ***infiltration guidance in Appendix E*** when considering a stormwater treatment measure that relies on infiltration to treat stormwater for the site.

Sites with contaminated soils and/or groundwater may want to consider flow through planters, green roofs, media filters, tree well filters and other systems that can be located above grade and are fully contained to prevent infiltration and conflicts with brownfield and/or site cleanup containment/protection systems. California Geotracker[25], the SF-based non-profit Center for Creative Land Recycling[26], EPA Region 9[27] and the California Department of Toxic Substances Control[28] all have information on brownfields and contaminated site remediation.

[25] https://geotracker.waterboards.ca.gov/

[26] https://www.cclr.org/

[27] https://www.epa.gov/brownfields/brownfields-and-land-revitalization-california-arizona-nevada-and-hawaii

[28] https://dtsc.ca.gov/brownfields/

5.11 Treatment Measures in Seismic Hazard Areas

The San Andreas Fault passes through the county near the Skyline Boulevard and I-280 corridors areas before exiting the coast at Mussel Rock Park in Daly City. State law prohibits the location of developments and habitable structures across the trace of active faults and limits the placement of these types of structures to no less than 50 feet of an active fault trace. Projects located near a fault typically need to incorporate special design features. For example, ***pipes built across a fault*** need to accommodate the gradual movement of the tectonic plates that meet at the fault line. If the project is located near a fault line, ***the local jurisdiction should be contacted*** to obtain any special requirements for storm drain pipes or other stormwater facilities included in the project.

Contact

Contact the local jurisdiction for recommendations on projects located near a fault line.

Steep slopes and areas of Bay fill may also be identified as seismic hazard areas, based on the damage to buildings, bridges, and other structures that may occur in these areas during a major earthquake. To date, stormwater professionals have not identified seismic-induced failure as a threat to stormwater treatment measures located in Bay fill areas or on steep slopes. There are, however, special concerns associated with stormwater treatment measures that rely on infiltration in areas with high water tables or steep slopes. These concerns are addressed in ***Appendix E.***

5.12 Artificial Turf and Stormwater Treatment

Artificial turf typically consists of a permeable synthetic grass layer over a permeable underlay, such as gravel, and a compacted sub-base, with a subdrain to collect water and convey it to the storm drain system. Artificial turf can be designed to allow infiltration of runoff to the underlying soils.

When reviewing plans for artificial turf, here are two items to check:

1. When calculating the total area of a project's new and/or replaced impervious surface, areas of artificial turf are considered pervious, if the underdrain is placed sufficiently high in the gravel base layer, so that the void space in the gravel below the underdrain is sufficient to store and infiltrate the amount of stormwater specified in Provision C.3.d of the MRP (see Figures 5-25 and 5-26 for more details).

2. If crumb rubber is used in artificial turf applications, precautions must be taken to avoid discharging the rubber pieces into storm drains and adjacent water bodies. Figure 5-7 below shows the accumulation of crumb rubber in a bioretention area treating runoff from an artificial turf sports field in Berkeley.

Although using artificial turf in place of natural turf can help conserve water and reduce pesticide and fertilizer use, it is advisable to ***weigh the benefits against potential environmental impacts,*** such as the heating effect of artificial turf (as opposed to the cooling effect of natural turf). Many athletes prefer natural turf to synthetic because of the damage that can occur to joints over time and the potential to negatively impact health over time[29]. Concerns have also been raised regarding the potential for toxic chemicals in artificial turf to pollute stormwater; however, data on this issue are limited and inconclusive to date.

Figure 5-7: This bioretention area treats runoff from an artificial turf field in Berkeley and has an accumulation of crumb rubber particles (the black areas in the photo). (Credit: EOA, Inc.)

[29] www.epa.gov/chemical-research/federal-research-recycled-tire-crumb-used-playing-fields

5.13 *Getting Water into Treatment Measures*

Getting water into treatment measures is a key challenge for designers. In the Bay Area over the last 20 years many designs have failed to achieve this crucial treatment measure element. The design flaws can be categorized into three areas: entry grading/slope, blockage and widths. Examples of each problem and better designs are shown in Figure 5-8. ***Sections 4.7 and 4.8 of the GI Design Guide contain additional guidance on how to capture and convey surface and roof runoff in Green Street and other projects.***

Figure 5-8 – Examples of common design problems with inlets of treatment measures. (Credit: EOA, Inc. and City of Mountain View)

The types of inlets for LID measures include: ***flush curb (sheet flow), roof leaders (downspouts), bubble up emitters, trench drains, or curb cuts*** *(green street inlets may have special design, construction and maintenance considerations –* ***see Chapters 3 and 4 of the GI Design Guide for more information)***. Once the water is in the system, erosion is the next challenge. To avoid erosion, cobbles or other energy dissipaters can be used. An example of a well-designed trench drain inlet into a flow-through planter with a concrete splash apron and grouted cobbles for energy dissipation is shown below in Figure 5-9. A minimum two-inch drop in grade between the impervious surface and the finish grade of the stormwater treatment facility is recommended. This drop in grade needs to take into consideration the height of any vegetation.

Figure 5-9: A concrete splash apron (with grouted cobble) is placed at the inlet to this stormwater treatment measure in Berkeley to help prevent erosion. Additional loose cobble is placed on the edges to prevent erosion. Other measures, such as using pea gravel or locating plants closer to the apron, could be used and would entail fewer maintenance issues than loose large cobble. (Credit: EOA, Inc.)

Figure 5-10: Another design option is to use vertical elements such as plants or concrete blocks at the inlet to dissipate energy and reduce erosion. This drain in a park in Denver has a large diameter pipe so more heavy-duty measures were required to manage the strength of the high-volume flows expected, but maintenance of the system is easier than with large rock such as cobble. (Credit EOA, Inc.)

Standard Curb Cut: Design Guidance

- Opening should be at least 18 inches wide; for smaller facilities 12” width may be allowed at more frequent intervals subject to municipal approval.
- Curb cut should have angled sides at 45 degrees (as shown in Figures 5-11 and 5-12).
- Curb walls at the cut can also be chamfered to reduce damage to wheels and aid runoff in entering the inlet. (Not shown).
- Curb cuts work well with relatively shallow stormwater facilities that do not have steep side slope conditions.
- Slope the bottom of the concrete curb toward the stormwater facility (a depressed throat opening).
- Allow a drop in elevation of 4 to 6 inches from the rim of the inner edge of the inlet to the surface of Biotreatment Soil Media (BSM) elevation. This provides for a two inch drop to the top of a splash apron or mulch so that vegetation does not obstruct flow.
- Provide a splash apron, grouted cobble, pea gravel, plants and mulch or other energy dissipater to prevent erosion. Loose cobble is not recommended due to maintenance and weed issues.

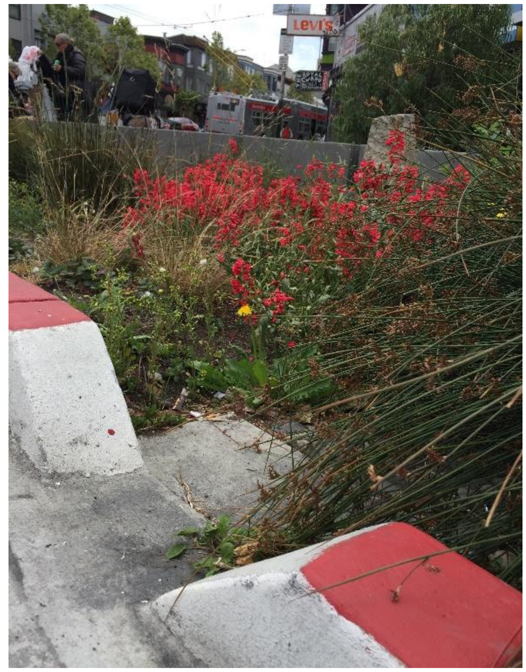


Figure 5-11: This standard curb cut in San Francisco has angled sides, a depressed throat and a 2-inch drop off to a splash apron. (Credit: EOA, Inc.)

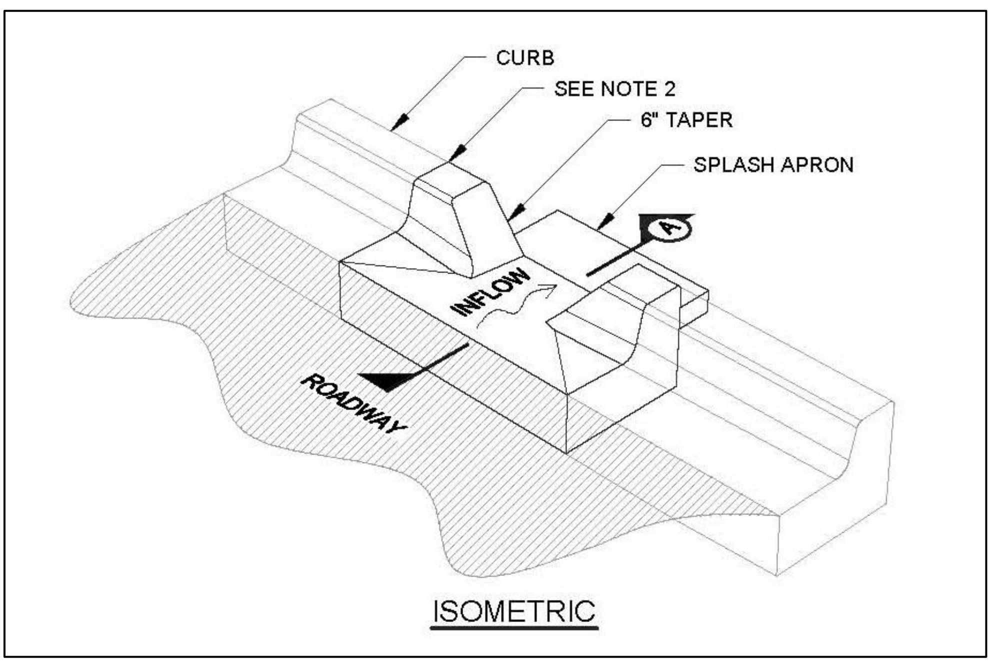


Figure 5-12: Standard curb cut: *isometric* view (Credit: SMCWPPP and SFPUC, 2019)

Standard Curb Cut with Side Wings: Design Guidance

- Openings should be at least 18 inches wide; for smaller facilities 12" width may be allowed subject to municipal approval. Narrow curb cuts or trench drains can work if the outlet is wide and protected (see Figure 5-13).
- Works well with stormwater facilities that have steeper side slope conditions.
- Need to slope the bottom of the concrete curb toward the stormwater facility.
- Allow a change in elevation of 4 to 6 inches between the paved surface and BSM elevation, so that vegetation or mulch build-up does not obstruct flow. Provide a 2" drop from the inlet to the splash apron or energy dissipator.
- Provide a splash apron, grouted cobble, pea gravel, plants, mulch or other energy dissipater to prevent erosion. Loose cobble is not recommended due to maintenance and weed issues.

Figure 5-13: The side wings and concrete apron of this trench drain curb cut prevent blockage & erosion. (Credit EOA, Inc.)

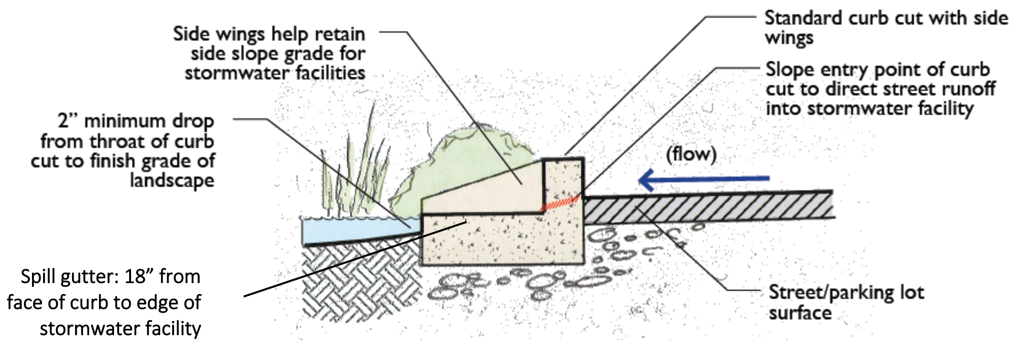


Figure 5-14: Standard curb cut with side wings: cut section view (Source: SMCWPPP, 2009)

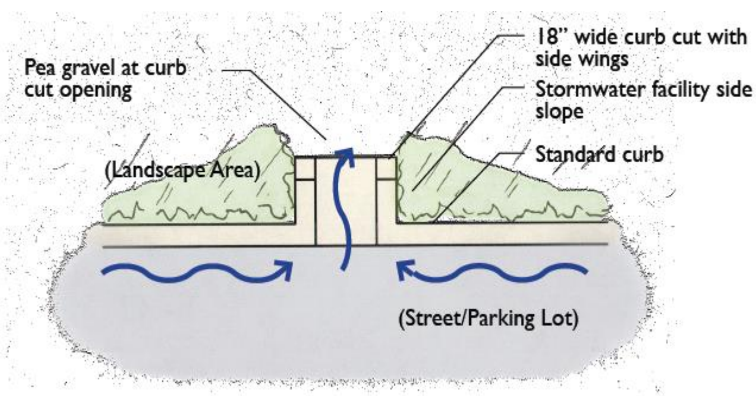


Figure 5-15: Standard curb cut with side wings: plan view (Source: SMCWPPP, 2009)

Wheelstop Curbs: Design Guidance

- Wheelstops allow water to flow through frequently spaced openings.
- Wheelstops are most common in parking lot applications, but they may also be applied to certain street conditions.
- Need to provide a minimum of 6 inches of space between the wheelstop edge and edge of paving. This is to provide structural support for the wheelstop.
- Allow a change in elevation of 4 to 6 inches between the paved surface and BSM elevation, so that vegetation or mulch build-up does not obstruct flow (see Figure 5-16).
- Provide a splash apron, grouted cobble, pea gravel, plants, mulch or other energy dissipater to prevent erosion. Loose cobble is not recommended due to maintenance and weed issues.

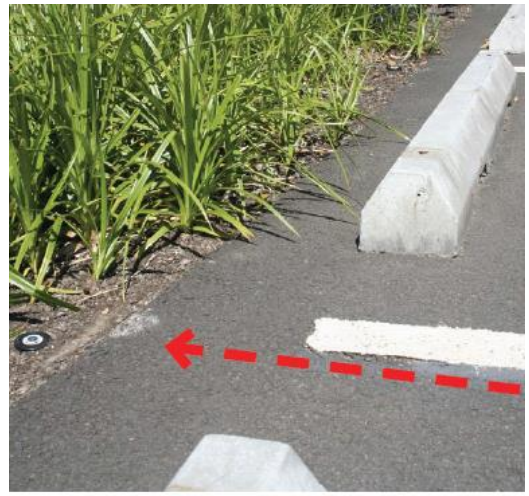


Figure 5-16: Stormwater runoff enters the stormwater facility through the 3-foot space between these wheelstops. The design could be improved by providing more drop in grade between the asphalt and landscape area. (Credit: SMCWPPP, 2009)

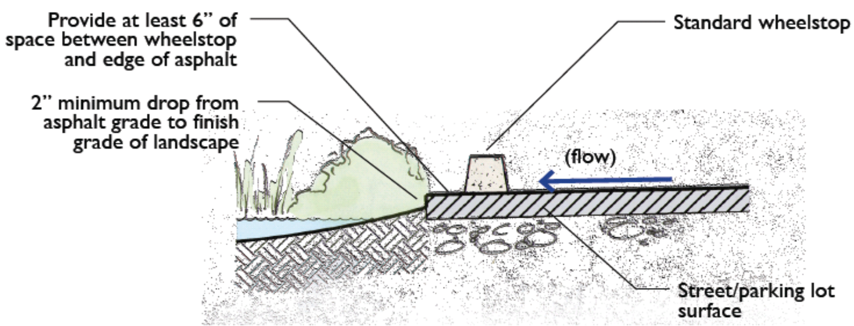


Figure 5-17: Opening between wheelstop curbs: section view (Source: SMCWPPP, 2009)

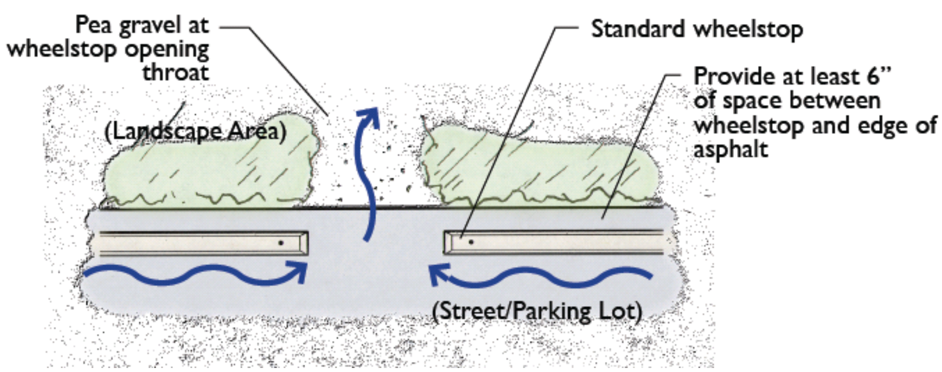


Figure 5-18: Opening between wheelstop curbs: plan view (Source: SMCWPPP, 2009)

Grated Curb Cut: Design Guidance

- Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway. The curb cut opening should be at least 18 inches wide; 12" may be allowed for smaller facilities subject to municipal approval.
- Grates need to be ADA compliant and have sufficient slip resistance.
- A 1- to 2-inch-high asphalt or concrete berm should be placed on the downstream side of the curb cut to help direct runoff into the curb cut.
- Allow a change in elevation of 4 to 6 inches between the paved surface and BSM elevation, so that vegetation or mulch build-up does not obstruct flow.

OURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

Figure 5-19: A grated curb cut allows stormwater to pass under a pedestrian egress zone to the stormwater facility.

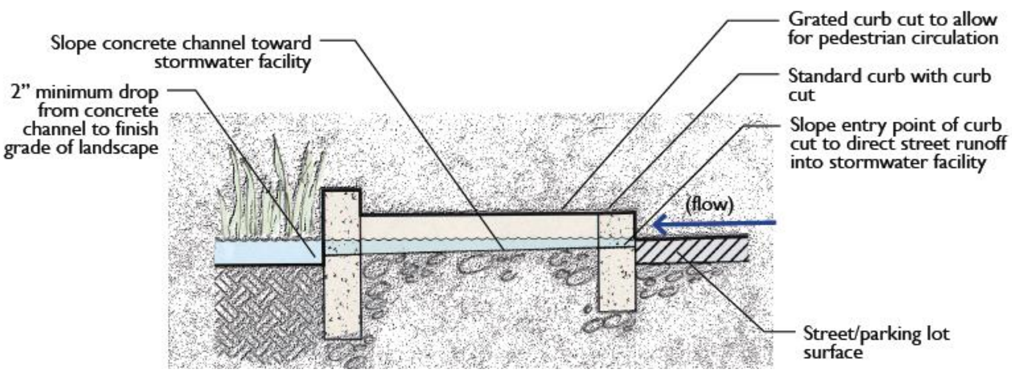


Figure 5-20: Grated curb cut: section view (Source: SMCWPPP, 2009)

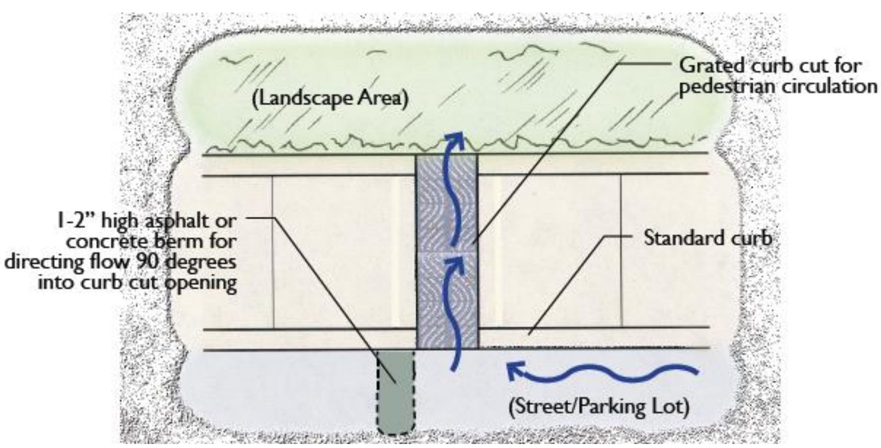
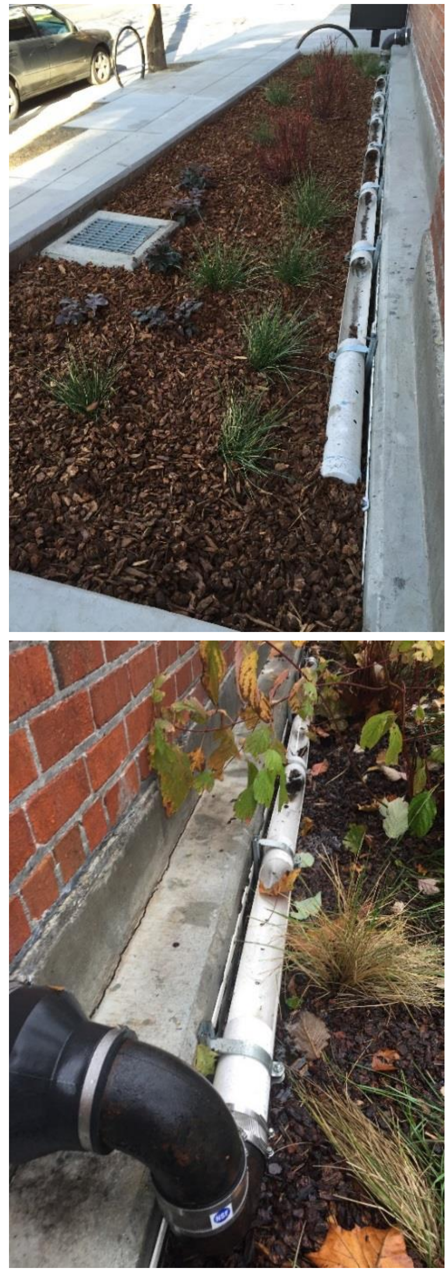


Figure 5-21: Grated curb cut: plan view (Source: SMCWPPP, 2009)

Roof Leader (Downspout): Design Guidance

Roof leaders (commonly known as downspouts) are typically used to convey stormwater from rooftops, awnings, balconies and other elevated impervious surfaces to treatment measures on grade or a podium level (e.g., flow-through planter). This type of conveyance has the advantage of gravity and elevation allowing for flexibility of placement within the treatment measure. The outlet can be designed such that it works with the design and width of the planter. The disadvantage of the type is that water can accelerate within the conveyance causing erosion downstream when adequate measures are not taken to slow and disperse storm flow.

- Splash blocks or aprons (Figure 5-11 and 5-23) are the recommended measure for placement under roof leaders to prevent erosion where bare soil and mulch are being used. Rock or gravel is another option.
- Roof leaders should have a minimum diameter of 3 inches and a maximum diameter of 8 inches to control flow levels. This range of pipe diameters prevents blockage and erosion.
- Flow spreaders can be a useful addition to a roof leader system – especially where only one roof leader is being used to convey flow. To maximize the efficiency of a stormwater treatment measure, the flow needs to reach as much surface area as possible. Remember the mantra – slow it, spread it, sink it – as a guide for designing bioretention systems (Figure 5-22).
- Flow spreaders can be constructed using metal gutters or half-cut plastic pipes with perforations on the bottom and a cap on the downstream end. The system should sit on top of or hang above the mulch layer.



↑ *Figure 5-22: This flow-through planter has a flow spreader pipe to distribute water around the surface and away from the one inlet in the images. (Credit: EOA, Inc.)*

← *Figure 5-23: Splash block (Credit: EOA, Inc.)*

5.14 Underdrain

Where the existing soils have a lower permeability than soils specified for a landscape-based stormwater treatment measure, it may be necessary to install an underdrain to allow the treatment measure to function as designed and ***prevent the accumulation of standing water***. In most of San Mateo County, underdrains will be required.

Underdrains are perforated or slotted pipes that allow water to enter the pipe and flow to the storm drain system. The following guidelines are provided by SFPUC and the Countywide Program:

- To help prevent clogging, two rows of perforations or slots should be cut into the pipe. If possible, the holes or slots should only be on the underside of the pipe, at 120 degrees and 240 degrees, so that water enters the pipe primarily from the bottom and lower sides of the pipe allowing for more water storage within the system. Pipes that come precut with holes or slots already in them including in the third location (as shown in Figure 5-24) at the top of the pipe can be accepted. Slots are considered less open to root intrusion than round perforations.
- Three pipe material options in order of preference are:
    1. Slotted single-walled underdrain pipes of the type HDPE SDR 17.
    2. Slotted or perforated triple-walled HDPE pipe with smooth inner and outer layers and a corrugated inner layer.
    3. Slotted or perforated PVC pipe. (HDPE is considered a “greener” building material.)
- Corrugated pipe (such as single or dual wall HDPE pipe - AASHTO M252 and M294 Types C, S and D) is not recommended. Pipes with smooth interiors are easier to clean and remove root intrusions. Corrugated pipe is also not considered as strong as solid smooth pipe.
- The SFPUC specification calls for slots to measure 0.032 inch-wide (max), be spaced at 0.25 inches (min), and provide a minimum inlet area of 5.0 square inch per linear foot of pipe. Slots shall be oriented perpendicular to the long axis of the pipe, and evenly spaced along the length of the pipe.
- The longitudinal slope of the underdrain pipe shall be a minimum of 0.5% slope.
- Cleanouts should be installed to allow access to underdrains to remove debris and root intrusion. More guidance on cleanouts is provided in Chapter 6.
- ***Underdrains should NOT be wrapped in filter fabric***.
- Underdrains should be installed within a recommended minimum 12-inch layer of Class 2 Permeable Material (Class 2 Perm) meeting the Caltrans specification below. Class 2 Perm provides an important function - replacing filter fabric - as it is permeable enough to allow water to pass through but enough fines to keep the BSM from migrating out of the system through the underdrain. A minimum depth layer of 2 inches of Class 2 Perm should be located above and below the underdrain pipe.
- Guidance for underdrains in pervious pavement systems is provided in Section 6-6.
- When designing a bioretention facility and infiltration is permitted onsite, the underdrain should be placed near the top of the Class 2 Perm layer (as shown in Figure 5-25) to allow as much water to infiltrate into native soils as possible before entering the underdrain and discharging to a storm drain. If infiltration is not permitted due to site conditions such as high groundwater, contaminated

soils, proximity to structures, etc., the bioretention facility should be lined and the underdrain placed near the bottom of the Class 2 Perm layer (as shown in Figure 5-26).

For more underdrain details, refer to the technical guidance for specific stormwater treatment measures in Chapter 6 of this guide, and in Chapters 2 through 4 of the GI Design Guide.

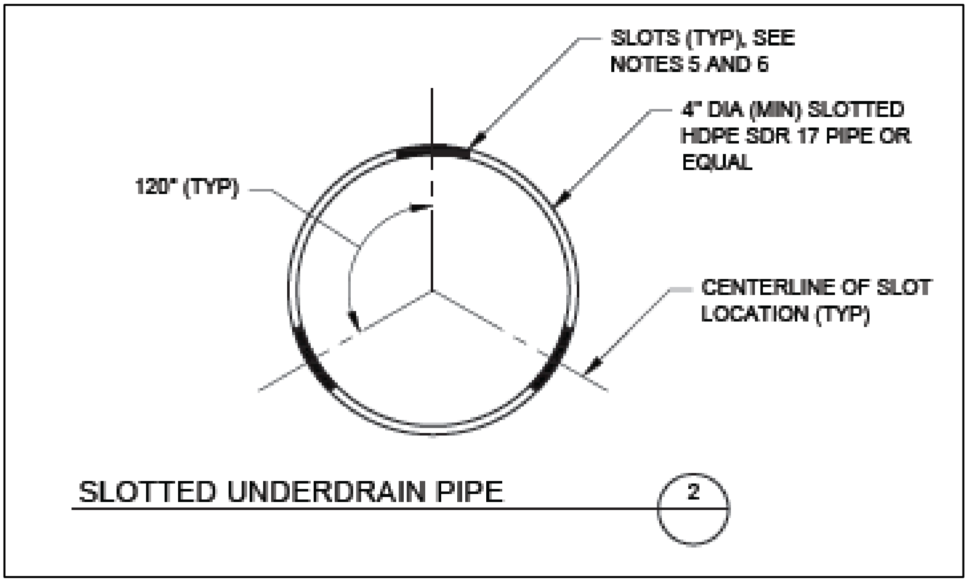


Figure 5-24: Slotted Underdrain Pipe Detail (Credit: SFPUC and GI Design Guide)

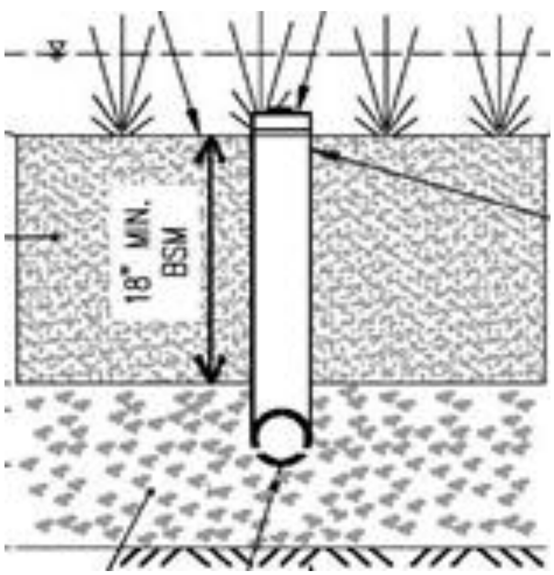


Figure 5-25: Underdrain Pipe Detail Location with maximized infiltration

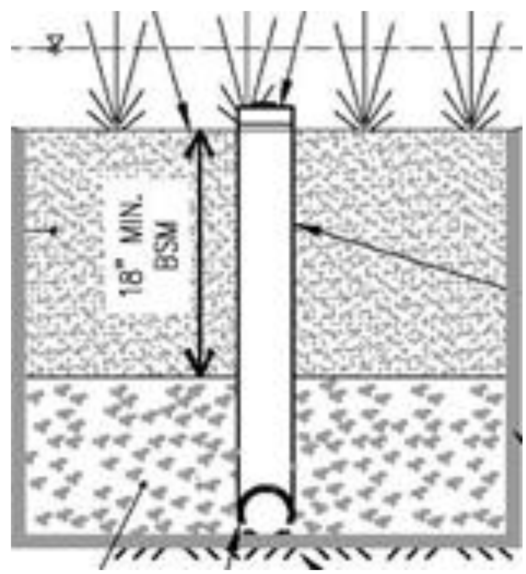


Figure 5-26: Underdrain Pipe Detail Location with no infiltration

Caltrans Specification for Class 2 Permeable Material: Section 68-2.02F(3)[30]

The Caltrans Class 2 Perm specification contains the following information: "Permeable material for use in backfilling trenches under, around, and over underdrains must consist of hard, durable, clean sand, gravel, or crushed stone and must be free from organic material, clay balls, or other deleterious substances. Permeable material must have a durability index of not less than 40. Class 2 permeable material must have a sand equivalent value of not less than 75. The percentage composition by weight of Class 2 permeable material in place must comply with the gradation requirements shown in the Table 5-5."

Class 2 permeable material is used instead of filter fabric around the underdrain; therefore, ***filter fabric should not be used with Class 2 permeable material.***

Table 5-5: Class 2 Permeable Material Gradation Requirements

Sieve sizes	Percentage passing
1"	100
3/4"	90–100
3/8"	40–100
No. 4	25–40
No. 8	18–33
No. 30	5–15
No. 50	0–7
No. 200	0–3

[30] Section 68 of the 2018 Caltrans Standards Specifications Manual: http://ppmoe.dot.ca.gov/hq/esc/oe/construction_contract_standards/std_specs/2018_StdSpecs/2018_StdSpecs.pdf